DEVELOPMENT OF A CAN PROTOCOL FOR ENGINE DYNAMOMETER TEST BENCH CONTROL AND MONITORING

NAM HOA HO, TAN CHAU VO*, QUOC SY NGUYEN, THANH LIEM HA, QUANG DU PHAM
Faculty of Automotive and Power Engineering, Industrial University of Ho Chi Minh City, Vietnam
** Corresponding author: votanchau@iuh.edu.vn*
DOIs: https://www.doi.org/ 10.46242/jstiuh.v83i5. 6185

Abstract. Laboratory-scale engine dynamometer test benches often evolve through incremental additions of stand-alone measurement and actuation units, which results in fragmented interfaces, limited interoperability, and poor time alignment across subsystems. This paper develops a CAN-based communication protocol intended for modular, multi-purpose integration of test-bench subsystems under a common message and diagnostic framework. The protocol specifies node roles, message identifiers, data scaling and units, update rates, command/feedback semantics, fault codes, and fail-safe behavior to support plug-and-play interchangeability across different benches and configurations. As a reference implementation, an electronic fuel supply and gravimetric fuel-consumption module is realized as an independent CAN node and integrated with an existing bench controller via minimal hardware and software modification. The same protocol structure is designed to generalize to additional subsystems—including load generation and speed–torque–power measurement, load-command actuation (throttle or pump rack), and secondary-fuel supply—without requiring modifications to the original engine control unit. The proposed protocol and modular architecture enable standardized bench upgrades, synchronized data logging, and scalable subsystem reuse, with direct applicability to teaching laboratories and automotive workshop test facilities.

Keywords. CAN protocol, Dynamometer, Engine test bench, Fuel monitoring, Modular architecture, Real-time communication.

1 INTRODUCTION

Engine dynamometer test benches play an important role in internal combustion engine research and development by providing a controlled environment for evaluating engine operating characteristics under different operating conditions [1,2]. Through load regulation and continuous monitoring of engine operating parameters, dynamometer systems enable accurate determination of engine performance characteristics, including torque, power output, fuel consumption, and operating stability. These experimental platforms are widely employed not only for conventional engine performance evaluation but also for combustion analysis, engine calibration, and validation of control strategies prior to practical implementation [1]. As engine technologies continue to evolve toward higher efficiency and stricter emission requirements, the demand for reliable and flexible experimental testing systems has become increasingly important in both academic and industrial applications [2].

In modern engine research facilities, dynamometer systems are often integrated with multiple measurement and control subsystems to improve testing capability and experimental reliability. Besides the main dynamometer controller, additional modules such as fuel consumption monitoring, exhaust gas analysis, temperature and pressure measurements, and engine operating parameter acquisition are commonly incorporated to support advanced experimental investigations [1,2]. The integration of these functional units enables simultaneous monitoring of different operating variables and provides more comprehensive experimental information during engine testing. However, in many laboratory-scale experimental platforms, additional subsystems are frequently implemented independently according to specific research requirements, making synchronized communication and centralized data acquisition more challenging.

To improve communication among distributed functional units, Controller Area Network (CAN) has become one of the most widely adopted communication protocols in automotive electronic systems due to its reliability, fault tolerance, reduced wiring complexity, and efficient real-time multi-node communication capability [3]–[5]. Since its introduction in automotive applications, CAN communication has been extensively employed for reliable information exchange among electronic control units (ECUs), sensors,

© 2026 Industrial University of Ho Chi Minh City

and distributed controllers while maintaining relatively low implementation complexity [4,5]. Due to these advantages, CAN communication has attracted increasing interest for subsystem integration and real-time monitoring in engine-related applications.

Several previous studies have demonstrated the applicability of CAN communication in distributed fuel and engine-related systems. Giron-Sierra et al. [6] proposed a distributed fuel management system based on CAN bus communication, demonstrating the feasibility of integrating independent fuel-related functional units through a standardized communication framework. In a subsequent study, Giron-Sierra et al. [7] further developed a CANbus-based distributed fuel system with smart components to improve subsystem coordination and communication reliability. Their findings highlighted the potential of CAN communication for integrating multiple independent functional modules while maintaining stable information exchange among distributed devices. Furthermore, Di Natale et al. [8] emphasized the capability of CAN communication to support reliable real-time data exchange and flexible subsystem integration in distributed applications. Johansson et al. [9] discussed the application of CAN communication in vehicle electronic systems, highlighting its capability for reliable information exchange among sensors, actuators, and electronic control units (ECUs) in distributed environments. These characteristics indicate the potential of CAN-based architectures for engine dynamometer systems requiring synchronized communication among multiple functional units.

Despite the advantages demonstrated in previous studies, the implementation of CAN communication in engine dynamometer systems remains limited, particularly for laboratory-scale platforms requiring flexible subsystem integration and future expandability. In many existing dynamometer systems, auxiliary modules such as fuel monitoring and additional operating parameter acquisition are still implemented separately from the original dynamometer controller, resulting in limited interoperability and difficulties in synchronized data acquisition. Furthermore, the absence of a standardized communication framework restricts the capability of integrating additional functional modules according to evolving experimental requirements.

