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FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION
DEPARTMENT OF CONTROL AND INSTRUMENTATION

CNC MACHINE MANAGEMENT

CONTROL OF CNC MILL

BACHELOR THESIS
BACHELOR'S THESIS

AUTHOR WORK
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MANAGING WORK
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Student: Jan Cedrych ***ID:*** 115159
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TOPIC NAME:

Control of the CNC milling machine

PROCESSING INSTRUCTIONS:

1. Learn about the Mao CNC milling machine
MH500 and discuss the possibilities of upgrading the milling machine control system.
2. Select the appropriate conception of the upgraded control system and draw its block diagram.
Fill in the missing parts of the documentation and draw the overall wiring diagram of the machine.
3. Design the necessary interface for connecting the machine to the control system and calculate the values
individual components. Consider galvanic isolation of inputs and outputs.
4. Create a Spool Gear Shift Control Program. Delay the program.

RECOMMENDED LITERATURE:

[1] FROHN, Manfred - OBERTHÜR, Wolfgang - SIEDLER, Hans-Jobst - WIEMER Manfred - ZASTROW, Peter. Electronics - semiconductor components and basic wiring. Prague: BEN 2006. 500 s. ISBN 80-7300-123-3.

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Chairman of the Sector Board

NOTICE:

Abstract

The possibilities of modernization of the milling control system are analyzed MAHO MH 500 C, taking into account the current state of the machine, assumed use and financial possibilities. The thesis deals with the connection of the existing one electrical equipment of the machine with a new control system. The proposed concept allows continuous three-axis machining and rotating table positioning.

Keywords

CNC, MAHO, Philips 432, retrofit, control system

Abstract

In this thesis is discussed the possibility of upgrading the control system of mill MAHO MH 500 C with respect to current condition of the machine, planned use and owner financial capacity. The thesis also deals with connecting existing electrical equipment with a new control system. The proposed design allows simultaneous machining in three axes and positioning rotary table.

Keywords

CNC, MAHO, Philips 432, retrofit, control system

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Declaration

"I declare that my bachelor work on CNC Milling has been elaborated
independently under the leadership of the Bachelor Thesis and with the use of specialized literature and other information sources that are all quoted in the work and listed
literature at the end of the work.

As the author of the bachelor thesis I further declare that in connection with the creation
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Thanks

Thank you to the bachelor thesis manager Ing. Tomáš Machová, Ph.D. effective methodological, pedagogical and technical assistance and other valuable advice in my work bachelor thesis.

Furthermore, I would like to thank CBG Impex sro for loaned equipment.

In Brno on: **May 30, 2011** ....

signature of the author

Content

1. INTRODUCTION

The aim of the thesis is to propose replacement of the faulty Philips 432 CNC control system installed on the MAHO MH 500 C milling machine, so as to keep as much as possible existing electrical equipment of the machine. Because the machining is not expected to be used machines in the commercial area, but only as a means of getting acquainted with the issues programming of CNC machines, the price of the proposed system plays an important role.

In the first part is briefly described the electrical equipment of the machine, so they are mapped signals needed to control the milling machine.

The second part deals with the reasons that led to the replacement of the control system. They are also here the reasons why the commercial control system was not selected. It is also done here designing a new machine control system.

The third part of the thesis deals with the necessary interface for the connection with the machine and the design expansion cards for digital inputs and outputs

The last part describes the design of the gearbox control program.

2 EXISTING ELECTRICAL EQUIPMENT

MACHINERY

2.1 Controller Philips 432 CNC

The CNC milling machine MAHO MH 500 C (milling machine) was manufactured in 1985 and its the equipment corresponds to the possibilities of the industry at that time. A control system is installed on the milling machine Philips 432 CNC, which consists of a power supply module, a video card, a processor cards, memory cards, digital input and output cards, two drive control cards slides, spindle control cards, and control panel operator cards. All parts are placed in a 19 "subrack module. They are used on the cards to connect to the milling machine canon connectors.

Power supply module

It serves to power the entire control system. There are clamps on the front panel power supply, terminals for connecting the backup battery, switch enabling select the size of the mains voltage. The backup battery is used to power the memory card when the mains voltage is disconnected. The output voltage of the source is applied to the backplane, to to which other cards are attached.

Video card

Creates a signal for the black and white CRT screen of the control system. The screen output is only text, this version of the system does not support the graphical preview of the machining program.

Processor and memory card

The processor card is equipped with the Intel 8088 processor, which manages the whole control system. There is a serial line module on the card. The control system is thus available connect to a personal computer and transfer a machining program. The memory card extends to 16 KB RAMs located on the CPU board with an additional 64KB.

