Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 26
ISSUE 1
January
2008

The signal connections in robot integrated manufacturing systems

D. Reclik*, G. Kost, J. Świder
Institute of Engineering Processes Automation and Integrated Manufacturing Systems, Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding author: E-mail address: daniel.reclik@polsl.pl

Received 11.12.2007; published in revised form 01.01.2008

Manufacturing and processing

ABSTRACT

Purpose: The main goal of this paper is that, the robot integrated manufacturing systems are more popular and useful in the industry. Moreover, the communication in those systems might be realized by many different data exchange solutions. Using this kind of solution causes the data exchange incompatibility. This paper deals with different ways in informatics connection of all of the components in robot integrated manufacturing system.
Design/methodology/approach: Incompatibility is a result of usage many different communication systems between components in lathe center. The way of mutual signal connections were the target of researches.
Findings: As a result of scientific work, the universal and compatible informatics connection system of the robot lathe center was created.
Research limitations/implications: The project of the data exchange system is confined to PROFIBUS DP lan.
Practical implications: The result of the researches was developing a technical element choice procedure of the data exchange depending on transport means quantity and system composition in the robot lathe system.
Originality/value: This is a brand new paper, which describes internal systems of data exchange in robot integrated manufacturing system in example of automatic lathe center.
Keywords: Robots mechatronics; Technological devices and equipment; Automation engineering processes; Profibus DP

1. Introduction

The continuous market economy development and the tendency to shorten the product life cycle cause constant incensement of requirements in the enterprise competitive. To assure the manufactured product's competitiveness, there is necessary to reduce production costs and, simultaneously, assure the highest quality of the elements produced, which is very important for short batches. The necessity for frequent product line changes causes the development in flexible production systems. The robot is a universal transport facility, which is used in integrated manufacturing systems because of the necessity to ensure automatic elements travel in a flexible work centre. A very important feature of robot integrated manufacturing systems is productive component varieties, which create the system structure (working machines, robot, conveyors, warehouses, etc.). The obvious result of such a state is informative incompatibility in the steering of the control systems, which has a influence on the range of possible collaboration between those systems. In every flexible manufacturing system it is possible to select the different streams flowing through particular elements of the system. Besides material and energetic streams, the most important stream flowing through the flexible manufacturing system is the information stream [12, 13, 16, 17, 18, 19].

2. The structure of the robot integrated lathe center with the signals exchanging by binary signals connection and Industrial lan (PROFIBUS DP)

The analysis of the mutual signal connections in the robot manufacturing system is carried through all of the elements in organizing structure, which consists of FANUC ARCMate 100iB manipulators [9], collaborating with EMCO Concept TURN155 numerical lathe with the SIMENS SINUMERIC 840D controller [1, 2, 4, 10] and the FLEXLINK plate conveyor with SEW drive, controlled by MOVIDRIVE INVERTER MDX61B0005-5A3-4-00 inverter (Fig. 1) [5, 6, 7]. The flexible lathe center is included in the input and output warehouses, the station to the elements reorientation and the security circuit (light curtains and security mats). Fig. 1 shows the analyzed work center. The robot controllers are provided with system software, the standard 48 channel I/O card (input/output) of the robot and, additionally, 32 input and 32 output digital cards [9] about positive logic with current protection on 0.5A level (AID32D and AOD32D card).

To make the collaboration possible between the robot system and the numerical machine, it is necessary to obtain opportunities of extorting operations, which are connected with the working process. Those operations are e.g. opening and closing the door, closing and opening the lathe chuck jaws and also shifting and removing the tailstock head. The realization of those operations can not be extorted by the working program, but it must be realized as an "on demand" procedure by reporting the working machine to operate by robot. For that reason, an idea was developed to initiate the particular supportive actions with the assistance of the I/O system (input and output card of the robot driver). The simplest way of exchanging information is to exchange the digital signals, therefore the zero-one system (positive logic) was used to synchronize the steering system of the EMCO Concept TURN155 working machine with FANUC AM 100iB robot. Fig. 2. shows the I/O multi card (EMCO Robot Interface), which is used to realize the information exchange between the control system of the working machine and the outer control system of the object which is co-operating with it, and which is responsible for extorting the particular supportive actions of the working machine. The received information about the realization of the main program, or also the action of the auxiliary machine tool, is the basis to starting the suitable subroutines of robot cycles. On every occasion the ending of the subprogram generates the suitable information for the extorting of the machine tool by special instructions in the robot program. Because of such