Therefore, this study proposes the development of a CAN-based communication protocol for an engine dynamometer system following a modular architecture approach. The proposed framework is designed to improve subsystem integration and enable reliable real-time communication among independent functional nodes through a standardized communication structure. In addition, the proposed architecture allows future expansion by enabling new monitoring and control modules to be integrated with minimal modification to the original dynamometer system. The developed framework is implemented on a Dynostar ECB500 engine dynamometer platform to evaluate its feasibility for laboratory-scale engine testing applications.

2 ENGINE DYNAMOMETER TEST BENCH OVERVIEW

2.1 Typical engine dynamometer system

An engine dynamometer is used to evaluate engine operating characteristics under controlled working conditions. A typical system generally consists of a test engine, a dynamometer unit, a transmission shaft, and a torque measurement device. During operation, the dynamometer applies a controllable load to simulate different engine conditions, while engine torque and rotational speed are measured for performance evaluation.

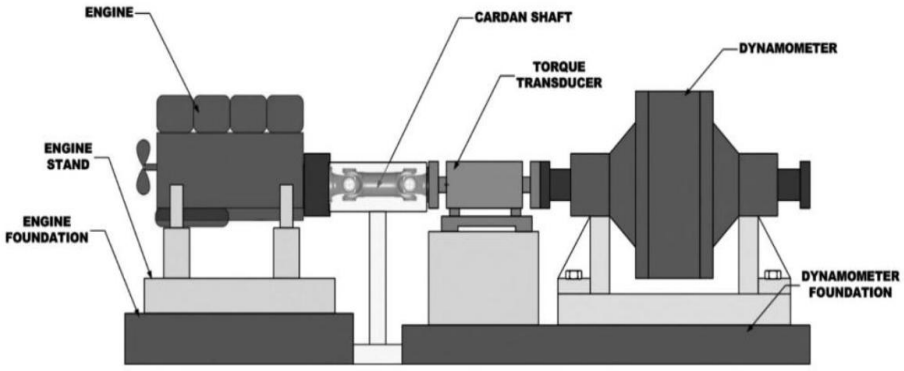


Figure 1: Foot-mounted dynamometer with torque transducer [10]

Figure 1 illustrates a typical engine dynamometer equipped with a torque transducer for measuring engine output torque. In this configuration, the engine is mechanically connected to the dynamometer through a transmission shaft, enabling load application and measurement of operating parameters during testing.

2.2 Typical experimental dynamometer architecture

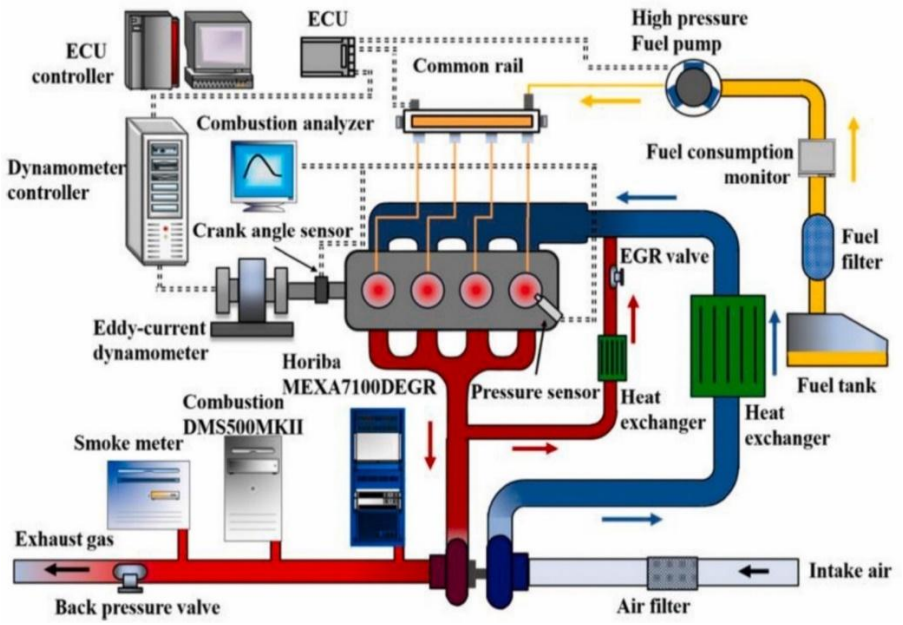


Figure 2: Schematic of a typical dynamometer based experimental system [11]

Figure 2 presents a schematic of a typical dynamometer-based experimental system consisting of several independent subsystems connected through a central control and data acquisition platform. In a typical configuration, the test engine operates together with an electronic control unit (ECU), which governs essential engine operating parameters such as fuel injection, ignition timing, engine protection functions, and overall operating stability. The engine is mechanically coupled to the dynamometer unit, where output torque and rotational speed are continuously measured to evaluate engine behavior under different load conditions. Meanwhile, a dynamometer controller is commonly employed to regulate the applied load and maintain the desired operating point during testing. Through this configuration, the system can reproduce a wide range of operating conditions for evaluating engine characteristics in a controlled environment.

