A Novel Way to Realize Standardization of UAV EMA Controller

Jiufeng Wu, Tao Yang* and Jianliang Lyu
China Academy of Aerospace Aerodynamics, Beijing, 100074, China

*Corresponding author email: sdyangtao@qq.com

Abstract. UAV (Unmanned Aerial Vehicle) application is becoming wider and wider, its flight safety and performance is quite important. As one of its key components, EMA (Electronic Mechanical Actuator) plays a significant role in deciding UAV performance. In order to reduce cost, shorten design period and save human power, a novel way to realize standardization of the EMA controller is presented in this paper. Based on analysis of the typical EMA with DC (Direct Current) brush motor as its power source used in UAV, the standardization controller is designed. The generalized hardware platform is built with all the functional parts required. And then the communication protocol is made for EMA controller configuration. The upper computer software and the embedded software collaborates to conduct various controller functions. The standardization controller features modularization, combination and seriation, which is better than the traditional EMA controller for it saves cost and time. Several ground tests and flight tests prove its feasibility and validity.

Keywords: Standardization; UAV; EMA controller.

1. Introduction

UAV is short for Unmanned Aerial Vehicle, an equipment which can complete flight missions autonomously through remote command from ground station or airborne flight control computer. Compared with the manned vehicle, UAV attracts more attention because of its advantages of low cost, strong viability, high mission efficiency [1-3]. EMA (Electrical Mechanical Actuator) as one of its key components, it is quite significant in deciding the UAV performance [4]. When there is a new type of UAV, the corresponding EMA has to be designed as well, which requires a certain time of design period, increases cost, and squanders human power [5]. EMA mainly comprises two parts, that is, the actuator and the controller [6]. Actuator design and production follows certain rules. Maybe different manufacturers can offer different services. However its production period is fixed and so hard to change. In order to reduce design period, it is urgent to figure out a way to realize standardization of EMA controller, namely, a certain hardware platform has to be designed while only the corresponding software is revised for different EMA applications according to UAV requirement.

So as to realize that goal mentioned above, a novel method of controller design is presented in this paper with the general hardware platform and flexible software. There are several advantages of the novel controller such as reduced cost, shortened design period, easier design procedure and fast production cycle, rendering it convenient for UAV flight tests with the standard EMA controller [7]. This paper is organized as follows. First, the working principles of the novel EMA controller are introduced and its block diagram of the hardware platform is presented. And then functions which the controller can be realized are listed in details. Thanks to the general platform, software realization can be conducted. The communication protocol, upper computer software and the embedded software are introduced one by one. Finally, the conclusion is given. Obviously, the novel way to realize
standardization of the UAV EMA is feasible and effective, thus saving design cost and offering convenience for application and maintenance.

2. UAV EMA Controller

As for the typical EMA widely used in certain types of UAV produced by our academy, it features analog communication between the flight control computer and the EMA. Also, its actuator is powered by DC brush motor and the position feedback is indicated by the potentiometer in the form of slide rheostat [8]. Based on these points, it is not difficult to figure out the solution to standardization of the EMA controller. The EMA controller designed in this paper is shown in figure 1.

![Block diagram of the EMA controller](image)

**Figure 1.** Block diagram of the EMA controller

The detailed descriptions for each part are as follow:

- The control core adopts the C2000 DSP (Digital Signal Processor) as its control core.
- Two channels of isolated CAN (Controller Area Network) transceiver exist for communication with the flight control computer.
- There is an external DAC (Digital to Analog Converter) to send analog feedback to the flight control computer.
- There is an external ADC (Analog to Digital Converter) to acquire the potentiometer feedback and the analog command.
- The PWM (Pulse-Width Modulation) drive signals are sent to the power drive circuit through the isolation circuit of photoelectric coupler.
- RS232 (Recommend Standard 232) serial communication interface is devised for testing purpose.
- There is the EEPROM (Electrically Erasable Programmable Read - Only Memory) chip in the controller to store and read system status as well as all kinds of information.
- Unlike the traditional method with a fixed amplitude of the actuator inrush current, the inrush current amplitude can be set at different values via software for convenience.
- The current sensor with Hall Effect acquires the actuator current. And then it outputs corresponding analog voltage meeting the measuring range of internal ADC for DSP to acquire and process.
According to the working principles as well as the need for standardization of the EMA controller, the hardware platform is designed as the layout of figure 2, in which different function parts are divided clearly and the important signals are listed. At the same time, there are two connectors, the up connector and the bottom connector. Those connectors play different roles in the controller.

