

Arm microcontroller learning kit

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Abstract: The Arm Microcontroller Learning Kit is built with the STMicroelectronics STM32H750VB microcontroller. The device is a small development system based on an Arm Cortex-M7 microcontroller. It has a modern modular design. The kit includes the most necessary peripherals to illustrate the capabilities of the microcontroller and it also supports a large amount of external peripherals. The cost of the kit is low due to the built-in periphery and the small number of additional external elements. The software uses a small fraction of the libraries provided by the microcontroller manufacturer and can be upgraded. This makes the device suitable for learning an ARM family of microcontrollers by beginners and advanced students.

Keywords: ARM MICROCONTROLLER, LEARNING KIT, DEVELOPMENT SYSTEM

1. Introduction

In recent decades, microcontrollers from various manufacturers have become widespread in various fields of human activity. They can be found in the most unexpected devices and designs in the computerization and automation of the processes around us. Without knowing the basics of programming, it is almost impossible to create modern competitive devices. The use of off-the-shelf microcontroller boards that eliminate the coding process and that students can use to create and prototype their work, is also widely used to meet demand [1].

The microcontroller modules use microcontrollers from different manufacturers with 8, 16 and 32 bit organization. The popularity of the microcontroller used is determined by cost and availability. The availability of technical information and the cost of software support play a significant role. The last few years have seen a rapid growth in the ArmRM Cortex-M group of 32-bit RISK Arm processor cores licensed by Arm Holdings. These cores are optimized for computing power, cost and energy efficiency microcontrollers, which are currently embedded in billions of devices worldwide [2].

Many manufacturers offer kits, development boards and systems based on Cortex-M Arm. There are 2 types: very cheap, in which the controller is mounted on a small board, where its legs are placed on rails, or expensive multifunctional development systems with a large amount of all kinds of peripherals, unusable for initial training. The former are unsuccessful for initial training, and the latter are too expensive and intended for professional development.

The offered learning kit includes the necessary hardware for mastering the work with Arm microcontrollers up to generation M7. It is intended for initial training. Due to the modular construction and the mounted extended interface connectors, this kit is modern and would be usable in the next few years.

2. Construction of the system

The kit consists of one main board with 5 modules mounted on it:

- microcontroller module,
- programmer module,
- keyboard module,
- expansion slots i
- input-output peripheral connectors.

A block diagram of the proposed kit is shown in Fig.1.

A photograph of the main printed circuit board (PCB) of the kit - side elements is shown in Fig.2.

The processor module is a self-contained device that can be used as a building block for other projects. It can be replaced with a similar module, implemented with another microcontroller from the same manufacturer with different number of feet, which requires small changes the design of the printed circuit board of the module.

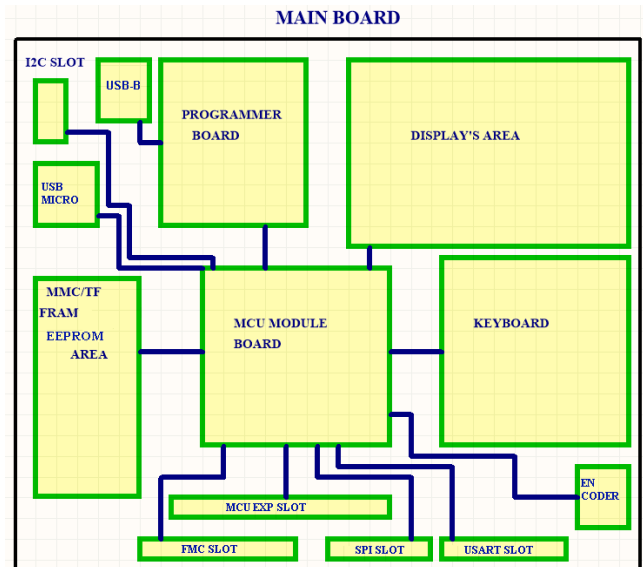


Fig.1. Block diagram of the learning kit.



Fig.2. Main kit's PCB - side elements.

The processor module is implemented with a microcontroller STM32H750VB in a case LQFP100. Instead, any STM32H7xx

series microcontroller (100 pins) can be mounted there, because in the case of the 7-series and the same housing, the integrated circuits have the same location of the pins signals. The built-in peripherals in the 7-series are the same too. All pins of the microcontroller and power supply for multifunctional use are connected to a universal slot. It is convenient for connecting various external boards, modules, sensors, etc. [3].

An electrical schematic diagram of the microcontroller module of the kit is shown in Fig.3.

