2D POSITION SYSTEM

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Abstract: The purpose of this paper was to design and build system for positioning ultrasound probe in 2 dimensions. 2D position system has modular construction and is driven by personal computer via USB interface. ATmega16, IRL520N and FT232R were used as the most important parts of modular hardware solution. Software for control of the position system was designed in C++ Builder and it is compatible with MS Windows XP or newer.

Keywords: Position system, stepper motor, USB, FT232R, C++, C, AVR, ATmega16, RS-485

1. INTRODUCTION

Positioning systems are widely used for handling and movement of products and equipment. Positioning systems are different in size – from millimeters and smaller in medicine to square kilometers in airport luggage systems. Other differences are robustness, speed and acceleration, accuracy, method of control and no less important factor: purchase price and maintenance costs.

The task was to design 2 dimensional positioning system for movement of ultrasound probe in aquarium with measured fluid. Predefined parameters were A3+ area of movement, position changing time negligible against the time when fluid is steady again, 1 mm and better accuracy, control by PC via USB and lower cost against similar, commercially available, systems.

2. CONSTRUCTION AND HARDWARE REALIZATION

Position system consists of three main parts: metal frame with moving parts (platforms), electronic and software. Metal frame (steel) is rectangular, outer dimensions are 70x55 cm, inner (for movement of the “endpoint”) 50x30 cm. Movement is provided by dragging of platforms on rails. On frame are rails for the first platform (moving in longer direction – 50 cm). On it, there are mounted rails with second platform, moving in right angle to the first one (30 cm). Mechanical power for movement of both platforms is provided by two unipolar stepper motors (one for each platform), transmitted to rod, which twists the cable connected to platform (Fig. 1 right). Rotating movement of rotor is transformed into linear movement of platform. On second platform is rod for attachment of probe. Midpoint of this rod is understood as endpoint, on it is attached probe. Change of its position is input given by user. [1]

Weight of second platform with rod and probe is about 0.4 kg, weight of first platform (with rails, second platform and probe) is about 1.6 kg. Facts, that movement is in horizontal direction and friction between rails and platforms is minimal, set the required parameters for stepper motors with 30% reserve. Used were unipolar Minebea PM55L (torque 1.2 Nm at speed of 250 steps per second) and unipolar Minebea PM42L (0.70 Nm / 250 sps). One step for both motors is turnaround of 7.5^0 and with used transmission it gives to platform the smallest available linear step of 0.313 mm. Compared to the dimensions, it takes about 10-15 seconds to change position between the farthest available positions, with higher safe speed and acceleration (maximal speed 250 steps per second, max. acceleration 80 steps per second, values safe against stuck, limited by software). [1][2]

Electrical part of position system has modular construction. There is module for providing communication between PC (with control software) and two power modules (one for each axis of movement). Because of 2 axes of movement (=2 power modules), a RS-485 serial interface, which allows to connect multiple devices, was chosen for communication between modules. Predefined interface for connection of position system to PC was USB, so converter between them is needed.