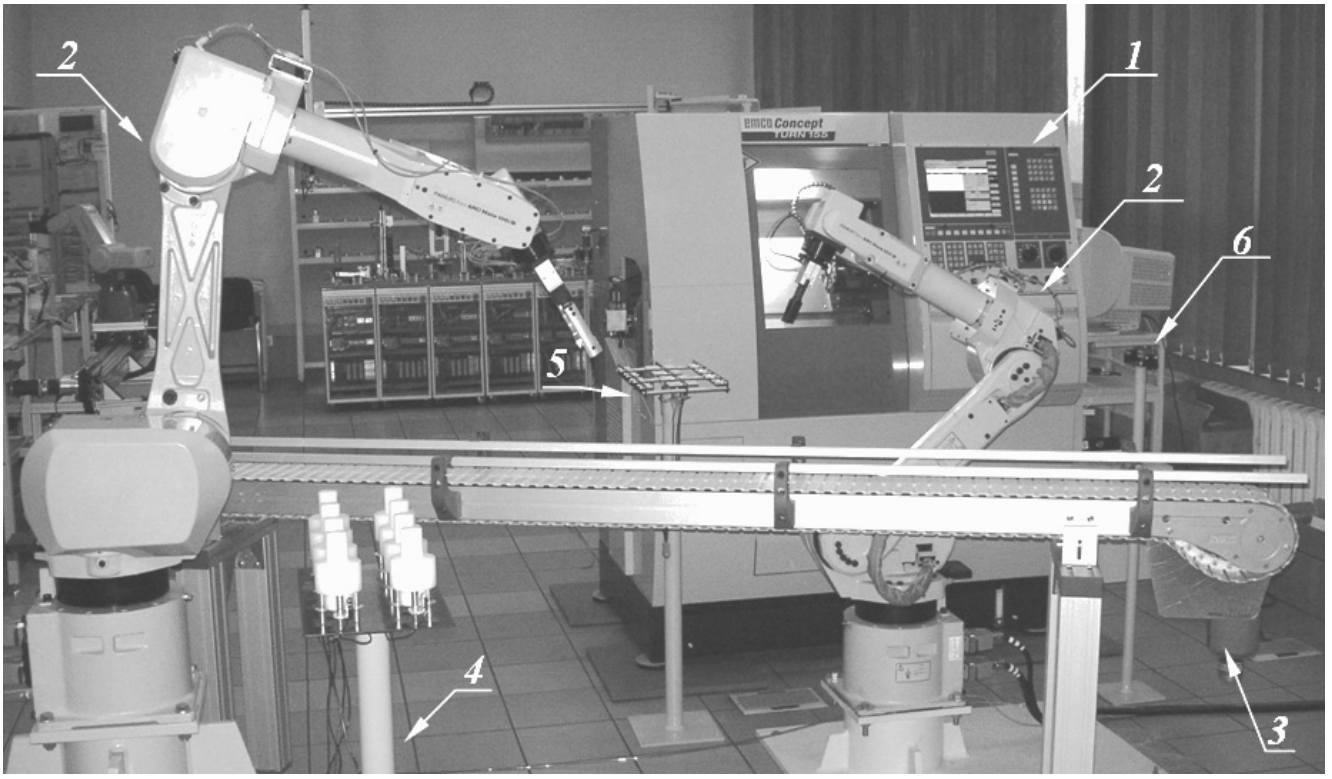

Fig. 1. The robot integrated lathe center: EMCO ConceptTURN 155 (1), FANUC ARCMate 100iB (2), FLEXLINK plate conveyor with SEW MOVIDRIVE INVERTER MDX61B0005-5A3-4-00 (3), input, reorganize and output magazine (4, 5, 6)

signal connection, full work synchronization between numerical machine and robot is obtained. The digital input and output card, which is added to the control system of CNC working machine, allows the generating of feedback information about readiness for working and loading, defining the working machine coordinate system, opening or closing the door, and also about the status of the lathe chuck (open/close). The EMCO Robot Interface card, which is superior to the operator panel of the lathe, enables the initiation of the reference movements, closing and opening the lathe chuck jaws, closing and opening the door, and also the initiation of the working program. By changing the robot digital outputs connected with lathe I/O multi card, there is also gained the switching of the lathe servo drive feed on, changing the working mode of the control system to automatic, and also error clearing and setting the feed rate on 0%, which means to stop all of the machine movements [1, 2, 4, 9, 10, 14].