The bottom connector mainly introduces all kinds of power sources and serves for the CAN interface as well. The power sources are +28V, ±15V and +5V. +28V is filtered first and then introduced into the controller. ±15V are generated from a DC-DC converter, offering power source for the analog part. +5V is generated by a DC-DC converter with great ability to counter surge current, providing power source for the digital part featuring high quality and high reliability. Also, there are two channels of CAN interface coming through the bottom connector, which make it easier for communication between different controllers mounted in the same set of control case.

The up connector comprises the interface comprises interfaces between the controller and the actuator as well interfaces between the controller and the flight control computer. Interfaces between the controller and the actuator mainly serve for the actuator and bring the drive power separately. At the same time, interfaces between the controller and the flight control computer are made up of the analog interface and the CAN communication interface. Analog interface offers a simple way of communication while the CAN interface provides a flexible way of communication. As for these two interfaces mentioned above, each works as backup of the other. Drive power sources are introduced into the controller respectively. In this way, if one channel of actuator is power off by accident, the other one is safe and sound, not effected by that at all.

3. Controller Function

Thanks to the hardware platform, various functions can be obtained with cooperation of hardware and software in the EMA controller [9]. The hardware offers the platform and the corresponding software can be designed based on different application requirement. The functions which the EMA controller can be conducted are as follows:

- Conduct control for a series of actuators (Brush DC Motor) with different rated output torque ranging from 15Nm to 100Nm.
- Each controller is able to conduct control over two channels, with one channel is separated from the other channel. Different isolation circuits, Power drive, Current sensors, power source.

Figure 2. Layout of the hardware platform
Communication with the flight control computer is in the form of dual redundancy, namely, the analog signal and CAN communication. And also there are two channels of CAN interfaces, with one is the main channel while the other is the backup channel.

The control circuit and the power drive circuit is electrically isolated. And the control signals and the drive signals are imported into the controller with different connectors.

There is a testing serial communication interface, serving to configure the controller into different work modes and test modes.

The controller is equipped with fault detection. All the fault information can be sent back to the flight control computer via CAN communication interface.

The controller is designed with the test mode. The upper computer software can turn the controller into the test mode, in which different test instructions are sent to the controller and with the help of standard instrument such as signal generator, oscilloscope, USB to serial interface hub and USB (Universal Serial Bus) to CAN logic analyzer.

4. Software Realization
The controller software is flexible in order to meet different application requirement. The communication protocol is the footstone of software realization, which instructing the upper computer software and the embedded software to collaborate. The upper computer software offers the human machine interface for various visual operations. The embedded software is running in the control core to conduct EMA controller function.

4.1. Communication Protocol
The serial communication between the controller and the testing computer is in the form of RS232. The testing computer serves as the host, while the controller serves as the slave. The communication is in the handshake mode and the communication protocol consists of two parts, the downstream command and the upstream data.

