General Calibration System Architecture of Automobile Electronic Control Unit

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***Abstract*—In typical calibration system based on ASAM (Association for Standardization of Automation and Measuring Systems) standard architecture, because UI (User Interface) is integrated together with other function layers of calibration system, the requirement of reconstructing UI according to upgrading or changing of the ECUs (Electronic Control Unit) can not be met. So the architecture is strong coupled and lack of openness and universality greatly. A solution of general calibration system architecture is presented to the problem. In this architecture, based on the concept of configuration technique, UI and other function layer are separated, and a XML file is proposed as interface to describe the configuration of UI totally. Correspondingly, the general calibration system architecture is composed of editing environment, XML configuration file and running environment. In design stage, the UI is reconfiguration in editing environment which is normalized by the user interface model, and described by the XML configuration file. In running stage, the XML configuration file is parsed by running environment to generate the UI components automatically. To different ECUs, only reconfiguring corresponding UI is required. Due to the flexibility, expansibility and platform independence of the XML file, the general calibration system according with the architecture presented can improve the development efficiency of ECUs greatly.**

***Index Terms*—General calibration system; Configuration; XML configuration file; Editing environment; Running environment**

I. INTRODUCTION

Modern automotive industry influences the economic, environment and human conditions of nearly every nation significantly. With more rigorous emission regulations and fierce competition, the demand to reduce development period and costs impels automotive enterprise to improve development means constantly. Effective calibration system of ECUs is one of the means [1]. ECU calibration is the process of adjusting, optimizing and determining ECU's control algorithms and parameters according to various performance requirements of vehicles, such as dynamic property, fuel economy, emission performance and other auxiliary functions [2].

However, modern automobile is equipped with more and more components involving ECUs, such as engine and power control, ABS and ASR, etc [3]. To different ECUs, manufacturers have to develop corresponding calibration system respectively. Once an ECU is upgraded or changed, the calibration system is needed to be upgraded. Therefore, conventional development pattern can not accommodate the development of ECUs with more complexity, functionality and performance. Now typical calibration systems are based on ASAM standard architecture, such as ETAS INCA, ATI Vision and Vector CANape, etc. But they are with the defects as follows:

1) Failing to meet the requirement of UI customizing and reconstructing. The UI of calibration system is invariable for a particular ECU, rather than from the viewpoint of automatic generation to analyze the structure and relationship in UI design.

2) Strong coupled architecture. UI and other function layers of calibration system, such as calibration, measurement and communication, are integrated and strong coupled, so trivial modification of requirement will result in upgrading of whole calibration software.

In a word, existing architecture of calibration system lacks of openness and universality greatly. Architecture of general calibration system based on configuration technique is presented. By configuration technique, UI of calibration system is constructed and described with a XML configuration file in editing environment, and generated automatically in running environment. Practical application shows that general calibration system of the architecture presented provides an effective, opening solution for variety of ECUs and calibration requirements.

II. GENERAL CALIBRATION SYSTEM ARCHITECTURE

A. Calibration system of ASAM standard architecture

ASAM is an international standard architecture with two criterions of calibration system: what's the

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corresponding calibration system and how to establish it. ASAM Working Group defines the MCD (Measurement, Calibration and Diagnostics) model to implement application system, which is divided by three protocols called ASAM MCD-1, ASAM MCD-2 and ASAM MCD-3. ASAM standard architecture is representative of existing calibration system which showed in Figure 1.