Digital Input and Output Card

This card has forty digital inputs and forty digital outputs.
Outputs are solved with common positive pole (PNP output), common inputs negative pole. The inlet and outlet sections are galvanically separated from the control system using optocouplers. Inputs and outputs of this card are designed to 24 V DC, which is commonly used in industry.

Drive control cards

The drive control of the individual feeds of the milling machine is performed with an analog signal -10 V to +10 V. The spindle motor is controlled in the same way. This signal is generated in control cards using the D / A converter and represents the required engine speed.
Sensing the feed position is solved by linear incremental metering rulers mounted on individual machine slides. To measure the rotation

rotary table serves an incremental rotary encoder. Linear and rotary sensors have the same quadrature output. Quadrature signals A, B are in the control card evaluated and transferred to location information. The control system includes three of these cards, each of which has two analog outputs and two encoder inputs.

2.2 Feed drives

They are realized using DC commutator motors permanent magnets and thyristor controlled rectifiers. This solution is u modern machine tools do not use for a long time. Commutator motors in this area replaced synchronous motors with permanent magnets on the rotor, which at the same output speeds and torques are smaller and lighter. A small moment of inertia rotor, compared to the commutator motor, enables high drive dynamics. Another advantage is the absence of commutator and brushes, so the engine is almost maintenance-free. The cost of these drives is, however, relatively high. Machine equipment with these drives in all four axes would mean an investment in the order of sixty thousand crowns. WITH taking into account the good condition of commutators and brushes on current engines, costly investment in new drives, it was decided to leave drives on the machine existing.

The drives in the X, Y and X axis are used to drive the rotary table Indramat MDC 10.20C. Its parameters are shown in Tab. 2.1.

Tab. 2.1 Engine Parameters MDC 10.20C

Parameter	Designation	Value
Torque constant of the engine	K_M	0.47 Nm / A
Rated current	I_{ef}	13 A
Top stream	I_p	100 A
Maximum voltage	U_{max}	170 V
Maximum speed	n_{max}	2000 rpm
Voltage constant tachodynama	K_{TD}	0.317 Vs / rad

Z axis positioning is provided by the Indramat MDC engine with a higher torque 10.40F, parameters see Tab. 2.2. The electromagnetic brake is mounted on the engine, which secures the motor shaft when the power is off. It is thus avoided by self-deception downward stroke due to gravity.

Tab. 2.2 Engine Parameters MDC 10. 40F

Parameter	Designation	Value
Torque constant of the engine	K_M	0.47 Nm / A

Rated current	I_{ef}	20 A
Top stream	I_p	200 A
Maximum voltage	U_{max}	170 V
Maximum speed	n_{max}	2000 rpm
Voltage constant tachodynama	K_{TD}	0.317 Vs / rad
Brake voltage	U_B	24 V
Braking torque	M_B	5 Nm

Both types of motors include a contact which is open when the engine is overheated. State contact is evaluated by the security and also monitored by the control system.

The motors are controlled by Indramat 3TRM2 and 1TRM2 two-pulse rectifiers. The 3TRM2 Rectifier contains three identical control and power parts that can be attached to it up to three motors connected. The 1TRM2 rectifier contains only one power and control part.

The control part consists of a PI speed controller and a motor current limiter. The controller and limiter settings are made by an additional TSS module that is chosen on the basis of the engine used. The input voltage corresponds to the current configuration ± 10 V, applied to the input terminals of the controller, to the maximum engine speed, ie ± 2000 rpm. The current motor speed data is obtained from the voltage generated tachodynam.

In Tab. 2.3 gives an overview of the signals that control the operation of the rectifier. The rectifier has no signaling outputs to report its status to the control system. Any loss of the rectifier will result in loss of feedrate position, here the control system evaluate and stop the machine. Digital inputs are controlled by 24 V DC.

Tab. 2.3 Indramat rectifier controlled clamps

Description	Clamp	Input type
Enable controller operation	RF	digital
Enabling the engine to move forward	JF	digital
Allow engine to reverse	JR	digital
Digital Earth	$0V_L$	-
Desired speed	E1	analog -10 V to +10 V

Analogue ground	$0V_M$	-

Because there is no need to block any of the direction of the motor, it is at the RF, JF and JR receives the same signal that allows the drive to run.

At the analog input terminals, the signal from the control system is not supplied directly, but it is to a differential amplifier to eliminate potential interference.

2.3 Spindle drive

The spindle drive provides a DC commutator pin driven by the Siemens motor GF3105 together with a six-pulse controlled Simoreg rectifier from the same company. This the solution is outdated, as in the case of the feed drive. Today he would be in this place an asynchronous motor with frequency inverter is probably installed. After finishing control of the existing drive has revealed the need to replace all the engine bearings. That's it also concerned the bearings in the auxiliary fan. After replacing the engine, the engine runs smoothly even at maximum speed, it is not necessary to use the new drive.