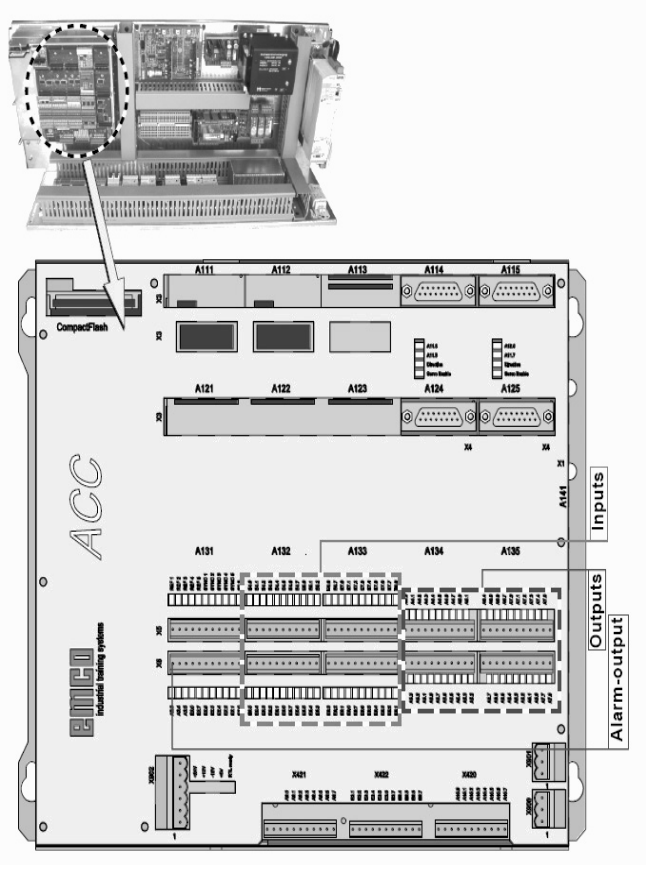

Fig. 2. I/O multi card addend to EMCO lathe control system [3]

To make it possible for the signal service coming from I/O card of CNC working machine through robot control system, it was necessary to add digital input and output modules to FANUC RJ3iB controller cubicle. Applied additional double input and output modules are shown on Fig. 3. The standard 48 channel I/O robot card was designed for initiating and monitoring manipulator conditions in their common workspace area, through signal exchange (condition variables) in robot program between RJ3iB control systems. Digital input and output modules (Fig. 3.) are used for connecting security circuits of the wiring system, e.g. for connecting light curtains and active security mat. Additionally, digital signals from the object detecting sensor in the input and output. As a result of using a binary information exchange system, it was possible to connect EMCO lathe control system and input and output warehouses with one of the FANUC manipulator control system. Fig. 4. shows mutual signal connections in that part of the flexible work center.