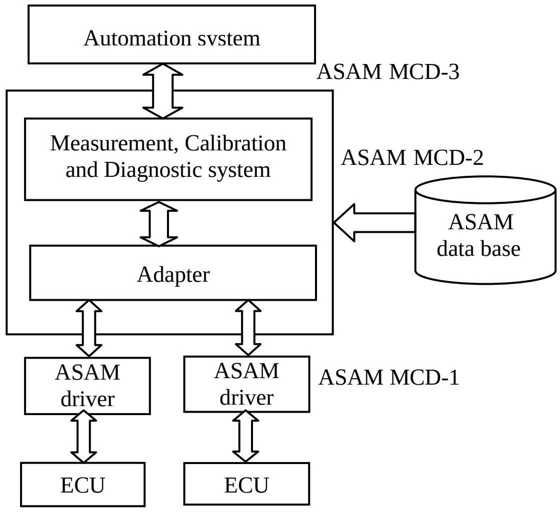

Figure 1. ASAM standard architecture of calibration system

In this standard architecture, calibration and measurement parameters of ECU are originated in map file (*.map) which generated by compiler of micro controller of ECU firstly. The map file is transformed to ASAM MCD-2 data base file (*.a2l) by ASAM MCD-2 editor. According to ASAM MCD-2 data base, MCD system of host uploads parameters from or downloads to ECU by ASAM MCD-1 interface such as CCP [4] (CAN Calibration Protocol) or XCP [5] (Universal Measurement and Calibration Protocol) to implement calibration and measurement of ECU [6].

Additional, CAN is with higher reliability and communication speed than UART [7]. It is used in many high-end automotive control systems like engine management as well as in industrial control systems widely. CCP is part of the ASAM standards for measurement and calibration between ECUs and calibration system, and is with few commands and easy to implement.

But this architecture is with the defect that the UI can not be customized for a particular application. The UI is integrated together with other function layers, such as data management layer and kernel communication layer, and the architecture is so strong coupled that small modification of ECUs or calibration requirement will result in the rebuilding or updating of total system. Consequently, the architecture lacks the universality and flexibility extremely.

B. General calibration system architecture

To solve the problems above, based on the concept of configuration technique, a XML [8] file is bring forward as interface to describe the UI totally. When calibration system operates, UI is generated automatically according to the XML configuration file. Then UI and other function layer are separated and decoupled effectively, and universality and flexibility of calibration system is achieved. The general calibration system architecture is showed in figure 2. The architecture is composed of editing environment and running environment, which is associated by XML configuration file.

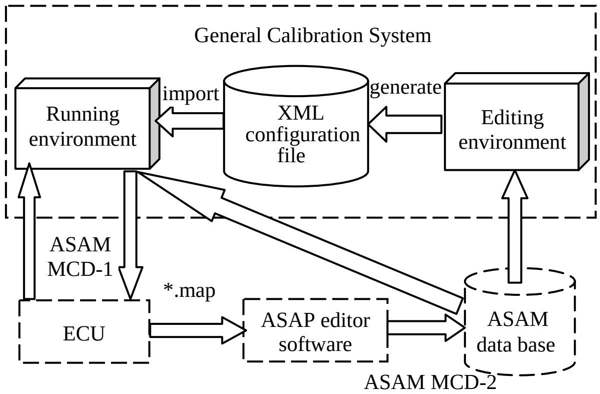

Figure 2. General calibration system architecture

The general calibration system architecture is an open and robust architecture. Editing environment provides a visualized development interface to define the manifestation of calibration parameters, and a user interface model is defined to specify the graphic user interface system. The UI customized in editing environment is stored in XML configuration file correspondingly. Thereafter, the XML configuration file is imported and parsed in running environment completely, and the corresponding UI components are generated automatically. If the characteristic of calibration parameters is upgraded, only reconstructing of UI in editing environment is necessary, the running environment is without any change.

The emphasis of this architecture to actualize universality and flexibility is the XML configuration file. Acting as the buffer and interface of editing environment and running environment, the XML configuration file is required to follow the UI specification. Then XML configuration file generated by third party editing environment can be applicable to running environment. Because of the expansibility and platform independence of XML file, the XML configuration file can be shared between different platforms. So the architecture is with high openness and adaptability.