Tab. 2.4 Parameters of the Siemens GF3105

Parameter	**Designation**	**Value**
Anchor tension	U_K	60 -380 V
Nominal current of anchor	I_K	13 A
Maximum performance	P_{max}	3.3 kW
Maximum speed	n_{max}	5000 rpm
Excitation voltage	U_B	170 V
Driving current	I_B	0.2 - 0.7 A
Voltage constant tachodynama	K_{TD}	20 mV × min

The rectifier includes a speed regulator, subordinate to the drive current regulator motor winding and anchor, power parts. There is also a signaling section state of the entire rectifier. An overview of the signals required to control the drive includes Tab. 2.5 a Tab. 2.6. The digital inputs are controlled as in the previous case with a voltage of 24 V DC. As relay outputs are used relay contacts, switched in active state.

Tab. 2.5 Input Terminals of the Simoreg 6RA2620-6DV51-D Rectifier

Description	**Clamp**	**Input type**
Authorization of the activity	64	digital
Emergency stop (negated input)	80	digital

Digital Earth	7	-
Desired speed	56	analog -10 V to + 10V
Analogue ground	14	-

Tab. 2.6 Output Terminals of the Simoreg 6RA2620-6DV51-D Rectifier

Description	**Clamp**	**Output type**
Actual speed = requested	126-127	relay
The maximum load on the drive has been exceeded	108-110	relay
Required revolutions <minimum	114-115	relay
Running the rectifier properly	72-73	relay

The spindle drive also includes a two-speed gearbox with a design. Thanks to her ensure the required speed and torque range on the spindle. Sort of gears is done using small electric motors. He turns the gear shaft through a set of gears, until the shaft reaches the desired position. In the case of the gearbox, there are only two end positions, ranked first or second. In the case of the original, it is still necessary Ensure ramp to middle position - discarded.

Fig. 2.1 Sorting system

The monitoring of the position of the shafts is ensured by a cam system and switching contacts. According to the current combination of closed contacts, the control system is able to distinguish in which the gearbox is located. The gearbox combinations are listed in Tab.
2.7, Tab. 2.8. Unlisted combinations can not be used
construction to occur.

Tab. 2.7 Checking the gearbox status

Contact		**State**
S6	S7	
unbuttoned	closed	First stage
unbuttoned	unbuttoned	Intermediate position
closed	unbuttoned	Second level

Tab. 2.8 Detecting the status of the original

Contact				**State**
S5	S3	S2	S1	
closed	open unbuttoned		closed	Pattern included
closed	open unbutton open			Intermediate position - neutral
closed	closed	open unbuttoned		Disabled
unbuttoned	closed	open unbuttoned		Disabled
open open open open open Intermediate Disabled - Neutral				
open unbuttoned		closed	unbuttoned	Draft removed

The gearshift gearbox is controlled by a relay. One serves to determine the direction rotation and the second to the supply voltage. The template must be neutral for sorting position the motor quickly to stop the inertia over the middle position. It serves a relay that attaches a braking resistor to the motorcycle. Control of this relay provides contact S4, which is closed only when the contact S3 is on.

2.4 End and emergency sensors

The end and emergency switches are mounted on each linear feed of the machine.
Opening the limit switch detects the control system and stops the machine in check. These the switches are also used for ramping to the zero point of the machine. After starting the emergency switch all drives are disconnected from the power supply, this is achieved without the participation of the control system using a safety circuit. This ensures stopping even in the event of a controller error system. Therefore, the ramp on the emergency switch should not occur in normal operation - it is stopped at the end switch, but if this happens, the operator must manually leave the emergency switch to enable the machine to run again.

The rotary table does not need any end or emergency switches, it can rotate continuously around. The zero position is determined by the Index generated in the rotary signal encoder once per revolution. This signal is evaluated along with other signals from encoder in the feed control card.

2.5 Refrigeration and tool change

The cooling emulsion used in machining is pumped from the container under the machine. Drive The pump is provided by an asynchronous motor that is controlled by the control system via contactors.

The tool holder in which the tool is clamped is held in the spindle by means of a set of the compression springs with a force of 10 kN, it is necessary to overcome the force of the springs when changing the tool the tool holder has been released. The milling machine is equipped with a hydraulic system, which will secure the release of the holder. This occurs when the hydraulic valve is switched on. Replacement the tool is provided by the operator, which must be confirmed by pressing the button on control panel.

2.6 Positioning

Rotary table positioning is provided by an incremental rotary encoder ROD 270 from Haidenhain. Angle encoder resolution is $\alpha = 1 \times 10^{-3}$ °. The encoder is right mounted on the rotary table axis. All parameters and connection of the connector can be made found in [8].