Filter capacitors and resistors for the four BOOT modes, a button and an RC group for automatic and manual initial setup are installed. There are connected quartz resonators HSE for frequencies 8 MHz and LSE for 32.768 KHz. 80 input-output pins are mounted on rails, which are organized in 5 input-output ports with 16 multifunctional lines. To the right of the schematic diagram are shown the signals for programming and debugging the serial synchronous SWD interface for connection to the programmer module.

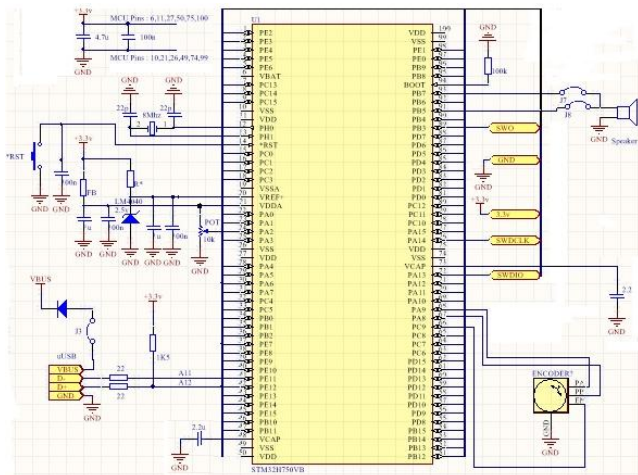


Fig.3. Schematic of the microcontroller module.

The STM32H750VB microcontroller that is used has a 32-bit Arm Cortex-M7 core that can operate at frequencies up to 480 MHz. It has a built-in Floating Point Unit /FPU/, L1 cash 16 KB for data and 16 KB for instructions. The microcontroller has a built-in 128 KB flash memory and 1 MB RAM memory. Its dual SPI interface operates at frequencies up to 133 MHz. The multifunctional external memory controller with a 32-bit bus running at 133 MHz supports SDRAM, 8-bit and 16-bit NAND flash memory. An external interrupt signal can be applied to each of the 80 input-output legs. The microcontroller has a regulator for analog reference voltage / VREF + /. The device can operate in 4 low power modes: Sleep, Stop, Standby and VBAT with battery power.

The microcontroller can use internal clock generators 32kHz, 4 MHz, 48 MHz, 64 MHz or external clock generators 32 kHz, 4-48 MHz. There are 4 built-in DMA controllers, 1 basic DMA controller of which has the ability to service 35 peripheral ports. The peripheral of the microcontroller includes 4 pcs. I²C interface, 4 pcs. USART controller, 6 SPI interfaces, 2 pcs. interfaces for control of 2 SD/SDIO/MMC memory cards, 2 CAN controllers, 2 pcs. USB OTG (IFS, IHS/FS) interfaces, Ethernet MAC interface, analog camera connection interface, 11 analog peripherals. The microcontroller has 3 pcs. Analog to Digital Convertors /ADC/ with 16 bit resolution, operating at a frequency of up to 3.6 MHz and the ability to include up to 36 analog input channels. In addition, the microcontroller has a built-in temperature sensor, 2 pcs. 12-bit Digital to Analog Convertors /DAC/, operating with a conversion frequency of 1 MHz, Liquid Crystal Display /LCD/ controller with resolutions up to XGA (1024x768), 22 pcs. timers. Two of them are 32-bit, which can be used for different purposes, e.g. pulse counters, pulse generators, Pulse Width Modulation (PWM) generators. The microcontroller also has a Real-Time Clock (RTC). The

microprocessor supports debug mode using SWD and JTAG programming interfaces.

An electrical schematic diagram of the programmer module is shown in Fig.4.

The programmer module is based on the microcontroller STM32F103C8T6 in LQFP48 housing. The module connects via USB port on PC module and STM32H750VB microcontroller via SWD programming protocol and Debug [4] – Fig.5.

The linear stabilizer, mounted on the programmer module, converts the 5V input voltage from the USB connectors into a 3.3V common supply voltage for the kit at current consumption up to 500 mA.

The programmer module can be used stand-alone to program STM microcontrollers outside the kit. It can be replaced with a similar module, implemented with another microcontroller from the same manufacturer with different number of feet, which requires a small processing of the PCB of the module.

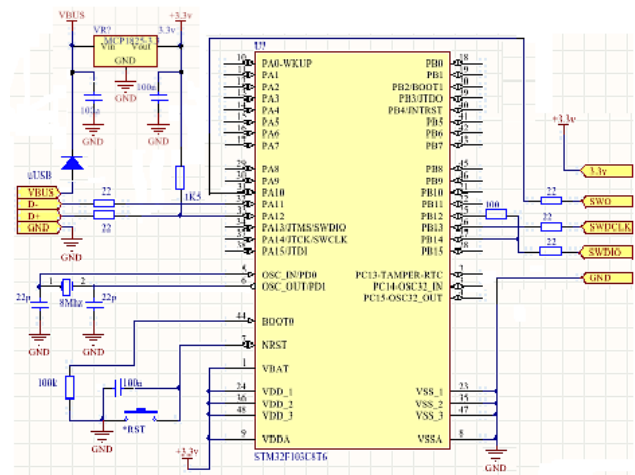


Fig.4. Schematic of the programmer module.