Besides the main control units, additional measurement systems are often incorporated to support advanced experimental studies and improve the quality of collected data. These subsystems may include fuel consumption monitoring devices, exhaust gas analyzers, temperature and pressure sensors, throttle control mechanisms, and engine operating parameter acquisition systems. The measured signals are generally transmitted to a central data acquisition (DAQ) system for real-time visualization, data logging, and post-processing analysis. Such an architecture enables researchers to simultaneously monitor multiple engine operating variables, thereby improving the capability to evaluate combustion characteristics, operating stability, and the influence of different control strategies or hardware modifications during engine testing.

2.3 Experimental dynamometer facility

Experimental engine testing facilities generally employ a centralized arrangement to support engine operation, parameter monitoring, and experimental data collection.

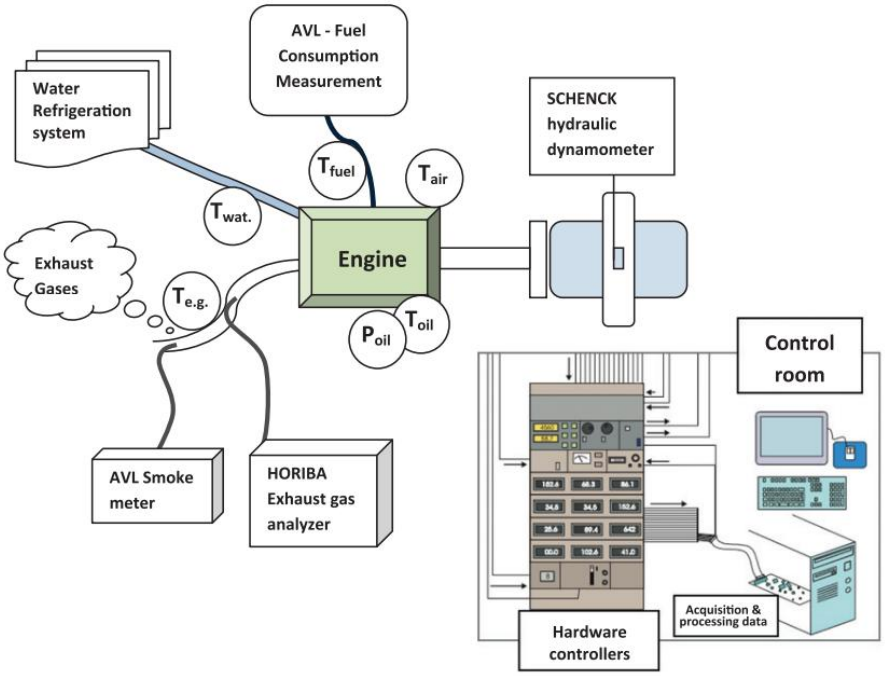


Figure 3: Engine dynamometer system in the Laboratory of Industrial Aerodynamics [12]

Figure 3 presents the experimental dynamometer facility used in the Laboratory of Industrial Aerodynamics. The system integrates several functional units, including the engine test bench, fuel consumption measurement, exhaust gas analysis, smoke measurement, and cooling systems. Through the centralized arrangement, different operating parameters can be monitored simultaneously during engine testing to support experimental investigations.

Although the centralized arrangement provides an effective platform for conventional engine testing, communication among functional subsystems is primarily implemented through independent connections, which may limit synchronized data exchange and flexible subsystem integration. As experimental requirements continue to expand, a more flexible communication framework becomes increasingly important for supporting subsystem coordination and future scalability. Therefore, CAN communication is considered as a promising solution for improving subsystem integration and enabling reliable real-time information exchange among different functional nodes owing to the distinct advantages outlined in Table 1.

Table 1: Advantages and disadvantages of CAN networks in automotive applications [13]

Advantages	Disadvantages
• Standardized; • Low use of wiring • Low cost • Easy to implement • Multi master and multicast feature • Robustness • Flexibility • Highly fault-tolerant • Fault confinement • Efficiency	• Limited length (40 meters) • Limited number of nodes (up to 64) • Low performance • Noise and electrical interference • High software and maintenance expenditure • Bus must be terminated with load resistors • Data packet size is too small • Communication delays • Each device listens to every message transmitted on the bus • Security

3 CURRENT LAYOUT OF DYNOSTAR ECB500 DYNAMOMETER

The current engine dynamometer system employed in this study is based on the Dynostar ECB500 platform, which follows a conventional engine testing configuration commonly used in laboratory-scale experimental

facilities. The system consists of a test engine, a dynamometer unit, a dynamometer controller, and a data acquisition system responsible for monitoring essential operating parameters during testing. In its original configuration, the engine operates independently through its electronic control unit (ECU), while the dynamometer controller mainly performs load regulation and measurement functions to achieve the desired testing conditions. Such a configuration provides a stable platform for conventional engine performance evaluation; however, additional experimental functionalities remain limited.