Philips PE2480 metering parameters are unavailable due to unavailability catalogs failed to find out. However, the connection of the connector is the same as in the case encoder. Therefore, signals A, B, and Index are also used here. The rulers were distinguished experimentally measured with the result of $r = 5 \times 10^{-5}$ inches.

2.7 Block diagram of wiring

In Fig. 2.2 is a block diagram of the Philips 432 CNC system with a milling cutter before upgrading. Here are only the most important signals required for driving machinery.

Fig. 2.2 Block diagram of the wiring diagram prior to the upgrade

3 MODERNIZATION OF THE CONTROL SYSTEM

The control system is currently inoperative. The previous owner left the machine has been disconnected from the mains for a long time and after the backup battery has been discharged loss of machine constants. Another problem is the size of the machining program the size of the installed memory. This is not a problem with short programs using fixed machining cycles. However, if we want to cut the shape surface according to the machining program created in the CAM system where the tool paths are folded from a large number of lines and arcs, is such a limitation problem. Other Annoying is the speed of transferring programs to the control system. That was one reason why the original owner almost did not use the machine, create and upload to the machine the program was often more lengthy than production on conventional machines, which is in piece production does not pay.

The price, designed by a service company for repairing the system and upgrading in the form of a replacement processor and memory cards for a newer model, was in comparison with the value of the machine high, outpacing the prices of some new control systems. This has led to this the decision to replace the control system.

When selecting a new control system, the main criterion was to leave it existing equipment of the machine and only replace the control system. The second criterion was the price system.

For price reasons, including the cost of any service work, they were included the control systems of renowned manufacturers are excluded from the selection. On the contrary, manufacturers Simple and inexpensive systems are often configuring their products only for control stepping motors using the step and direction signals that are for direct control of the actuator with an analog speed input not applicable.

The Enhanced Machine Controller has best served the requirements. It is not about a complete control system but only a software part because it is available free of charge with extensive documentation and the cost of purchasing the necessary hardware will probably not exceed CZK 15,000, this is the cheapest option. Another the reason for its selection is the ability to drive both the servo and stepper motors. Availability a The ability to modify source code is also an advantage.

3.1 Enhanced Machine Controller

It is a software package designed for control of cutting, cutting, burning machines, or, where appropriate robotic manipulators using a regular PC. A second version is currently being released abbreviated as EMC2, which is distributed under the General Public License. EMC2 needs a Linux operating system with a real-time kernel extension to run. The installation instructions can be found on the project pages [12] for the novice user

ready-to-use variant, Linux Live CD distribution Ubuntu with RTAI expanding the kernel and compiling the EMC2 package.

This system has become part of many hobby CNC devices, but also industrial projects. SMITHY, for example, uses the real-time part of EMC2 as its foundation Ez-Trol system.

3.1.1 Advantages of EMC2

Compared to the current 432 control system, EMC2 can process machining program practically indefinitely long. It has the Look ahead function when it reads ahead blocks the program and allows the user to choose the way they will be individual tool paths to connect. These two properties predetermine it for machining shapes part.

The system uses the capabilities of the Linux operating system, enabling transmission cutting program via network, using flash drive, CD drive. It is also possible use one of the machining program guides.

3.1.2 Hardware Abstraction Layer

It was created by EMC2 developers to easily connect and configure many different ones hardware devices, its capabilities are now much wider. HAL can be uploaded a component that exits the set of pins and parameters when initializing. Individual pins components can be interfaced with signals to create the required configuration. Parameters are used to set and monitor component status. Initializing HAL threads are created, lists of functions that are run with the set period. To run a real-time component, it's necessary to add it to these threads.

Another kind are user-space components that do not have the maximum time responses and runs as a normal application in the operating system.

There are components that perform simple functions such as a logical product, components that run hardware devices (drivers), and more complex to include the component creating the PLC automaton. The motion controller itself, which provides trajectory planning and generates signals for drives, it is also a component in HAL. An overview of available components can be found in [9]

Thanks to this layer, EMC2 is very flexible and you can create a target configuration for given machine. Halmeter and Halscope are available to debug the configuration selected items in HAL. A detailed description of the layer and the procedure for creating your own component contains a handbook [7]

4 INTERFACE FOR CONNECTING THE MACHINE

4.1 Device Selection

For the EMC2 run, a PC set was placed in a housing to accommodate up to 19 " rack so that it can be placed in space instead of the existing control system.