III. DESIGN OF GENERAL CALIBRATION SYSTEM

A. Design of editing environment

The editing environment realizes the conception of configuration technique, i.e. separating the UI design from system design. Now the method of generating UI automatically according to the interface description model is drawn more attention. Meanwhile, as the base of interface between the user and the system, UI is the important component of interactive system. So many interfaces development models [9] come out to accelerate the development efficiency and increase the development quality and quantity. Therefore, the user interface model for general calibration system is constructed to standardize the output format of editing environment. The structure of editing environment is showed in figure 3, which consists of function module, object module and interface module.

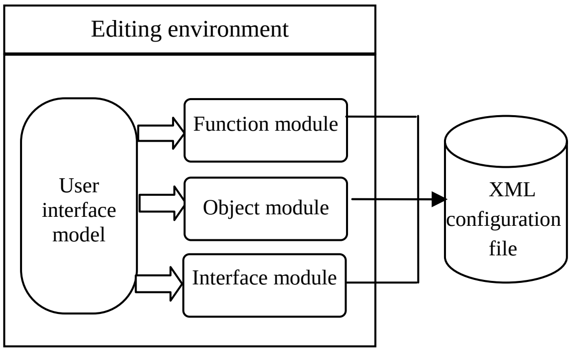

Figure 3. Frame of editing environment

Function module analyses the entire requirement and constructs the framework of UI, which reflects the relationship between graphic interface windows, and their actual demand to object module. Meanwhile, Function module holds the navigation of UI and inherent connection between each module.

Object module is the internal reflection between graphic interface windows and data base, which describes characteristics of data members and types. Object module can be universal by importing the ASAM MCD-2 data base file which stores the detail of all calibration and measurement parameters of ECU.

Interface module defines the visual graphic interface, which illuminates the composition of UI and disposes the display and layout of graphic interface components. Many graphic interface elements, such as dial, oscilloscopes, 3D dynamic maps, single data frame, and matrix data frames, are defined in interface module to provide abundant representation.

Users can customize the UI of practical calibration system in editing environment according to ASAM MCD-2 data base. Editing environment provides the operations as follows.

1) Parsing ASAM MCD-2 data base to obtain calibration parameters and their properties.

2) Selecting calibration parameters and performing the configuration operations to set manifestation.

3) Increasing, decreasing and editing properties of each configuration component.

4) Transforming defined UI to a XML configuration file which accords with UI specification and can be parsed in running environment.

Further more, editing environment can import and parse XML configuration file generated by third part tools or from other platform to support to the openness of the architecture.

B. Frame of XML configuration file

XML configuration file is the primary part of general calibration system to associate editing environment and running environment. A XML configuration file with well structure can provide high efficiency and capability of resource sharing and resource reuse among different editing environment and running environment.

The frame of XML configuration file is showed in figure 4. This frame is with tree structure which includes two kinds of nodes: common attribute node and window resource node. The common attribute node describes overall information of the calibration system, and includes document information sub-node, data object sub-node and running software sub-node. Document information sub-node expresses certain information about the general picture of calibration system and the XML file, such as the author, version, generating time and some remark information. Data object sub-node represents the information of ASAM MCD-2 data base. Running software expounds the attributes of running environment where the XML configuration file will import. Meanwhile, window resource node expresses all graphic interface windows formed by configuration operation in editing environment.

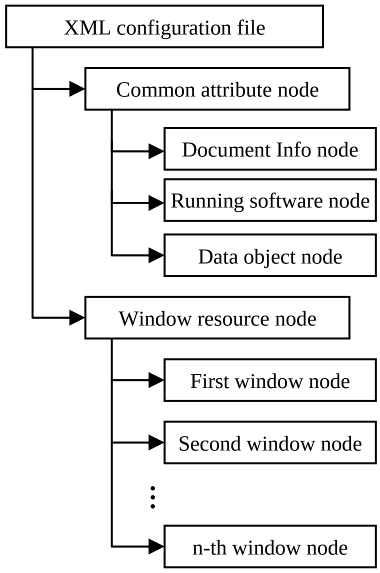

Figure 4. The tree structure of XML configuration file

As the middle layer of general calibration system, XML configuration file separated the editing environment and running environment, and the correlation between them is decreased. As a result, UI is decoupled with other function layers to a large extent. Considering the extensibility and platform-independence of the XML configuration file further, the frame can guarantee the universality and openness of general calibration system.