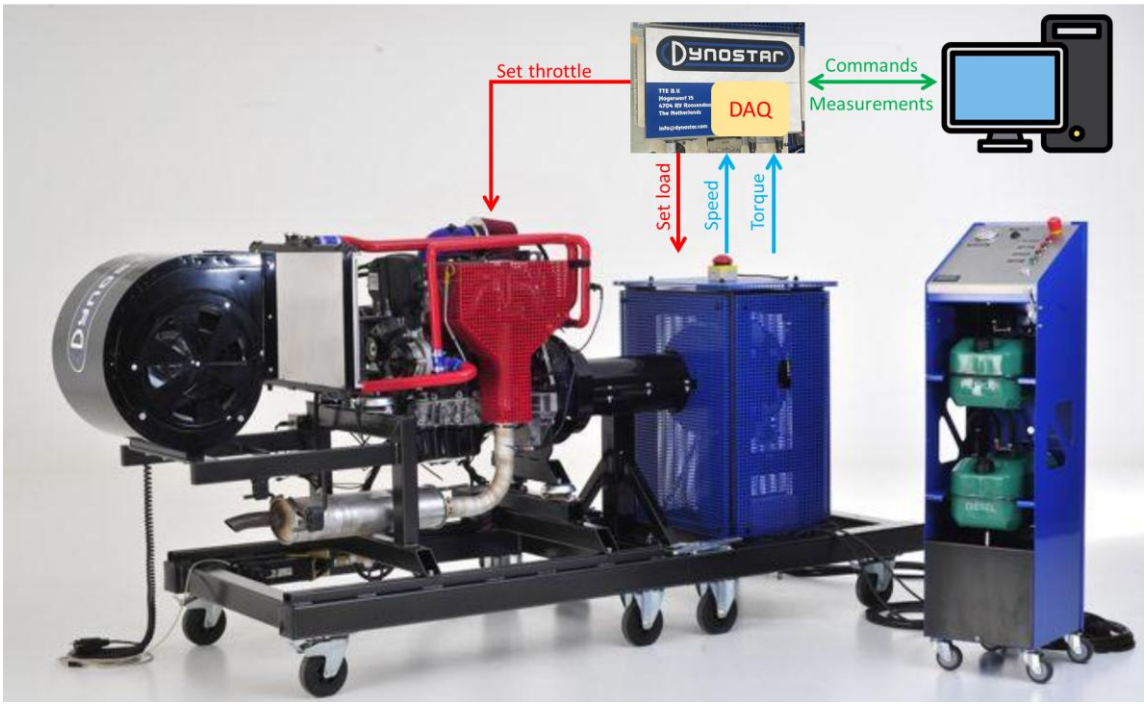


Figure 4. The existing Dynostar ECB500 engine dynamometer system used in this study

Figure 4 presents the existing configuration of the Dynostar ECB500 engine dynamometer system used in this study. In the current setup, the data acquisition system primarily controls the throttle position and dynamometer load while continuously monitoring the two main operating parameters, namely rotor speed and torque generated by the dynamometer unit. These measured signals are transmitted to the monitoring platform to support engine performance evaluation under different operating conditions. Although the system is suitable for conventional power and torque measurements, its capability remains limited when additional monitoring and control functions are required.

One limitation of the current system is the absence of a dedicated fuel consumption monitoring subsystem, making it difficult to evaluate fuel economy characteristics and determine real-time fuel consumption during engine operation. Since fuel consumption represents an important parameter for evaluating engine efficiency, the lack of integrated fuel monitoring restricts the capability of conducting more comprehensive engine performance investigations.

In addition, the existing dynamometer configuration does not provide direct monitoring of several important engine operating parameters, such as ignition timing, exhaust gas recirculation (EGR) status, engine temperature, or other ECU-related variables. These parameters are often required for studies involving engine calibration, combustion analysis, and dynamic operating condition evaluation. Furthermore, the current system architecture provides limited flexibility for integrating additional functional modules, since most subsystems are designed to operate independently with restricted communication capability. Therefore, a more flexible communication framework is required to improve subsystem integration and support future expansion of the engine dynamometer platform.

4 OVERALL DESIGN OF CAN-BASED DYNAMOMETER

To overcome the limitations of the existing dynamometer configuration, a CAN-based communication

architecture is proposed to improve subsystem integration and enable reliable real-time data exchange among functional units. The proposed system is developed following a modular approach, in which each subsystem is implemented as an independent CAN node connected through a common communication bus. This architecture allows functional modules to operate independently while maintaining coordinated communication within the overall dynamometer platform. As a result, additional measurement or control modules can be integrated without requiring major modifications to the original system configuration.

Figure 5 illustrates the proposed CAN-based architecture developed for the engine dynamometer system. In this configuration, multiple functional nodes are connected through a shared CAN communication network, where each node is responsible for dedicated measurement or control tasks. The distributed architecture enables different subsystems to exchange operating data through a standardized communication framework while maintaining independent functionality. Compared with conventional standalone subsystems, the proposed configuration improves system flexibility and facilitates subsystem integration according to different experimental requirements.