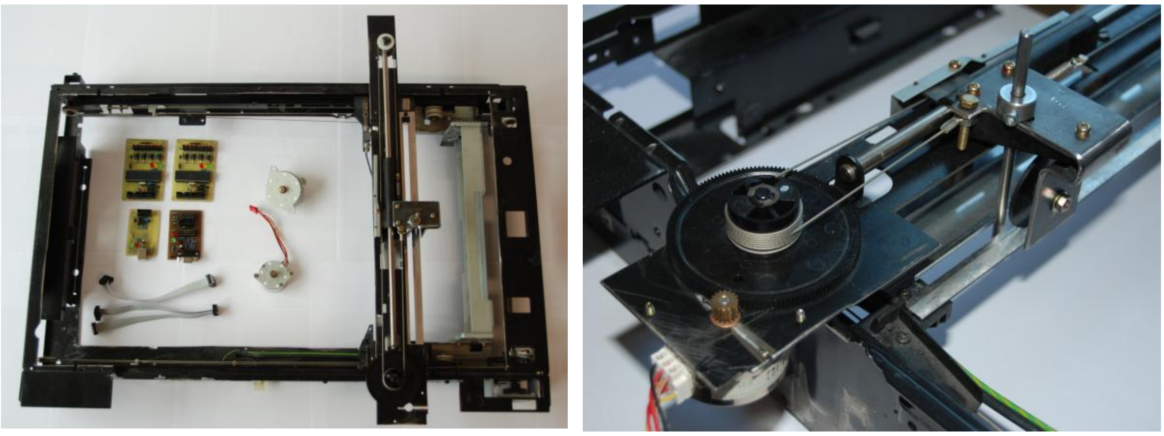
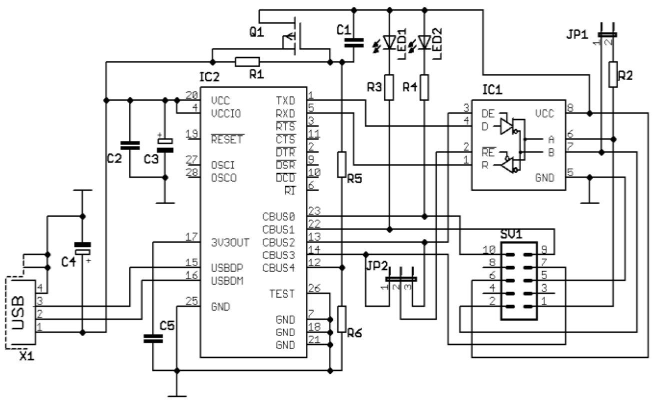


Figure 1: Position system components (2 power modules, converter, ISP, stepper motors, frame with platforms) and on right detail of motor with transmission and 2nd platform with rod

2.1. CONVERTER USB-RS485

For conversion of USB standard to RS-485 was chosen circuit FT232RL (SSOP-21 package), configured as USB-powered, with control of external logic and a pair of signal LEDs. Design-bonding scheme and the board and was designed in a freeware version of Eagle 5.10.0. Driver for RS-485 is SN7517 (SN7517GBP, DIL8). For switching power (+5V), to the external logic, was used p-channel MOSFET IRF7314PBF (SO8 package). It is controlled by logical pin of FT232RL (CBUS setup # PWRON - PoWeR ON). PCB contains B USB connector and MLW10 (for output in the form of flat 10-core cable), several filter capacitors, pull-up resistors and wire jumpers.



List of components

R1	100k	R2	1k
R3, R4	470R	R5	10k
R8	120R	C1, C4	100n
C2	4.7u	C3	10n
LED1	red	LED2	green
Q1	IRF314PBF		
IC1	SN75176BP		
IC2	FT232RL		
X1	USB B 900 for PBS		
SV1	MLW10		
JP1, JP2	pinnhead		

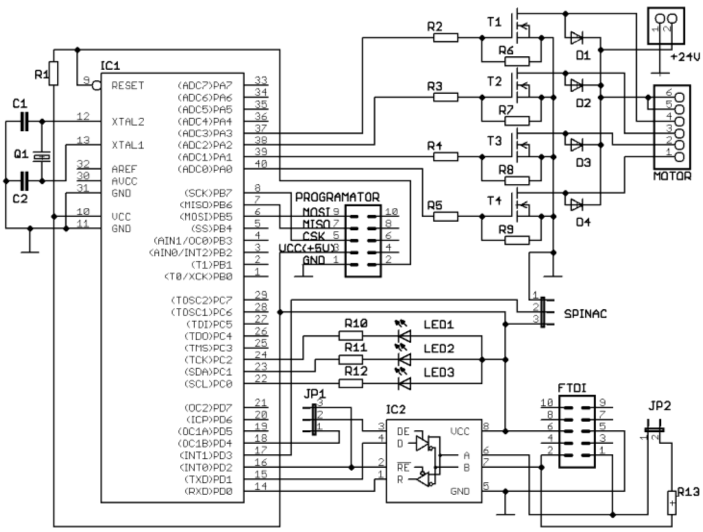
Figure 2: Schematics of USB-RS-485 converter with list of components