C. Frame of window resource file

Window resource file is a XML file utilized to describe idiographic calibration windows designed in editing environment, and corresponds with window resource node of the frame. Window resource file is with tree structure also. It consists of common properties node and component nodes. Common properties node expounds the properties of the graphic interface window, such as position, size and name. Component nodes are sub-node of window node, and specify the number and properties of the components included in the graphic interface window. Each component sub-node describes properties of corresponding graphic interface component. For instance, the component sub-node of an angular gauge indicating rotate speed of engine is expressed as following XML segment.

```
<Object value="Dial" >
    <Dial>
        <Top>10</Top>
        <Left>10</Left>
        <Height>200</Height>
        <Width>241</Width>
        <FingerPosition>
            <Position>30</Position>
            <PositionMax>300</PositionMax>
            <PositionMin>0</PositionMin>
            <CurrentMax>100</CurrentMax>
        </FingerPosition>
        <ArcDecription>
            <ArcRadius>80</ArcRadius>
            <ArcRangeDegrees>270</ArcRangeDegrees>
            <ArcStartDegrees>225</ArcStartDegrees>
        </ArcDecription>
        <Label1Text>seconds</Label1Text>
        <Label2Text>RPM</Label2Text>
    </Dial>
</Object>
```

Each component begins with object mark identifying component type. The properties “Top”, “Left”, “Height” and “Width” of sub-nodes denote the position and size of component “Dial” in the graphic interface window. “Finger Position” illuminates the index of dial, and four sub-nodes of it expound the current value, maximum and minimum limit, and actual maximum of rotate speed. “ArcDecription” expresses the scale information of the angular gauge, and contain three sub-nodes to illuminate radius, range degree, and start degree respectively. “Label1Text” and “Label2Text” denote the variable name and unit of calibration parameter associated with the dial component. The descriptions of other components, such as oscilloscopes, 3D dynamic maps, single data frame and matrix data frames, are with similar structure with dial component.

Each graphic interface window is represented as a window resource file and a window child node of window resource node, and can be shared and accessed between different XML configuration files expediently. Therefore, the XML configuration file can describes UI of general calibration system precisely and effectively.

D. Design of running environment

According to the functional division of calibration system, running environment, the kernel of calibration system, is divided to user interface layer, data management layer, and communication layer. The structure of running environment is shown in figure 5.

User interface layer is required to provide abundant manifestation of calibration parameters according to editing environment. XML parser of user interface layer parses the XML configuration file and generates corresponding graphic interface automatically to achieve the customizing of UI.

Data management layer manages the definition, attributes and store of all calibration parameters parsing from ASAM MCD-2 data base. It provides a link between the user interface layer and the communication layer.

Communication layer actualizes and encapsulates the communication protocol (such as CCP or XCP) and bottom driver (such as CAN driver). In the light of ASAM MCD-1, it connects the ECU and general calibration system, and provides data exchange and command transmission.