4.1.1. Downstream Command. The downstream command is listed in table 1. The data format is as follows: 1 bit start bit, 8 bits data bits, 1 bit stop bit and 1 bit old-even check bit. The transmission baud rate is 115200 bps.

| No. | Item               | Contents | Description                           |
|-----|--------------------|----------|---------------------------------------|
| 1   | Frame Head         | 0xAA55   | Indicating a command frame             |
| 2   | Mode Set           | 0: Work Mode 1: Test Mode 0: Para1 1: Para2 2: Para3 3: Para4 4: Custom Para | Set the system mode |
| 3   | Para Load          | 0: No Operation 1: Custom Para Write 2: Current Para Read 3: Correction Para Write 4: Correction Para Read | Load the Parameters before the controller begins to work |
| 4   | Para R/W           | 2: Current Para Read 3: Correction Para Write 4: Correction Para Read | Read or Write the Working Parameters |
| 5   | Potentiometer Angle Range Command | 0~360° | Set the Potentiometer Range |
| 6   | Command Angle Range Command | 0~±100° | Set the Command Angle Range |
| 7   | Angle Limit        | 0~±100° | Set the Command Angle Limit |
| 8   | Inrush Current Limit | 10A | Set the Inrush Current Limit |

Table 1. Downstream command
Proportion Coefficient 0~500 Set the Proportion Coefficient
Integration Coefficient 0~50 Set the Integration Coefficient
Differentiation Coefficient 0~50 Set the Differentiation Coefficient
Correction Parameter 0.8~1.2 Set the Correction Parameter
Communication Interface Set 0: Analog Interface 1: CAN1 Interface 1: CAN2 Interface Set the communication Interface
CAN Mailbox ID 0~0x3FFA Set the CAN Mailbox ID
CAN Trans Period 0~1000ms Set the CAN Transmission Period

4.1.2. Upstream Data. The downstream command is listed in table 2. The data format is as follows: 1 bit start bit, 8 bits data bits, 1 bit stop bit and 1 bit old-even check bit. The transmission baud rate is 115200 bps.

| No. | Item                        | Contents                | Description                              |
|-----|-----------------------------|-------------------------|------------------------------------------|
| 1   | Frame Head                  | 0xAA55                  | Indicating a data frame                  |
| 2   | Current Work Mode           | 0: Work Mode            | Feedback the system mode                 |
|     | 1: Test Mode                |                         |                                          |
|     | 0: Operation Failed         |                         |                                          |
|     | 1: Para1 Load Success       |                         |                                          |
|     | 2: Para2 Load Success       |                         |                                          |
|     | 3: Para3 Load Success       |                         |                                          |
|     | 4: Para4 Load Success       |                         |                                          |
|     | 4: Custom Para              |                         |                                          |
| 3   | Para Load Feedback          |                         | Feedback whether the Parameters are set |
|     |                             |                         | successful or not                        |
| 4   | Potentiometer Angle Range   | 0~360°                  | Feedback the Potentiometer Range        |
|     | Command                     |                         |                                          |
| 5   | Angle Range Angle Range     | 0~±100°                 | Feedback the Command Angle Range        |
|     | Command Angle Limit         |                         |                                          |
| 6   | Inrush Current Limit        | 10A                     | Feedback the Inrush Current Limit        |
| 7   | Proportion Coefficient      | 0~500                   | Feedback the Proportion Coefficient      |
| 8   | Integration Coefficient     | 0~50                    | Feedback the Integration Coefficient     |
| 9   | Differentiation Coefficient | 0~50                    | Feedback the Differentiation Coefficient |
| 10  | Correction Parameter        | 0.8~1.2                 | Feedback the Correction Parameter        |
| 11  | Communication Interface Set |                         | Feedback the communication Interface     |
|     | 0: Analog Interface         |                         |                                          |
|     | 1: CAN1 Interface           |                         |                                          |
|     | 1: CAN2 Interface           |                         |                                          |
| 12  | CAN Mailbox ID              | 0~0x3FFA                | Feedback the CAN Mailbox ID             |
| 13  | CAN Trans Period            | 0~1000ms                | Feedback the CAN Transmission Period    |
4.2. Upper Computer Software

The upper computer software is shown in figure 3. There are buttons, drop-down list, textbox and checkbox in it. Different configuration functions are divided in different regions in that human machine interface. And also, the related information can be printed in the upper computer software. The functions conducted are as follows:

- **The Mode SEL function** decides which mode the controller works at, namely, the work mode or the test mode. In the test mode, the controller enters a status of self-test, mainly used for preliminary test after electric fitting. In the work mode, the controller is at normal work status, whose working parameters can be configured by the upper computer software.