On the single-layer PCB there are two jumpers. The first one is for the inclusion of load resistance for RS-485 in the event of disconnection of the module. The second allows user to choose type of control of RS-485. In position one the broadcast is driven by CBUS pin configured as # TXDEN and receiving is driven by the second pin in configuration # PWRON, which ensures that in case of circuit is in sleep mode, it won’t accept communication and another station, on the basis of response, may find that there is no communication. In position two receiving and transmitting is driven only by one CBUS pin in configuration # TXDEN. [1][3][8]

2.2. POWER MODULE

Second module of position system consists of signal and power circuit. Signal one is contains ATmega16, converter SN75176 (RS-232 – RS-485), connectors for ISP programmer, output from USB-USART converter and LED controls. FTDI module outputs are A, B, VCC (+5 V) and GND. VCC brings to the board +5 V from USB (the consumption is controlled FT232RL, which switches the P-channel MOSFET). Thus it’s not necessary to have power supply with two levels of output voltage (5V logical and 24V for motors). Signals A and B are input / output signals (RS-485) to the transmitter SN75176, which produces signals in standard RS-232 (RX, TX, RX enable, TX enable) in an appropriate logic level for ATmega16. These are then routed to the pins PD0-PD2 of the microcontroller. Between the lines A and B is connected resistor 120R, which need to load the line if the module does not work. To the pins 12 and 13 is connected crystal with the frequency f = 16MHz, and two capacitors. These components give the ATmega16 clock frequency. Three LEDs are connected to pins C0-C2 to indicate direction of the communication (RX and TX) and any equipment error (ERROR). The terminal pins (pinhead) are brought GND, VCC and one to the microcontroller pin (with interruptions) for connecting the terminal microswitch, which will be used for signaling the position of moving platform during calibration. To the PCB was added connector for the programmer. ATmega16 has the possibility to connect to the pins MOSI, MISO, SCK, RESET, VCC and GND of serial programmer (ISP - In-System Programmer). When recording the code, it’s not necessary to choose a microcontroller out from the slot.

The power part of the board consists of four excitation circuit consisting of IRL520N type MOSFET, 1N5408 diodes and other components. The switching transistors MOSFET are switched on by the 5V voltage level which is high level on the output pin ATmega16. Type IRL520N the threshold around 1.5 V, so it is securely closed by five volts, with a reserve and easily handle the required performance (maximum 1.7 A at 24V). Used unipolar stepper motors are Minebea PM42L and PM55L detaily described in [1]. [1][2][4][5][6][7]



List of components
Q1 crystal 16MHz
R1 10k
R2,R3,R4,R5 120R
R6,R7,R8,R9 5k
R10,R11,R12 1k5
C1,C2 22p
D1,D2,D3,D4 1N5408
T1,T2,T3,T4 IRL520N
LED1 – LED3 red,green,blue
IC1 ATmega16
IC2 SN57176BP
Programator, FTDI MLW10
JP1,JP2,MOTOR,24V pinnhead

Figure 3: Schematics of ATmega16 module with list of components

3. SOFTWARE SOLUTIONS

Two programs were designed for position system: control software for providing communication through converter and driver for ATmega16 module which provides communication and drives stepper motor’s operation.

3.1. COMMUNICATION PROTOCOL

Serial line was used as a way of communication between modules of position system, concretely RS-485 which allows system to control multiple modules at once. FT232R module has a serial line and ATmega16 USART interface. As an interface to a standard RS-485, converter SN75176 is used. After sending the data, marked with address of module they belong, via USB, they are converted and sent to all subordinate modules and evaluated.

Each management control, which is composed of ASCII characters, is in curly brackets, and various parameters such as address, command, and other necessary data are separated by a comma. The actual command might look like this: {1,1,1456,80,10}, where {address, command, position, velocity, acceleration}. Module, with address 1, moves to position (command "1") 1456, at a speed of 80 steps per second, to which it will accelerate and decelerate by 10 steps per second.