Test set:

- Source: Fortron ATX-300PNR
- Case: Eurocase IPC 4U-500
- Motherboard: Intel BLKD945GSEJT
- Operating memory: OCZ 2GB DDR2 667 SO-DIMM
- HDD: Transcend Compact Flash 4GB + reduction from 2.5 "ATA (Female) to CF (CompactFlash)

EMC2 offers more ways to physically connect the machine. In this case, when they are required analogue outputs and a large number of digital inputs and outputs of the supported devices appear to be the most advantageous PCI card with the designation 5I20 produced by Mesa Electronics. The core of the card is the Spartan II programmable gate array, whose 72 input input terminals (TTL compatible) are available in three connectors. It is also up to the user to connect these connectors. FPGA is programmed from a PC via the PLX9030, this bridge also provides communication between FPGA and PCI bus. The manufacturer delivers the package to the card demonstration software to help create your own project.

4.2 Inputs of metering and analogue outputs

Mesa Electronics also manufactures a number of daughter boards for their PCI cards for signal processing. To solve the problem of connecting a rotary encoder, three linear measuring rulers with quadratic output and the needs of five analogue ones of outputs is considered to be the board 7I48. It has six analogue outputs in the range ± 10 V and six inputs for connection with quadrature output for each the user can choose whether they are TTL or RS-422. In this case they will all set to RS-422.

The analog signal is obtained by filtering the PWM signal generated by the gate array on the PCI card. There are two digital inputs for each analogue output called PWM + and PWM-, according to the signal to which the signal is fed, such is polarity of output voltage.

Measuring inputs can be connected to signals A, B, Index from metering units. This is a total of 18 signals for six inputs. To connect 7I48 to PCI card with one connector, the signals are multiplexed.
PWM signal generation and input evaluation are performed up to the PCI gate array cards.

4.3 Digital Inputs and Outputs

For connection of industrial digital inputs and outputs, Mesa Electronics produces a card 7I37, which includes 16 inputs and 8 outputs that are galvanically isolated from the PCI card separate. However, neither of these cards would provide the necessary number of inputs and outputs. Adding a third would mean purchasing a PCI card 96 by input / output pins. Because the price of this card is considerably higher, if the toolmaker and controllers are connected the available number of inputs would be insufficient, it was decided to take advantage of the options of the gate array and attach an input and output expansion card of its own design.

4.4 Design of expansion cards

Before the proposal itself, it was necessary to choose the type of communication between the expansion card and the gate field. Finally, an eight-bit three-state bus system was selected, six-bit address buses and read-write signals with negative logic. Six-bit the address will ensure an address range of 64 bytes, ie up to 512 input and output digital ones lines. The expansion card must then include an address decoder and set of capture registers.

4.4.1 Output Card Design

The following requirements were set for the output card itself:

- 32 outputs with common plus pole (PNP output)
- maximum switching voltage of 30 V
- maximum output current 500 mA
- Insulation voltage of 250 V between logic and output circuits
- Each output should further include at least a simple current limit, to prevent damage to the card during accidental short-circuiting.

Address decoder is resolved by IC1 74LS85 and IC2 74LS138 and connector JP2 to select the full card address. Circuit 74LS85 is a comparator which compares the four most significant bits to the address bus with the extension address plates set by jumpers on the JP2 connector, if the output A = B is the same is set to the logic value 1. The decoder circuit 74LS138 is selected a specific register on the card whose address is given by the remaining two address bits bus. The current state of the data bus is then written to the register by the

the downward edge of the write signal. Pull-up resistors R1 to R5 were with respect to the input voltage levels and input currents are chosen as follows:

$$R5 \text{ to } R1 \leq \frac{AT_{CC} - AT_{OH}}{AND_{IH}} = \frac{5 - 2.4}{40 \times 10^{-6}} \leq k65 \text{ Oh}$$

The resistor value of 10 kΩ reliably ensures that log input is maintained. 1.

Fig. 4.1 Address decoder

The state of outputs is stored between ICs to IC6 type 74LS374. Entry into the register takes place at the time of the leading edge at CLK input. Behind these registers is the galvanic isolation through a set of optocouplers of the type PC817. Since all outputs are the same, only the first one will be described.

The current limit by the diode of the opto-coupler is provided by a resistor R7 whose value is chosen current I_F = 10 mA and diode voltage U_F = 1,4 V indicated in [10] calculated according to of the following relationship (after → the used value from the E12 series is given):

$$= \frac{AT - AT}{} = \frac{5 - 1,4}{} = \text{Oh} \rightarrow 330 \text{ Oh}$$

7R CC D 360
AND 0.01
F

As the most suitable output power switching element, Smart-MOSFET. It is a MOSFET transistor supplemented with a series of protection (ESD, thermal, current limitation). The output part could be implemented, for example, with the NCV8450 company ON Semiconductor. Unfortunately, I could not find a company that would make these circuits sold in piece quantity. Similar products are rather expensive (integrated other, in this case unusable features) or again in a piece quantity unavailable. That is why the output part was made from common components.