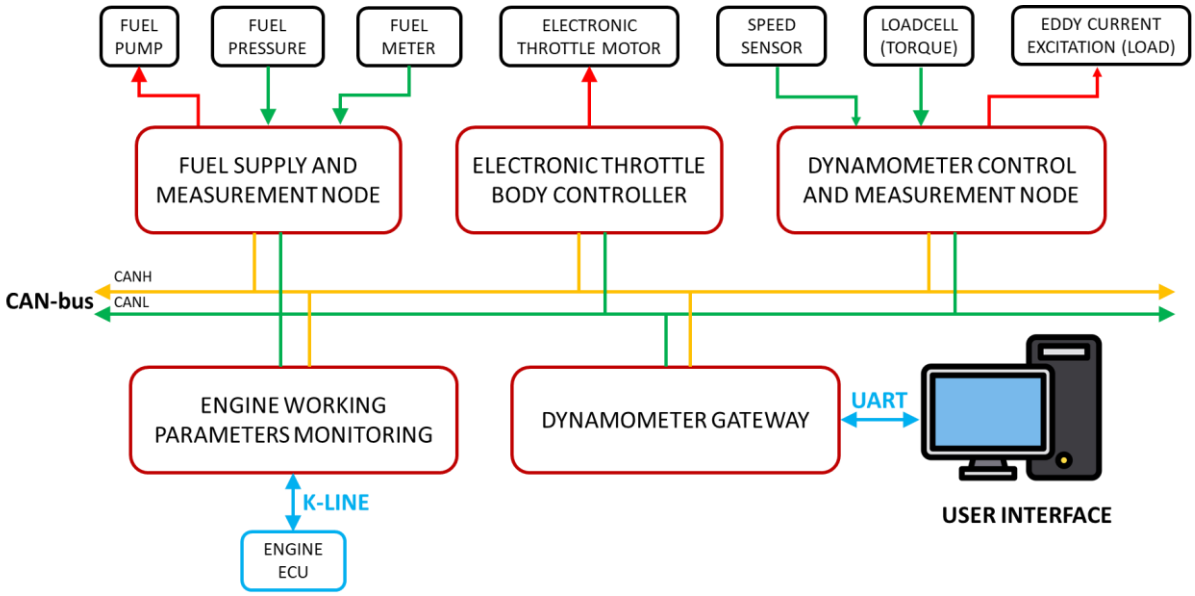
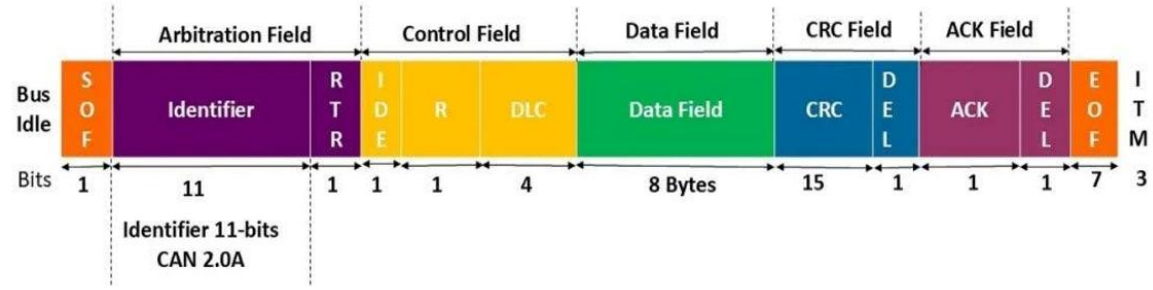


Figure 5: Functional node-based CAN network architecture for the dynamometer system

In the proposed system, engine operating parameters are acquired through an ECU communication node using the K-line interface, enabling access to engine-related information required for monitoring and analysis. Additional CAN nodes can be implemented for functional purposes such as fuel monitoring and pressure control, throttle control, or auxiliary measurement tasks depending on experimental requirements. Meanwhile, communication between the CAN network and the supervisory computer is established through a UART interface to support data visualization, monitoring, and system configuration. This approach enables centralized supervision while maintaining distributed communication among functional units.

One of the main advantages of the proposed architecture lies in its modularity and scalability. Since each functional unit is developed as an independent CAN node, additional modules can be integrated or replaced with minimal impact on the original system structure. Furthermore, the priority-based communication mechanism of the CAN protocol enables stable and reliable data transmission among different functional units, thereby improving synchronization capability and supporting future expansion of the engine dynamometer platform.



BIT	10	9	8	7	6	5	4	3	2	1	0
	Priority	Parameter ID						Transmit node ID			
	0-command 1- broadcast	Allows communication of up to 64 operating parameters of the force measuring device.						Allow development up to 16 functional nodes of the dynamometer			

Figure 6: Proposed CAN 2.0A message structure and identifier allocation scheme

To enable reliable communication among functional nodes, a standardized CAN communication protocol was developed for the proposed dynamometer system. The communication framework is based on the CAN 2.0A standard using an 11-bit identifier format, baudrate 500 kbps, providing sufficient communication capability for the developed modular architecture while maintaining compatibility with embedded controllers.

Figure 6 presents the developed CAN communication structure and identifier allocation scheme. In the proposed protocol, the message frame consists of a standard CAN 2.0A structure with up to 8-byte data field for information exchange among functional nodes. To improve communication management, the 11-bit identifier is divided into three sections, including priority, parameter ID, and transmit node ID. This configuration enables organized data transmission, reduces communication conflicts, and facilitates future subsystem expansion.