To all signals sent to the ATmega16 there is an answer in unified format {x, x, x, xxxx} where first x is the address first, followed by the command, the current position and status AHPO (Action Homing Power Operation). Action status provides information about ongoing operations in the processor ATmega16. Is it possible to determine whether the motor axis of the work place, or is even the exact situation (for example: engine accelerates). Homing provides information whether a given axis is calibrated, respectively, in which part of the calibration it is. The last two indicators report about engine power and the situation that takes place. Complete list of commands is in [1]. [1][2][3][4][8]

3.2. DRIVER FOR ATMEGA16

ATmega16 program consists of two main parts: a motor controller and USART operation's driver. The USART operational driver provides communication with the FT232R module, there are set all registers needed for USART operation (UDR, UCSRA, UCSRB, UCSRC, and UBRRL UBRRH). USART unit works in asynchronous mode, so every event (incoming communication or error) generates an interruption. Function of this module is driven by main switch/case loop, which takes data from incoming message and calls appropriate function (stop, move, homing,...).

The second part of the program drives the motor windings by logical switching of MOSFETs that are connected to one port of a microcontroller. Stepping is performed as a function, which is counting time (by using counter) between every change of output sequence. Sequences are defined as: `Step[]={0b0011,0b0010,0b0110,0b0100,0b1100,0b1000,0b1001,0b0001}`, where every half-step is represented by combination of powered windings. To accelerate the engine, keeping a constant speed or decelerate, it is necessary to calculate the duration of one sequence. The acceleration is calculated as $t=F_{clk}/sqrt(2*s*a)$, where F_{clk} is frequency of counter without prescalers, *s* is trajectory and *a* is acceleration.

A calibration (homing) of the position system is performed so that the platforms (in both axes) are moving in a given direction (to the terminating microswitch which define limit / border of movement) at a speed of 30 steps per second. After there is a contact between moving platform and terminal microswitch, platform stops, moves 30 steps backward, microswitch and platform are not in contact. Then it moves forward again (at speed of 5 steps per second) until the platform slowly hits the microswitch contact for the second time for precise calibration. After this, message, that homing is complete, is sent to control software and actual position is set as [0;0].

Driver for ATmega16 was physically programmed by using ISP programmer and PonyProg2000 software. RS-485 communication was debugged with Docklight 1.9. [1][2][5][6][7]

3.3. CONTROL SOFTWARE

Program to control position system was written in Borland C + + Builder 6.0, which offers programming languages C and C + + and also creation of graphical interface. Created program process input data, entered by the user (giving numbers and pressing the button). Output is a command, which is sent via USB to FT232R module.

First of all FT232R module has to be located and communication established, then the communication parameters on the output side FT232RL are set as well. Software finds all connected FT232R, acquire and create a connection handle (in the program this parameter is also passed as the address of the device where the data is sent). Then it sets the baud rate, characterization of data frame (8 data bits, 1 top bit, even parity) and data flow control. Verification of execution of each command is provided by the statement (ftStatus! = FT_OK), as an automatic response of FT232R, whether or not a specific command was executed successfully. Thus any error is quickly detectable.

If the connection is set and external power supply is on, position system is prepared to work. Functions for change the location of the endpoint (with probe), perform homing, stop, and other options are now available. Wanted position and speed is put into edit fields, software provides control, if it is in allowed limits of speed possibilities of stepper engines or if wanted position lies inside of the frame. Ultrasound probe is usually immersed in aquarium with measured liquid and the size of probe and aquarium is also checked against input data. After this procedure command for erasing content of transmitting and receiving buffers is sent, followed by instruction. The frame of ASCII characters as mentioned above (3.1). In respond (send by ATmega16 modules) there is information about current status visible in “INFO” frame. Because there is no synchronization of axis (modules) there is 10 ms delay between sending commands and reading answers. [1][2][7][8]

4. CONCLUSION

Designed position system is fully functional, and easy to use. Control software runs under Win XP or newer and uses USB interface to communication with electronics. Construction is modular and communicates via RS-486 bus. System needs only one external power supply for stepper engines.

The best advantage is possibility to modify this system. Add can be other axis of movement, limited only by number of available pins of microcontroller. It can be easily modified to version with bipolar stepper motors. Also control software can be modified, for example by adding possibility to predefine movement of probe.

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