As an output switching element, therefore, the transistor Q2 is of type BD679. Darlinkton the transistor is used here to provide sufficient current gain and transistor the Optocoupler was not jammed. Transistor T2 together with resistors R12 and R13 ensures limit the output current. Threshold is selected by 100 mA greater than nominal output stream.

$$R13 = \frac{AT_{T2\ BE}}{AND_{OUT}} = \frac{0.65}{0.6} = 1.08 \text{ Oh} \rightarrow 1 \text{ Oh}$$

$$P_{R13} = AND_{OUT}^{2} \times R13 = 0.6^{2} \times 1 = 0.36W$$

In place of R13 it is possible to use SMD resistor size 1206 with maximum loss of 0.5 W. The D2 diode serves as a surge arrester circuit protection inductive load eg relay.

Fig. 4.2 Output circuits

4.4.2 Design of an Input Card

The following cards were required for the entry card:

- 32 inputs with a common minus pole
- maximum input voltage 30 V
- 0 to 5 V input voltage as a log. 0, 15 to 30 V as a log. 1
- Insulation voltage of 250 V between logic and input circuits

- filter disturbance - pulse shorter than 150 μs
- Input resistance 3 kΩ

The input card uses the same address and data bus as the address decoder
almost identical. At the downstream edge of the read signal, a leading edge is generated on the pin
CLK of the appropriate registry, this is how the current state of the eight inputs is taken. For the duration of stay
read v log. 0 are captured on the data bus (pin OC in log 0),
which, however, are inverted against the actual input state.

The Pull-up resistor value in the OK2 emitter's emitter was accelerated
take-off and descending edges are reduced to 4.7 kΩ. Dependence of the lengths of these edges on
of the size of the load indicated by the manufacturer in the data sheet [10]. With this resistor value
the open-circuit current I_c = 1.1 mA will be applied to the transistor . The size of the gearbox
the resistor for the diode of the optoelectron was chosen to flip the input gate

of the register occurred when the input voltage transition exceeded the value of U_{IN} = 10 V. Provided that,
when the gate is tilted at voltage U_P = 1.6V, the current of the transistor collector will flow:

$$AND_{CP} = \frac{AT_{CC} - AT_{P}}{R_{C}} = \frac{1.6\text{-}5}{4700} = 0.72\ \text{mA}$$

The manufacturer's dependence of the collector current on the input diode current was
the input current I_{INP} = 0.9 mA is subtracted , the resistor has the following value:

$$R_{P} = \frac{AT_{PIN} - AT_{D}}{AND_{PIN}} = \frac{1{,}4\text{-}10}{0.72 \times 10^{3-}} = 9.55\ \text{k}\Omega$$

This value was reduced to R_P = 9 kΩ after measuring the test connection . Ratio
the values of the resistors R10 and R11, which together make up the resistor R_P ,
with a capacitor C10 to form a filter that filters out positive pulses of magnitude 24
Less than 150 μs. The C10 value was selected at 100 nF, the largest which is commonly available
SMD housing 1206 for ceramic capacitors. Subsequent determination of R10, R11 occurred
using simulation.

Fig. 4.3 Input circuits

4.4.3 Firmware

In order to communicate with the expansion boards of the inputs and outputs, they had to be in HostMot2 firmware package that can be used to configure and download the FPGA along with the development version of EMC, the LMIO has been added. Therefore, it was necessary to understand the activity individual parts of this package, which is completely written in VHDL. There is a description of the functions of each part and the necessary changes.

The Entita Top9030HostMot2 provides the whole FPGA communication with the environment, above all provides data transfer between the internal bus via the controller and the PLX 9030 controller the source file of this entity has selected the firmware configuration and layout used function on the pins of the connector. The user has a choice of several presets configuration, or you can create your own configuration. To add a securing entity

communication with the expansion boards did not need to be changed here. He was only a custom configuration file has been added.

The HostMot2 Entity connects individual entities that perform the functions themselves (PWM generator, stepper motor generator, quadrature signal decoder), to internal ones data buses, and contains address decoders for selecting registers individual entities to read or write. It was necessary to add address decoders and linking the LMIO entity to the existing bus system. Furthermore, the part which was extended according to the configuration file, the layout of the inputs and outputs for work inputs and outputs entity LMIO.

In the IDROMConst package, constants associated with the LMIO entity have been added Registry addresses and constants used to create function distributions on pin connectors

A number of needed is configured in the PIN_LMIO file components and function distribution on the connectors according to the attached cards. Communication with the expansion board itself is provided by the newly created LMIO, which contains two processes. The ALMIO process responds to requests from the parent the bus to which it reports the status of the inputs or writes the required state outputs to the capture memory. It can also write data to configuration registers, thus sets the range of read / written to expansion boards and reading speed a enrollment. The second LMIOBUS process provides data update. Cyclically reads the data from the input card registers by the range and speed set in the configuration register reading and storing them in the capture memory. If new data is written to the capture memory the ALMIO process (PC data) completes the current read cycle and the process passes to write these new data to the output card registers again according to the settings configuration registry.