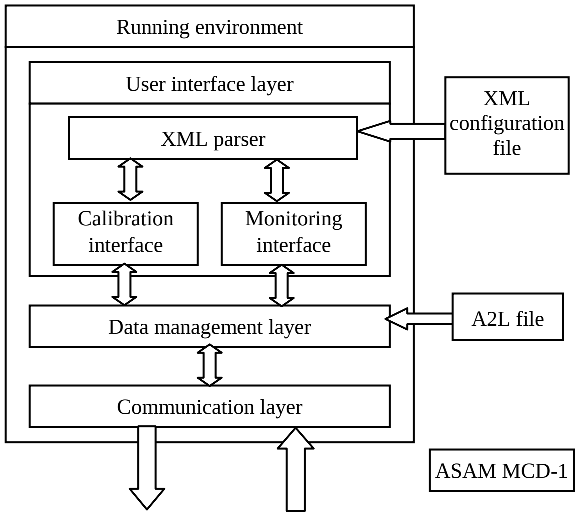

Figure 5. The structure of running environment

IV. Application of General Calibration System

A. the construction of General Calibration System

General calibration system has been successfully used in the development of controlled gas engine. The composing of hardware structure is a host calibration computer with one USB interface and one vehicle ECU with the CAN communication interface. The host calibration computer must be high-performance that is used for running general calibration system, the microcontroller of product ECU is MC9S12DG128 used for communication and data access and exchange. Because the host has no CAN controller, an USB-to-CAN interface is used to connect them together.

For the optimal effect of engine function, the ignition advance table and graphic 3D dynamic maps window are designed for calibrating respectively, and the main parameters of engine speed, throttle opening, cooling water temperature, and intake air temperature, intake manifold pressure are chose for Real-time monitoring with the graphic component of dial , single data frame and oscilloscopes.

From all above, the realization steps of general calibration system are shown as follows.

1) Importing ASAM MCD-2 data base of controlled gas engine generated by ASAM MCD-2 editor into editing environment to obtain calibration parameters, defining their manifestation with configuration operations, and saving UI (see figure 6) as XML configuration file.

2) Importing the XML configuration file to running environment to generating the UI defined in editing environment automatically.

3) Importing ASAM MCD-2 data base to running environment, implementing the connection of general calibration system and ECU, and performing the monitoring and calibrating (see figure 7).

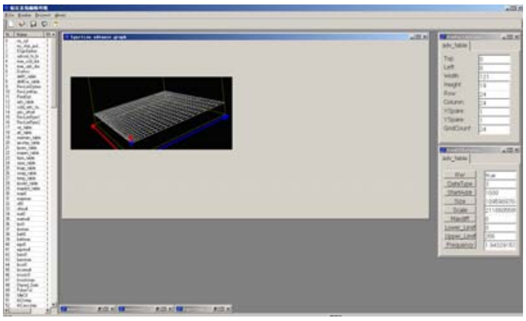

Figure 6. The UI designed in editing environment

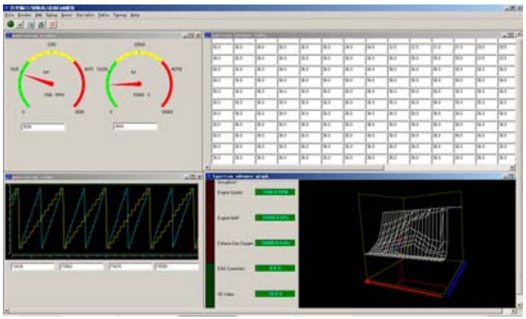

Figure 7. The running environment

Figure 6 shows the UI designed in editing environment, which consists of data area (left), window area (middle) and variable inspector area (right). The calibration parameters are chose in the data area and showed in the window area with the configuration operations to set the layout. The properties of the graphic component can be watched in the variable inspector area.

Figure 7 illustrates the running environment with the UI designed in editing environment. It composes of monitoring part (left) and calibrating part (right). The monitoring part reactions the real-time value of measurement parameters and the calibrating part with the matrix data frames and 3D dynamic map shows the calibration parameters, which response the calibration operation and realize the data change to the ECU.

From the above two figures, the general calibration system performs well. When the ECU is changed or upgraded, by reconfiguring the UI, it can also function perfectly. Therefore, this system does accelerate the efficiency of ECU development.

B. Calibration result of controlled gas engine

By means of the test bench and corresponding measurement instruments and equipments in China automotive Engineering Research Institute, the developed general calibration system was experimented. The main parameters of controlled gas engine were calibrated, such as the calibration of ignition advance graphic map and Injector quantity graphic map. Meanwhile, the HC and CO emissions data are also measured for analysis and validation.