Based on the proposed identifier allocation, communication priority can be assigned according to node functionality, while parameter and node identifiers enable flexible integration of additional modules within the dynamometer system. The communication database developed for the proposed architecture is summarized in the following tables.

Table 2: Transmit node ID allocation of the proposed CAN protocol

Transmit node ID	**Functional node**
0x00	Dynamometer gateway
0x01	Dynamometer control and measurement node
0x02	Fuel supply and measurement node
0x03	Electronic throttle body controller
0x04	Engine working parameters monitoring
0x05 – 0x0F	Reserve

Table 2 summarizes the transmit node ID allocation developed for the proposed CAN communication protocol. Each functional subsystem is assigned a dedicated node identifier according to its measurement or control function, enabling organized communication and facilitating future expansion of the dynamometer system. In addition, several node identifiers are reserved for future subsystem integration.

Table 3: CAN bus communication parameter transmitted from the Dynamometer control and measurement node

DYNAMOMETER CONTROL AND MEASUREMENT NODE					
Parameter	**Parameter ID**	**DLC**	**Gain**	**Offset**	**Unit**
Dyno rotor speed	0x00	7	1	0	rpm
Dyno torque			0.01	0	Nm
Dyno power			0.01	0	kW
Dyno temperature			1	0	^{o}C

Control mode	0x01	8	1	0	Speed/Torque/Const
Set torque			0.01	0	Nm
Set speed			1	0	rpm
Set excitation duty cycle			1	0	%
Actual excitation duty cycle			0.01	0	%

Example

Priority	**Parameter group ID**	**Transmit node ID**	**Message ID**	**DLC**	**Message data field**	**Data raw value**	**Actual value**	**Note**
1	0x00	0x01 (10 ms)	0x401	7	0x1C 0x66 0x09 0x3F 0x0C 0x35 0x20	0x1C 0x66	7270 = 7270 rpm	Unsigned
						0x09 0x3F	2367 = 23.67 Nm	Signed
						0x0C 0x35	3125 = 31.25 kW	Unsigned
						0x20	40 = 40 °C	Unsigned
1	0x01	0x01 (25 ms)	0x411	8	0x02 0x06 0x1C 0x04 0x29 0x2C 0x11 0x24	0x02	Const excitation duty cycle	Enum
						0x06 0x1C	1564 = 15.64 Nm	Signed
						0x04 0x29	1065 = 1065 rpm	Unsigned
						0x2C	44 = 44 %	Unsigned
						0x11 0x24	4388 = 43.88 %	Unsigned

The CAN message database of the Dynamometer control and measurement node was organized into two parameter groups based on data response frequency requirements, as shown in Table 3. These groups include measured parameters by the functional node and the controlled parameters received from the Dynamometer gateway node. The excitation feedback is transmitted by the Dynamometer Control and Measurement Node through node ID 0x01 to confirm that the command from the Dynamometer gateway node has been received and interpreted by the actuator-side controller. The corresponding excitation command is issued by the Gateway node, and is assigned the highest message priority to ensure deterministic response of the dynamometer during control operation. This signal is transmitted by node ID 0x00 and also encoded as a signed parameter, allowing negative excitation values to represent motoring operation, where the dynamometer supplies driving torque to rotate the engine instead of absorbing mechanical power. This definition extends the applicability of the proposed architecture beyond conventional load absorption and provides a foundation for future integration with reproduction in transient operating conditions, such as vehicle coast-down or downhill driving. In addition, the same node periodically broadcasts the measured torque and rotational speed signals to the CAN bus for real-time monitoring and data logging. Torque is defined as a signed parameter to represent both absorbing and motoring conditions, whereas speed is treated as an unsigned measurement. Since the proposed frame structure does not specify a destination node, the transmitted messages operate in broadcast mode, allowing multiple functional nodes to access the same information simultaneously. This design reduces redundant point-to-point communication, lowers bus occupancy, and supports scalable integration of additional test-bench modules.



Figure 7: Oscilloscope capture of a CAN message from Dynamometer control and measurement node using Picoscope 4424 hardware and PicoScope 7 T&M software

The signals on the physical layer of CAN bus were captured using an oscilloscope and shown in Figure 7. Differential signals on a transmission line are easy to see on the capture. The data decoded from these signals, included all fields of the CAN message matched perfectly with the simulated data used to verify bus operation.

The network was checked with all configuration parameters and database at the most intense communication intensity of the test bench simulate drive-cycle, where the gateway node must continuously send setpoints to other functional nodes, the total bus load calculation reaches the maximum value at 7.80% in Table 4.

Table 4: CAN bus load calculation

	Messages	**ID Type**	**Data [bytes]**	**Cycle [ms]**	**Message Load [%]**
Message groups: Classical CAN 500 kbps	1	11-bit	6	25	0.86
	2	11-bit	5	25	0.78
	3	11-bit	8	10	2.51
	4	11-bit	8	200	0.13
	5	11-bit	7	10	2.33
	6	11-bit	8	25	1.01
	7	11-bit	4	100	0.18
Results Bus Test	**Total Bus Load**		7.8		
	Effective Bitrate Used		38.98 kbps		
	Total Frames per Second		335 fps		

Performance testing of the system's communication using the specialized Kvaser CAN analysis tool in Figure 8 also yielded results comparable to the theoretical calculations. The testing was conducted continuously for nearly an hour, involving a total of over 1.2 million CAN messages, with absolutely no errors detected.

