Analysis of functional parts and technological software of the control device for a two-phase synchronous electric motor

Boris Utkin
National Research University Higher School of Economic
Moscow, Russia
butkin@hse.ru

Nikolay Grachev
National Research University Higher School of Economic
Moscow, Russia
ngrachev@hse.ru

Dmitriy Babanov
JSC Academician M.F. Reshetnev Information Satellite Systems
Zheleznogorsk, Russia
babanov.d.a@gmail.com

Anna Magazinnikova
Tomsk State University of Control Systems and Radioelectronics
Tomsk, Russia
magazinnikova.anna@tusur.ru

Abstract—**This article analyzes the functional parts and technological software for the developed device for a control of a two-phase synchronous electric motor. An experimental model of a control system for a two-phase synchronous electric motor and software for its operation were designed. The device consists of a source of driving action, a microcontroller that outputs signals to drivers that perform the role of converting the output signals of the microcontroller, filters that smooth out ripples of current flowing through the motor windings, a power source and a two-phase synchronous electric motor. Based on the results obtained, one will plane to create prototypes and conduct their experimental studies in order to further introduce the development into production.**

Keywords—two-phase synchronous electric motor, functional components, technological software, microcontroller, control system.

I. INTRODUCTION

Currently various control systems are developed. These systems include electric motor control systems. This article analyses of functional parts and technological software for the developed device for control a two-phase synchronous electric motor.

There are a lot of publications on this topic. The development of the device was based on the methods described in patents [1, 2] and articles [3-11].

In [3], it is determined in which operating modes for the period of the pulse-width signal at an arbitrary point of the mechanical characteristics of the engine can be located.

In [4] an original method for correcting the error in calculating the electric angle using phase-locked frequency control in the implementation of vector control is proposed.

In [5] a universal control system is proposed that has a minimum cost and dimensions with the function of changing the engine control algorithm without involving additional equipment.

In [6] the question of constructing opto-mechanical systems with a scanning function was considered. These systems are made using a two-phase asynchronous motor operating in step, oscillatory or pulsating modes of operation. development of the device.

The main disadvantage of the devices is requirement the speed sensor that complicates design for the space application.

In addition, the considered systems do not allow the control of two-phase synchronous electric motors, which limits the scope of their application.

II. DEVELOPMENT OF THE DEVICE

A. Development of the device structure scheme

The structure scheme of the control device for a two-phase synchronous electric motor is shown in Fig. 1.

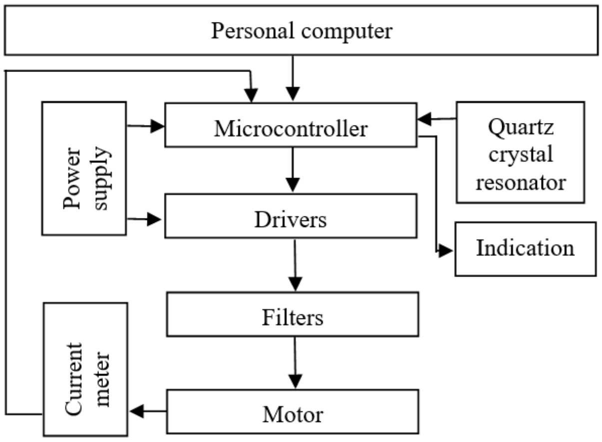

Fig. 1. The structure scheme of the control device for a two-phase synchronous electric motor

The device consists of a source of driving action (a personal computer with technological software), a microcontroller that outputs signals to drivers that perform the role of converting the output signals of the microcontroller, filters that smooth out ripples of current flowing through the motor windings, a power source and a two-phase synchronous electric motor.

A microcontroller of the STM32F407VGT6 type is used to perform all the main functions of the module. This microcontroller is built on a high-performance ARM Cortex-M4 core. The clock source of the microcontroller is provided from the quartz resonator. The frequency of the quartz oscillator is increased to 168 MHz using the frequency multiplication unit built into the microcontroller based on phase-locked loop synthesizer. The microprocessor core operates at this frequency.