- In the test mode, the self-testing is conducted as follows. Once received the self-testing construction, the PWM output a signal with duty cycle set as fifty percent. The controller sends one certain set of data “0xAA 0x55 0x01 0x02 0x03 0x04 0x05” to the upper computer, with the transmission frequency of 50Hz. The DAC outputs the voltage amplitude exactly the same as that acquired by the ADC. Also the CAN interface works at the loopback mode. The controller sends what it receives without any modification.

- Through the Para Load function, the controller can load the working parameters of different actuators. The full set of parameters to be loaded are Para 1, Para2, Para 3, Para 4 and Custom Para.

- As for the Custom Para, there are several parameters to set such as Potentiometer Angle Range, Command Angle Range, Command Angle Limit, Proportion Coefficient, Integration Coefficient, Differentiation Coefficient and Correction Para. Once the parameter configuration is done, press the Custom Para Write button and then these parameters records into the controller. However, these parameters do not take effect immediately. The corresponding Para Load button has to be pressed before that.

- As for different channels of actuator, the current working parameters can be read to indicate the working status. And the correction parameter can be set and valid in real time without parameter loading, for the simpler reason that this operation has to be verified by real-time performance.

- The communication interface is the analog interface by default. Besides that, other interfaces are CAN1 and CAN2 interface. Each time a new actuator is connected to the controller, the current communication interface has to be reset to its desired status. When the communication interface is set as CAN communication, configuration of the mailbox ID and transmission period are also needed.
• For each configuration, the controller sends back the feedback and the upper computer software can print the corresponding information in its Information Tips region.

4.3. Embedded Software
In order to realize standardization controller, in addition to the upper computer software, there is also the embedded software, running in the hardware platform. Excellent embedded software design improves the system performance. With the help of DSP software project template, software design is relatively convenient. The embedded software mainly conducts the actuator control and accomplish the digital communication between the controller and other devices.

![Flow chart of the embedded software](image)

**Figure 4.** Flow chart of the embedded software

The structure of embedded software is in the form of foreground and background [10]. The main program stands in the foreground which initiates all the peripheral modules while the interrupt subprogram operates in the background, conducting signal acquisition and processing, control algorithm and digital communication in real time. The flow chart of main program is shown in figure 4. And the modules used in the controller are PWM, ADC, IIC, SCI, CAN, SPI and Timer. Once reset, the controller starts the modules mentioned above. In the meanwhile, the interrupt is initiated and enabled. After that, the main program enters the while (1) infinite loop. As for the interrupt subprogram, there are mainly two interrupts in the embedded software, namely, the Timer interrupt conducting the control algorithm and the SCI interrupt accomplishing the serial communication. The flow chart of interrupt subprogram is also shown in figure 4.

5. Conclusion
In the modern world, UAV application is becoming more and more prevalent in military aspects. The flight safety is of top concern. EMA is one of its key components, which plays an important role in UAV performance. In order to reduce cost, shorten design period and save human power, the standardization EMA controller is designed in this paper. The hardware platform is built for generalization and the corresponding software is designed for EMA for different models of UAV. The controller feature various functions and it cooperates with the corresponding software. This way to realize standardization of EMA is a pretty convenient for maintenance, whose advantages are modularization, combination and serialization. Undoubtedly, the standardization EMA controller designed is superior to traditional EMA to some extent, for the simple reason that it is able to save time and cost. The standardization EMA controller has already been equipped in one certain UAV.
And ground tests are conducted 3 times and results show the standardization controller is easy to configure. And then it is equipped in a certain scout UAV and there are 5 flight tests for 10 hours in total, proving that performance of the EMA controller designed in this paper is great and satisfactory. And also the accuracy and reliability of the proposed method in this paper are verified by the tests mentioned above.

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