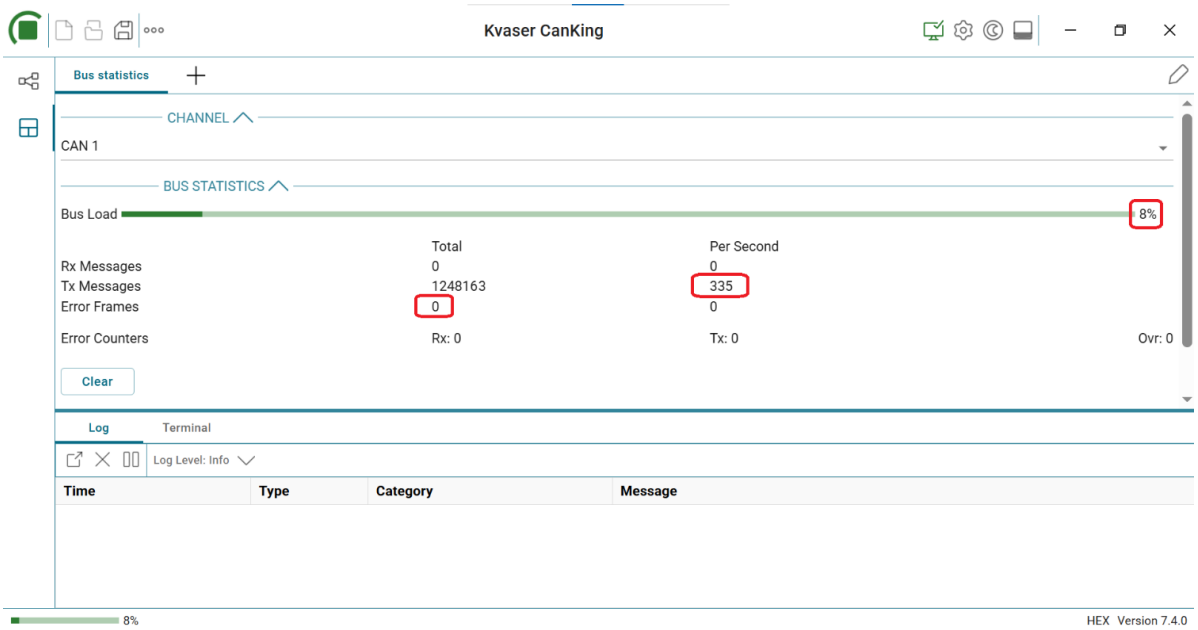


Figure 8: CAN bus statistics with Kvaser

Based on these results, expanding the communication system is entirely possible. Furthermore, the classical CAN bus has the potential to double the transmission bandwidth by increasing the baudrate to 1 Mbps, reducing system communication latency. Alternatively, the baudrate could be reduced to ensure system synchronization when functional nodes operate at lower clock speeds to minimize power consumption, or when other tasks are consuming functional nodes' microcontroller resources.

5 CONCLUSIONS

In summary, this study has proposed an architecture that improves the flexibility, synchronization, and affordability via reusage of laboratorial systems, making it suitable for teaching, experimental research, and modular test-bench development. Based on the developed architecture, the following contributions can be drawn:

- The proposed CAN protocol enables modular integration of different dynamometer subsystems, allowing functional modules to be reused across test benches with minimal hardware and software modification.
- The proposed fuel supply and fuel-consumption measurement module can be integrated as an independent CAN node and reused on other single-cylinder engine test benches, including motorcycle engine test benches coupled with generator-based loading systems.
- The protocol provides a scalable framework for future expansion of the test bench, particularly for integrating an EGR-rate control module to investigate the effects of exhaust gas recirculation on engine operating characteristics.
- The integration of OBD-II/CAN communication allows the Gateway node to simultaneously perform engine working-parameter monitoring when testing modern engines equipped with CAN-based electronic control systems.

REFERENCES

[1] J. Martyr and M. A. Plint, "Engine Testing: Theory and Practice", 4th ed. Oxford, U.K.: Butterworth-Heinemann, 2012.
[2] S. Keder, M. Jasztal, and A. Borkowski, "Design of a New Engine Dynamometer Test Stand," Journal of KONES, vol. 21, no. 4, pp. 111–118, 2014.
[3] Robert Bosch GmbH, "CAN Specification Version 2.0," Stuttgart, Germany, 1991.
[4] W. Lawrenz, "CAN System Engineering: From Theory to Practical Applications," Springer, 1997.
[5] K. Etschberger, "Controller Area Network: Basics, Protocols, Chips and Applications," IXXAT Press, 2001.