The USB interface is implemented for programming the memory of the microcontroller. Also, the device

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communicates with the technological control software on the personal computer through this interface. The interface signals are output to the connector. From the connector, the interface signals are sent to the microcontroller.

The SWD interface is implemented for programming and debugging the microcontroller firmware. This interface is a standard microcontroller debugging interface and it is supported by many debugging tools, such as ST-Link / V2 and J-LINK V8.

The UART interface is implemented to provide additional telemetry information from the microcontroller.

The operation modes are indicated by three LEDs: the presence of power (red), the presence of communication with the technological control software (green) and the presence of engine rotation (yellow).

The power subsystem is designed to generate the power supply voltages to the module parts: for powering the power transistor drivers, for powering the digital part, for powering the analog part. The power subsystem consists of a power module and power stabilizer chips.

Drivers for controlling the lower and upper power transistors are implemented on discrete elements. The output signals of the microcontroller are converted by the driver into signals for switching power transistors.

Output filters smooth out the ripple current flowing through the motor windings.

The feedback circuit contains a current sensor with amplifier.

B. Development of technological software for a personal computer

The development of the program for the microcontroller took place in two stages. The initial configuration of the I / O ports, the configuration of the clock blocks and the peripherals was carried out using the STM32CubeMX software. This software is a visual graphical editor for configuring microcontrollers of the STM32 family and it is intended for pre-configuring the MCU and generating the initial code for various development environments. In this case, the initial code for the Keil µVision 5 development environment was generated.

The clock frequency source is a high-speed oscillator with an external quartz resonator (HSE) with a frequency of 8 MHz. With a PLL block is formed mesh frequency: 48 MHz for USB; 144 MHz for the CPU core, 36 MHz for APB1 bus peripherals; 72 MHz for APB1 timers; 72 MHz for APB2 bus peripherals; 144 MHz for APB2 timers.

The USB interface is implemented on the personal computer to connect the device with the technological control software.

To provide additional telemetry information from the microcontroller, the UART interface is implemented (UART is a universal asynchronous transceiver).

The microcontroller firmware consists of the following modules: the initialization module and the main cycle; the communication module via digital interfaces; the motor speed generation module; the timer interrupt handler module; the motor phase current stabilizer module.

The initialization and the main cycle algorithm are shown in Fig. 2. When the MCU starts the firmware performs initialization function: HAL_Init() – initialization of the HAL library (HAL – device-independent library functions Hardware Abstraction Layer) that is designed to create applications for the STM32 MCU; SystemClock_Config() – clocking blocks initialization; MX_GPIO_Init() – I/O ports initialization; MX_USB_DEVICE_Init() – USB interface initialization; MX_ADC1_Init(), MX_ADC2_Init() – initialization of analog-to-digital converters; MX_USART1_UART_Init() – initialization of the UART interface; initialization of variables.

The algorithm of the communication module digital interface is shown in Fig. 3. The presence of the data in the receive buffer of the UART and USB interfaces are analyzed, and when full input data packet is received, new parameters are applied (frequency and direction of rotation of the motor, the amplitude of the current in the phases of the motor, etc.) and generates output data packet (response). The response is sent via the same interface that the request was received through. The "New data" flag is set for the engine speed generation module.

The algorithm of the engine speed generation module is shown in Fig. 4. Here it checks whether the "New data" flag is set, and, if the result is true, a new current amplitude setpoint and a value for setting the timer to the new frequency are calculated.

The algorithm of the timer interrupt handler module is shown in Fig. 5. At a positive engine speed, the required position of the engine shaft (phase) increases, and at a negative speed, the required position of the engine shaft (phase) decreases. Then, the required current values in the motor phases are calculated from the value of the required phase, which are used in the motor phase current stabilizer module.

The algorithm of operation of the current stabilizer module in the motor phases is shown in Fig. 6. It is checked whether the ADC (ADC – analog-to-digital converter) has completed the next cycle of converting the analog signal from the current sensor, the current value in the motor phase (instantaneous value) is analyzed, and a decision is made to switch the power switch to maintain the current at a given level.