Fig. 4.4 Signals of the LMIO entity

In Fig. 4.4 are the waveforms of the LMIO's most significant signals, here it is an overview of their functions.

- a clk clock signal that is common to all entities in HostMot2
- clklow is derived from clk by the ratio set in control register and serves to bus timing of input and output cards
- loaddata request to write data from the ibus bus to the cache memory on address given by waddr
- readdata request to expose data from the capture memory at the address of the raddr on bus obus
- loadctrlread, loadctrlwrite request to write configuration data from the ibus bus into the appropriate configuration register
- readctrlread, readctrlwrite the requirement to display the contents of the control registry on bus obus
- writeflag signals the request to write to the output cards after the end reading cycle
- lmobus, lmibus together form a data bus that is brought up to PCI card connector. In order to preserve the structure of the project, it occurs to switch outputs to high impedance by the lmobushiz signal in the entity wordpr
- The lmioaddr address bus, once again plugged into the connector, determines from which card and the register will be read respectively. write
- When the lmiowrite descends, the data is written to the output card register
- the current state of inputs and time is captured at the downstream edge of lmioread the low-level signal staying is transmitted on the data bus

Communication with expansion boards takes place on an 8-bit data bus, but the internal data bus is 32-bit, so you need to convert it. Here you can used internal RAM in dual-port configuration. Because the circuits of the series Spartan II do not allow configuration with 32/8-bit data ports but only 16/4 bit two blocks of RAM had to be used on each of the communication paths.

In Tab. 4.1 shows the configuration register partition. Using Start addr and Count the area that is scanned from the expansion boards is set. writes. Configuration the write and read registers have the same structure.

Tab. 4.1 Structure of the configuration registry

Bit 31 24 23 18 17 12 11 6 5 0

Clk Div div Count 1 Start addr 1 Count 0 Start addr 0

4.4.4 Driver

The communication between the HAL layer and the firmware in the gate array is of the same name HostMot2 driver (HAL component). He will upload the FPGA by the user at startup the required firmware, then the current configuration is read out from the FPGA (number of individual components, location of individual functions on the connectors) and, according to it, they are in the HAL layer exported pins, parameters, and functions to work with individual components.
The user has the option to enter the parameters by which he can change the automatic configuration. So the driver had to be complemented with the new component functionality LMIO.

If the initialization part of the driver is found to be the configuration recorded in the FPGA contains the LMIO component called hm2_lmio_parse_md. The first one check whether the driver is capable of the currently uploaded version of the LMIO component work and perform basic checks, if everything is OK, continues configuration components according to user-specified parameters. It is not possible to complete automatic configuration because the expansion boards do not contain any kind of autodetection, which would increase their complexity and price. The user must in the startup parameters drivers to specify the number of connected expansion boards. According to these parameters, there are functions hm2_lmio_create, hm2_lmo_create, hm2_lmi_create created all pins and HAL layer parameters for each physical input and output on expansion cards, function they also allocate the necessary storage space and register the areas written and / read from the FPGA functions hm2_tram_write resp. hm2_tram_read . You write or write. they will read at the same time all component data except configuration registers. Initial settings control registers is performed using the hm2_lmio_force_write function , on the other hand hm2_lmio_write writes to the registry only if the settings change.

The hm2_lmo_prepare_tram_write function is based on the current state of the HAL pins the layer prepares the data to write together with hm2_tram_write. It's the opposite hm2_lmi_process_tram_read, which sets the value of the pins based on the loaded data.

For testing purposes, a control panel has been created to set the value outputs and track inputs.

Fig. 4.5 Input / output board control panel

Fig. 4.5 shows the state of inputs and outputs when testing the driver, firmware, and of the boards themselves, where the boards were connected by a loopback cable.

5 CONNECTING THE MULTIMEDIA WITH A NEW CONTROLLER SYSTEM

No electrical documentation was delivered to the milling machine at first, because it was successful to find and do not expect to use a milling machine with an existing connection, but only with connected new control system, a requirement for complete drawing was dropped of the existing electrical connection. For these reasons, the following section only deals by designing a schematic connection with a new control system according to which the machine will be connected after necessary mechanical repairs.

5.1 Block diagram Connection

Fig. 5.1 captures the anticipated engagement after modernization. In connection with the machine of the control system, virtually no changes have been made as requested. Only the spindle is complemented by a rotary encoder rotation sensor. That's it Synchronization of axis feeds with spindle rotation required for threading is possible without Ridgid Tapping.