[6] J. M. Giron-Sierra, J. L. Esteban, M. Chacon, and F. de la Cruz, "Distributed control system for fuel management using CANbus," IEEE International Symposium on Industrial Electronics, 2000.
[7] J. M. Giron-Sierra, M. Chacon, and J. L. Esteban, "CANbus-Based Distributed Fuel System with Smart Components," IEEE Transactions on Industrial Electronics, vol. 44, pp. 897–912, 2008.
[8] M. Di Natale, H. Zeng, P. Giusto, and A. Ghosal, "Understanding and Using the Controller Area Network Communication Protocol," Springer, 2012.
[9] K. H. Johansson, M. Törngren, and L. Nielsen, "Vehicle Applications of Controller Area Network," in Handbook of Networked and Embedded Control Systems, D. Hristu-Varsakelis and W. S. Levine, Eds. Boston, MA, USA: Birkhäuser (Springer), 2005, pp. 741–765.
[10] J. S. Killedar, Dynamometer. 2012.
[111] A. K. Agarwal and N. N. Mustafi, "Real-world automotive emissions: Monitoring methodologies, and control measures," Renewable and Sustainable Energy Reviews, vol. 137, p. 110624, Mar. 2021.
[12] Luis M.V. Serrano, Rui M.O. Câmara, Vasco J.R. Carreira, M.C. Gameiro da Silva, "Performance study about biodiesel impact on buses engines using dynamometer tests and fleet consumption data," Energy Conversion and Management, vol. 60, pp. 2–9, 2012.
[13] Douss, Aida Ben Chehida, Ryma Abassi, and Damien Sauveron, "State-of-the-art survey of in-vehicle protocols and automotive Ethernet security and vulnerabilities," Mathematical Biosciences and Engineering, vol. 20, pp. 17057–17095, 2023.

PHÁT TRIỂN GIAO THỨC TRUYỀN THÔNG CAN CHO HỆ THỐNG ĐIỀU KHIỂN VÀ THU THẬP DỮ LIỆU VẬN HÀNH BĂNG THỬ CÔNG SUẤT ĐỘNG CƠ

HỒ NAM HOA, VÕ TẤN CHÂU*, NGUYỄN QUỐC SỸ, HÀ THANH LIÊM, PHẠM QUANG DƯ
Khoa Công nghệ Động lực, Trường Đại học Công nghiệp Thành phố Hồ Chí Minh
** Tác giả liên hệ: votanchau@iuh.edu.vn*

Tóm tắt. Các hệ thống thử nghiệm động cơ quy mô phòng thí nghiệm thường phát triển thông qua việc bổ sung dần các cụm chức năng bao gồm các thiết bị đo lường và cơ cấu chấp hành độc lập, dẫn đến tình trạng giao diện vận hành và thu thập dữ liệu rời rạc, gây khó khăn trong việc sử dụng của người dùng và sự thiếu đồng bộ về mặt thời gian thu thập dữ liệu cũng như điều khiển giữa các cụm hệ thống chức năng. Bài báo này phát triển một giao thức truyền thông CAN nhằm tích hợp các hệ thống chức năng của băng thử động cơ theo hướng mô-đun và cho phép tích hợp đa chức năng dựa trên một bộ quy ước chung về khung truyền dữ liệu cũng như chẩn đoán. Giao thức quy định cụ thể vai trò của các nút chức năng trong mạng, mã định danh của các dữ liệu hay thông điệp gửi lên mạng, phương pháp quy đổi giá trị và đơn vị dữ liệu, tốc độ cập nhật, ngữ nghĩa dữ liệu điều khiển/đo đạc, mã lỗi và cơ chế an toàn, qua đó hỗ trợ khả năng thay thế và kết nối nhanh các cụm chức năng giữa các băng thử động cơ có cấu hình khác nhau. Để minh họa thực tế, một mô-đun điều khiển cung cấp nhiên liệu điện tử kết hợp đo tiêu thụ nhiên liệu theo khối lượng đã được triển khai dưới dạng một nút CAN độc lập và tích hợp vào hệ thống điều khiển băng thử công suất động cơ hiện có với những thay đổi tối thiểu về phần cứng và phần mềm. Cấu trúc giao thức này được thiết kế để có thể áp dụng cho các hệ thống chức năng khác, bao gồm hệ thống tạo tải và đo tốc độ - mô-men - công suất, hệ thống điều khiển mức tải động cơ, hệ thống cung cấp nhiên liệu khác phục vụ nghiên cứu mà không cần điều chỉnh bộ điều khiển động cơ ban đầu. Giao thức mạng và kiến trúc hệ thống dạng mô-đun được đề xuất cho phép chuẩn hóa việc nâng cấp băng thử động cơ, đồng bộ hóa quá trình ghi dữ liệu và tái sử dụng các hệ thống chức năng một cách linh hoạt, với khả năng ứng dụng trực tiếp tại các phòng thí nghiệm, phục vụ giảng dạy và cơ sở thử nghiệm trong xưởng ô tô.
Từ khóa: Giao thức CAN, Băng thử công suất, Bệ thử động cơ, Giám sát nhiên liệu, Kiến trúc mô-đun, Truyền thông thời gian thực.

Received on August 28 – 2026
Revised on October 08 – 2026