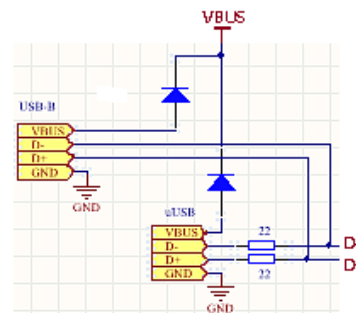


Fig.5. USB interface connectors.

The electrical schematic diagram of the keyboard module is shown in Fig.6.

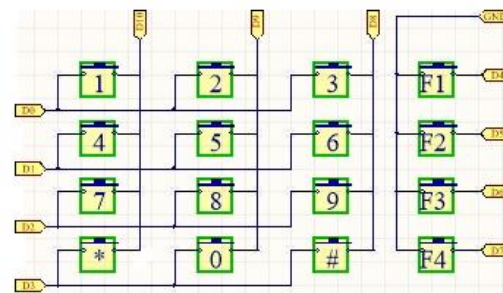


Fig.6. Keyboard module.

A membrane keyboard is used. The keyboard matrix consists of four rows and three columns. The numbers 0 - 9 and the symbols *, #, F1, F2, F3, F4 are written on the keys. The buttons are connected to the terminals of port D of the microcontroller and are controlled by it.

The expansion slots include:

-an expansion slot with all the legs of the microcontroller, which allows the use of the full functionality of the microcontroller by connecting external boards and modules (for example, Arduino);

-an expansion slot for Flexible Memory Controller (FMC) – Fig.7;

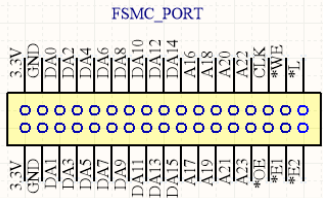


Fig.7. FMC expansion slot.

This hardware is software-activated for operation in parallel input-output mode. In this mode are activated: 24-bit parallel address bus, 16-bit parallel data bus, multiplexed with the lower 16 bits of the address bus, control signals ALE, * WE, * OE, NE1 and NE2.

The flexible memory controller (FMC) includes 3 controllers for different types of memory: NOR, NAND and synchronous DRAM memory.

Its bus is designed to connect to external static, parallel memories and devices addressed throughout the 24 bit external address space, such as: Flash, SRAM, NVRAM, FRAM, parallel TFT LCD displays, etc .;

-connecting rails for 3 types of displays – Fig.8.

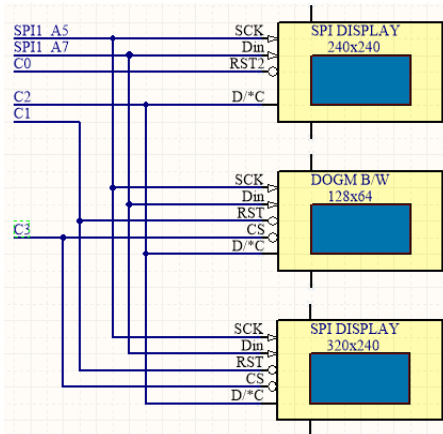


Fig.8. Display's expansion slot.

The first type is a color TFT LCD display module powered by an SPI bus. It can be a different type with a diagonal size of 1.8 "to 3.4" and a resolution of 320x240, 320x480 and 960x480, with 65K or 256K colors. A display of this type with a resolution of 320x240 and 65K colors is mounted on the demonstration board.

The second type is a color TFT IPS LCD, with a size of 1.3" and a matrix of 200x200 pixels.

The third type display is a black / white LCD with a resolution of 128x64 pixels, SPI interface and external backlight. It is possible to change the intensity of the backlight by PWM pulses.

The I/O peripheral connectors consists of lines to external peripherals and standard interfaces for studying various communication protocols. There are 2 slots with output lines on the I2C, SPI and USART interfaces – Fig.9.

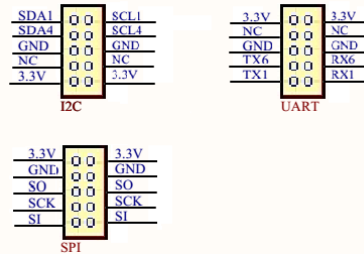


Fig.9. I²C, SPI and USART slots.