Fig. 5.1 Block diagram of the milling machine after modernization

5.2 Design of the overall engagement

The design of the overall scheme was primarily based on the original engagement and the standard [13]. There have been several changes to the original engagement. The biggest of them is the replacement of the control system, and the control contactor voltage with the rest has been unified machines for 24 V DC. Changes have also been made to the safety circuit. That's what it took using a stabilized 24 V DC control voltage. Most fuses are replaced by circuit breakers to save space in the switchboard.

The evaluation of the thermal protection status is transferred to the control system (originally as part of the safety circuit plus signaling to the control system), in case overheating will result in a controlled stop of the machining program.

In the connection, the possibility of connecting a second rotating axis, controlled, was envisaged the rectifier, relays and clamps belonging to this axis will be installed in the switchboard. Possible assembly will be very easy. The overall wiring diagram can be found on the enclosed data carrier.

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6 SPINDLE SHIFT

6.1 Sort Requirements

The milling machine, as mentioned in the previous sections, contains a two-speed gearbox with the possibility to include the original. Thus, there are a total of four rows of revolutions available. Used series is selected by the technologist in creating the NC program, then selects the required spindle speed. The transmission control program must therefore ensure that the gear and the master are included On the basis of the selected speed range, the entered spindle speed is recalculated to the engine speed according to the currently selected series. It is also necessary to ensure that there is no jamming mechanism and thereby stop the gear shift motor, which could cause it to overheat.

These are provided by the MAHO_GEAR component that is inserted into the HAL layer. Her the inputs are the required speed, the speed range and the signals from the monitoring contacts sort order. The output is engine speed, the signals driving the gear motor and the braking relay. Parameters are set for individual rotation rows ratios between input and output of the gearbox, minimum and maximum limits speed and acceleration.

6.2 Description of the MAHO_GEAR shifting component

The component was created using the COMP tool that is part of the development version EMC2, it is not necessary to write the initialization and ending code code that is created automatically. The custom function that is cyclically called when the control system is running is written in C language.

When a function is called, it is checked if it has occurred to exceed the maximum time for inclusion, if yes the ongoing order is stopped and an error has been announced. This prevents overheating of the motors as a result jam. If the required revolutions series do not match, the gearbox is started sorting process. The condition for start is zero engine speed and completion of the previous order. The sorting is done in the form of a simple automaton, which, on the basis of the required speed and gear condition, switch the relay on of the gearmotors and waiting for the gearbox contacts to be moved to the position. At (speed range 0), it is necessary to stop the shift gear motor quickly, a braking relay is used for this purpose. The last part of the feature is calculate the engine speed with the application of all the limits. If required speed out of range, are set to the nearest possible and this status is signaled.

6.3 Component Testing

The component was tested along with the sorting system and previously designed inputs output plates. Furthermore, it was simple to test and debug a component a control panel through which the gearbox was operated. In operation, it takes over the function of this Motion Controller panel.

7 CONCLUSION

The thesis describes the state of the milling machine control system and the reasons for its modernization. It was further mapped electrical equipment, its status and the signals needed for driving.

Linking existing equipment without the need for big changes was once of the conditions for selecting a new control system that has chosen the Enhanced Machine Controller. The system was installed on a PC complete with a PCI card 5I20 with 72 inputs output lines. This card has been joined with a PWM switching board 718 signal generated by the gate array of the PCI card to analog voltage and enabling connection of measuring rulers and encoder. A system of expansion boards has been designed digital inputs and outputs that can be connected to a PCI card. Plug - in functionality, firmware and The drivers were verified on the prototype of one input and output board.

Because of the ongoing machining of the milling machine, the configuration was not verified as a whole, but only by the gradual attachment of individual measuring rulers, encoder and drives. The ability of the system to position itself with the engine shaft, to which a rotary encoder has been mounted for this reason. After recalculating the maximum angular positioning of the motor shaft, which was 0.67 °, over the gear ratio between engine shaft and table feed we get a maximum error in table positioning 4.7 µm. It is therefore to be seen that the proposed system is capable of accurate steering.

The gear shifting program was tested along with the expansion plates connected to the sorting system.

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9 LIST OF ANNEXES

Appendix 1 - Output Board Wiring Diagram

PART 1

PART 2

PART 3

Annex 2 - Input board wiring diagram

PART 1

PART 2

PART 3

Appendix 3 - Output Board Template

PART OF COMPONENTS

Plate size 160 × 100 mm, scale M 0.75: 1

THE PART OF THE SPOJES

Plate size 160 × 100 mm, scale M 0.75: 1

Appendix 4 - Input board template

PART OF COMPONENTS

Plate size 160 × 100 mm, scale M 0.75: 1

THE PART OF THE SPOJES

Plate size 160 × 100 mm, scale M 0.75: 1

Appendix 5 - Photos of the test report