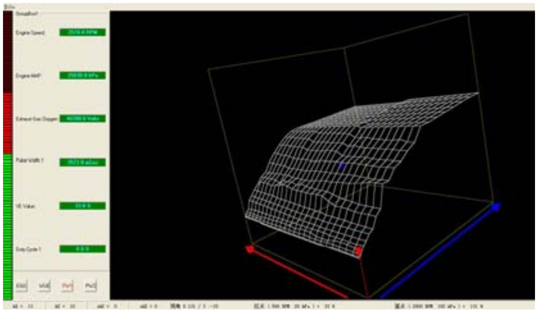

Figure 8. Injection quantity map

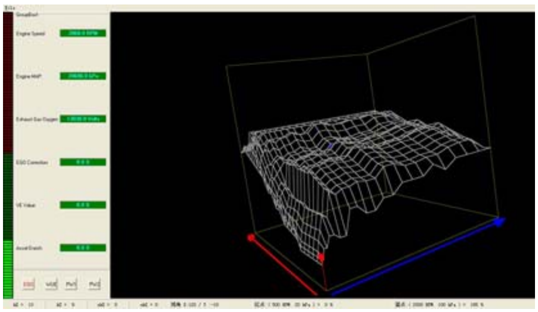

Figure 9. Ignition advance map

Figure 8 and 9 show the calibration results of injection quantity map and ignition advance map respectively. The blue-axis denotes the engine speed and the red-axis represents manifold pressure. The calibration of injection quantity is the basic of the whole system, which directly influence the air-fuel ratio. The injection quantity is usually substituted as injection opening time in the ECU. Ignition advance angle influences the burning process. To make the burning process efficiency, it should be varied with the engine speed and load. Within the common air-fuel ratio, increasing the ignition advance angle will improve the power performance and fuel economy.

To further validate the system functionality, the emission data were measured at the 75% of throttle opening. Figure 10 and 11 show the emission data of HC and CO. the black line marks the original emission data provided by the industry factory and the pink line denotes the emission data after calibration.

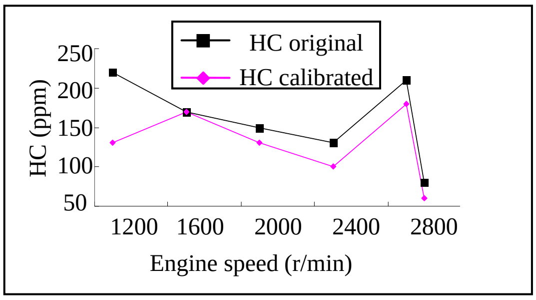

Figure 10. Emission data of HC

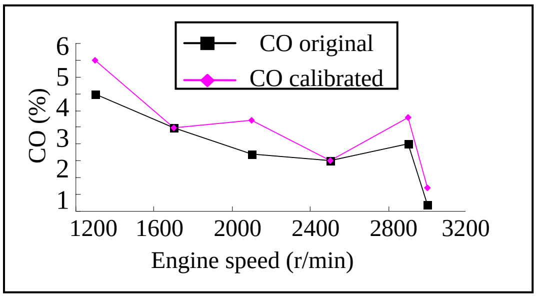

Figure 11. Emission data of CO

Comparing with the original emission data, the calibrated emission data can meet the requirement of economy emission standard. Therefore, the general calibration system can achieve the desired functionality and the control parameters are reliable.

V. Conclusions

Being different from standard ASAM calibration system, general calibration system architecture is established based on configuration technique, and the UI is described with XML configuration file. Then the general calibration system consists of editing environment, XML configuration file and running environment. The UI and other function layers are decoupled. To different ECUs, only reconfiguring corresponding UI is required, and efficiency of ECU development is improved.

Due to the flexibility, expansibility and platform independence of the XML file, the general calibration architecture is with more openness and adaptability.

Acknowledgment

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