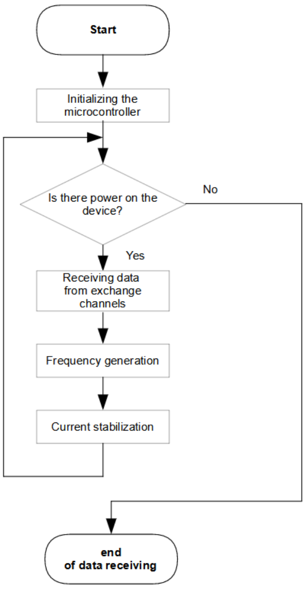

Fig. 2. The initialization and the main cycle algorithm

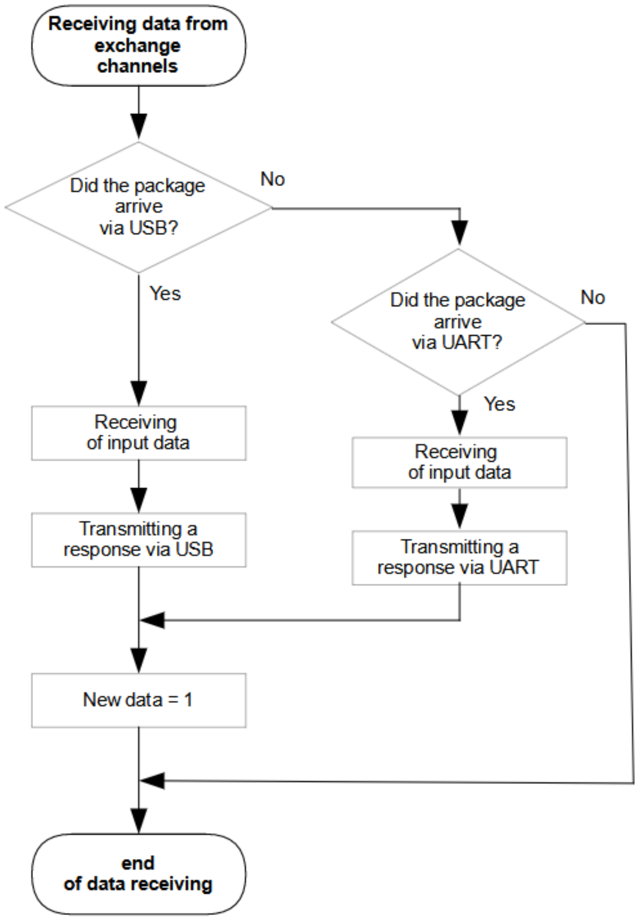

Fig. 3. The algorithm of the communication module digital interface

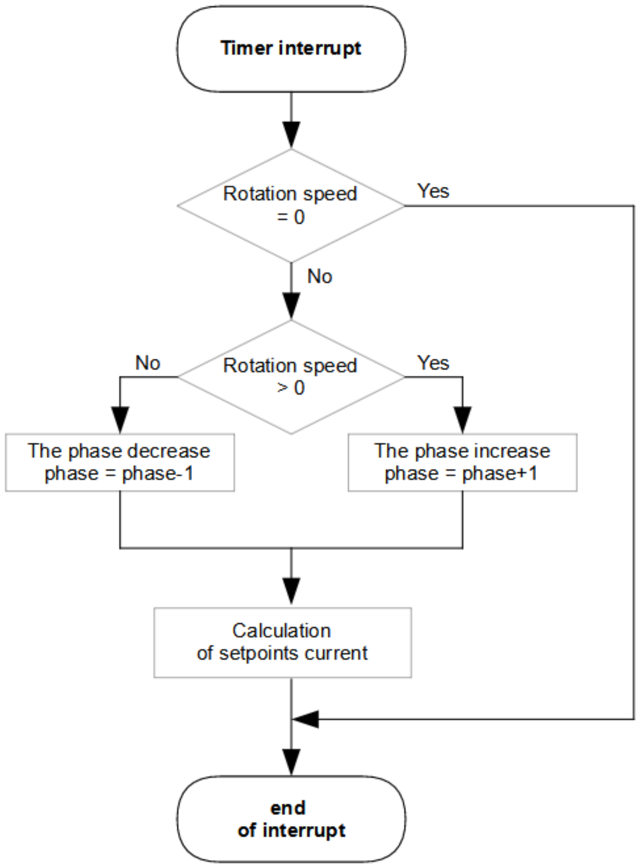

Fig. 5. The algorithm of the timer interrupt handler module operation

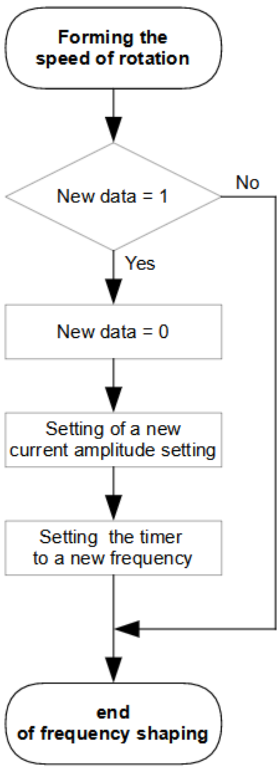

Fig. 4. The Algorithm of operation of the engine speed generation module

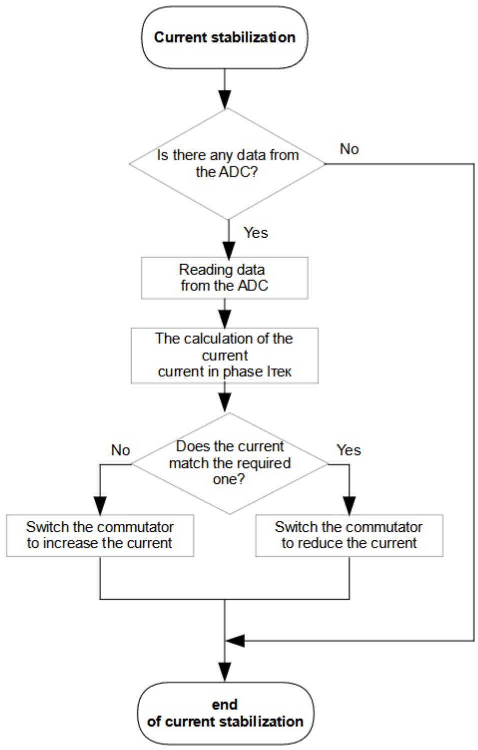

Fig. 6. The algorithm of operation of the current stabilizer module in the motor phases

III. Device operation analysis

Debugging of the microcontroller firmware was carried out in the Keil µVision 5 development environment.

Analysis of the operation of the microcontroller at a frequency of 168 MHz showed that under such conditions it is impossible to obtain a frequency of 48 MHz for the USB interface. In this regard, the software algorithm was adjusted to reduce the frequency of the microcontroller to 144 MHz.

In the process of debugging the communication module via digital interfaces, the reception of a sequence of bytes via the UART and USB interfaces was simulated by writing data to the corresponding receiving buffers and setting the corresponding flags. Verified the correctness of the packets reception, parameters decoding (frequency and motor rotation direction, the amplitude of the current in the phases of the motor, etc.), and the proper generation of a response packets and the validity of its transfer.

When debugging the timer interrupt handler module, it was found out that the timer interrupt flag is not automatically reset, as a result of which, after exiting the interrupt handler, it is immediately called again, thus completely blocking the execution of the remaining modules. A manual reset of the interrupt flag in the timer interrupt handler module solved the problem.

The general view of the developed device is shown in Fig. 7.

Fig. 7. The general view of the developed device

IV. Results

During this stage of work, an experimental model of a two-phase synchronous electric motor control system and software for its operation were developed.

Tests have been conducted that the device fulfils the stated tasks and satisfies the claimed technical parameters (weight, dimensions, accuracy of current stabilization in the motor phase).

Based on the results obtained, one will plane to create prototypes and conduct their experimental studies in order to further introduce the development into production.

Acknowledgment

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