Connectors for I²C EEPROM or FRAM for the 24Cxx series, SPI EEPROM or FRAM for the 25Lxx series are mounted on the printed circuit board - Fig.10.

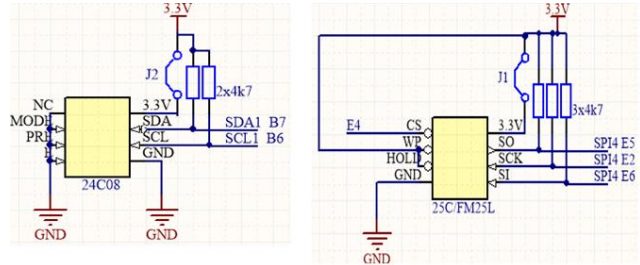


Fig.10. Connecting I²C and SPI memories.

There is a standard USB-B connector for programming and power supply of the kit, µUSB for connection of the microcontroller to PC as guest, encoder and speaker are installed. PWM and DAC outputs connected to the mounted speaker are provided. They generate and produce frequencies in the sound range. A voltage divider is implemented with a potentiometer and a voltage of 0-3.3V is applied to one of the three 16-bit ADC channels of the microcontroller. On the PCB is also mounted a rotary encoder, which allows converting the angle of rotation into a number – Fig.3. The pulse encoder is of the mechanical type. It has one button with a normally open contact, which closes when pressing the shaft and two other keys that close and open when the shaft rotates. Thus, pulse sequences with a phase shift of 90° and a uniform pulse period are formed, which allows the conversion of the angle of rotation into a number. This encoder is convenient when working with menus for fast up and down navigation and marking.

There are 8 digital outputs – the lines D8-D13 of the microcontroller, which are connected to separate slot of the PCB. Their levels are indicated by two-colour (red/green) LEDs – Fig.11.

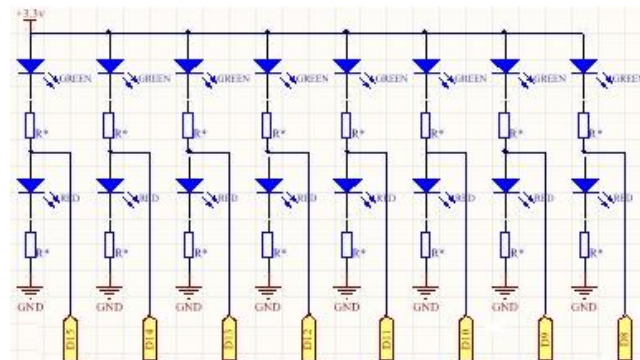


Fig.11. Digital outputs and LED's indicators.

3. Software support

The following software is used to work with STMicroelectronics microcontrollers:

- μ Vision5 by Keil. This is a free development environment for short programs, up to 35-40 KB HEX file, which is enough for training purposes. For larger volumes the version is paid. In this environment, it is easy to write and edit Assembler and C/C++ code, it can be compiled and debugged.

μ Vision IDE is an integrated development environment for project management and code execution. Offers tools for creating and editing source code and debugging the program. μ Vision Debugger provides an integrated environment in which the user can test, verify and optimize the code of their application. The debugger includes traditional features such as simple and complex breakpoints, performance monitoring and control windows, providing full visibility of device peripherals [5].

-STM32CubeMX, STM32CubeProgrammer is a part of the manufacturer's development software. STM32CubeMX is a graphical configuration tool that allows automatic generation of C initialization code using a graphical wizard.

The programmer STM32CubeProgrammer supports STM32 devices, based on Arm® Cortex® processors. It allows you to delete, program, view the contents of the device's Flash memory. The software includes both a GUI (graphical user interface) and a CLI (command line interface).

-Keil® MDK / Microcontroller Development Kit / is the most comprehensive software development solution for Arm® based microcontrollers and includes all the components needed to create, build and debug embedded applications [6].

MDK-Core is based on μ Vision (Windows only) with leading support for Cortex-M devices, including the new Armv8-M architecture. MDK includes Arm C / C++ compiler with assembler, linker and highly optimized libraries, which are adapted for optimal code size and maximum performance.

Software packages can be added to MDK-Core at any time, making support for new devices and middleware updates independent of the toolkit. They include device support, libraries, middleware, PCB support, code templates, and sample projects.

4. Conclusions

The presented learning kit is intended for basic training in universities and high schools. It is modern, affordable and low cost. This makes it suitable for initial training. Specially designed processor boards for a wide range of microcontrollers from the same manufacturer can be used. The software can be easily upgraded.

The kit can also be used by advanced users, because it provides full use of the set processor.

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