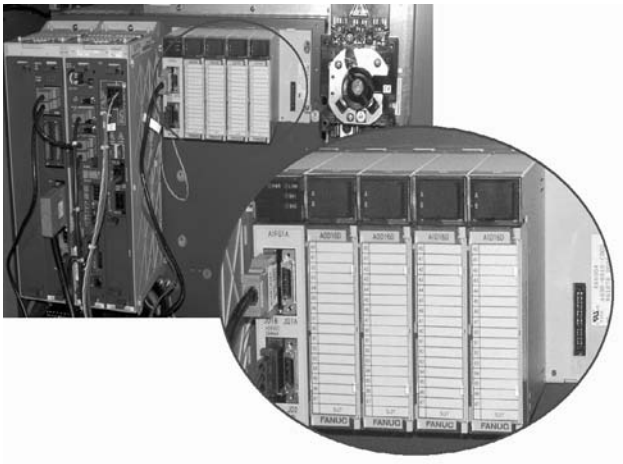

Fig. 3. Digital input and output module added to RJ3iB driver of FANUC robot

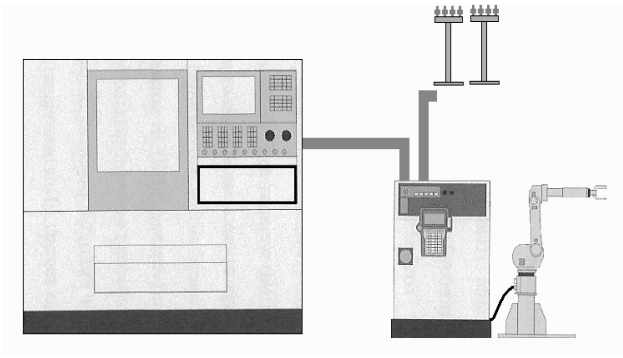

Fig. 4. Computer structure of binary information flow

Because of the need to feed all the signals of the binary information exchange channel to the control system of one of the FANUC manipulators, it was decided to make the RJ3iB controller of that robot superior with respect to the remaining components of the lathe work center. Setting one of the FANUC controllers as a superior with respect to remaining components of flexible manufacturing system requires the creation of a robot program, which must link subprograms connected with information exchange, and also with the realization of the proper manipulation goals.

Because the plate conveyor with a SEW controller steered by MOVIDRIVE INVERTER MDX61B0005-5A3-4-00 inverter is one of the robot center components, it was necessary to run a transfer protocol between the superior system unit (the RJ3iB

driver of the FANUC robot) and the interface of SEW inverter. An analysis was made of any possibilities connected with using the inverter transport with other center components, e.g. industrial nets: DeviceNet (CAN) and PROFIBUS DP, RS-485 serial protocol and the transmission by using digital inputs and outputs. It turned out that using the PROFIBUS DP industrial net is universal and, as a result of it, the best solution. To create the industrial LAN there was necessary to add PROFIBUS card (Fig. 5) to the superior RJ3iB driver. According to PROFIBUS DP standard there was defined the industrial LAN with one of the superior station (MASTER).

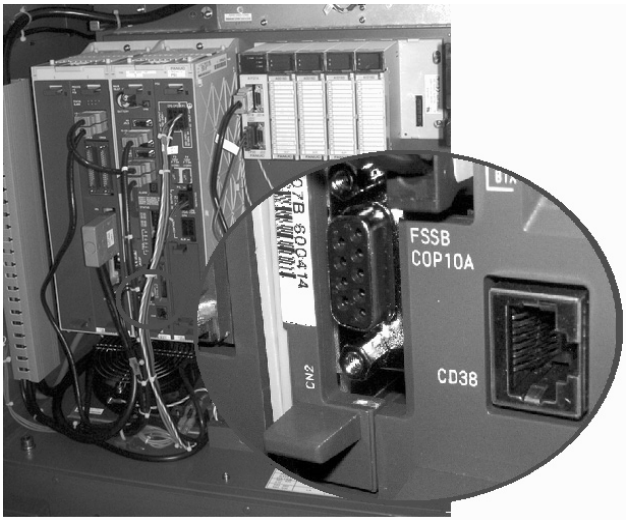

Fig. 5. PROFIBUS DP Master/Ethernet card added to RJ3iB controller of the FANUC superior robot

Fig. 6. MOVIDRIVE INVERTER MDX61B0005-5A3-4-00 inverter steering the FLEXLINK conveyor work [7]

The superior station is responsible for reading off the subordinate station (slave), and then processing that information and based on that, sending instructions in serial mode. Fig. 6 shows SLAVE interface of SEW inverter [15].

To make possible the communication with all SLAVE stations, there was necessary to assign the DP-SLAVE station to the DPM1 station (PROFIBUS DP MASTER first type). There are three basic modes of the subordinate station cooperation:

⇒ **STOP** – no information exchange,

⇒ **CLEAR** – DPM1 station reads inputs off and sets output in zero safe state,

⇒ **OPERATE** – DPM1 station exchange the data with SLAVE stations. The data, read off from SLAVE station, is set as value on output.

The goal of the original PROFIBUS DP industrial LAN configuration is to make possible the collaboration between the DPM1 controller and MOVIDRIVE controller of the plate conveyor drive. During LAN progressive development, the RJ3iB controller of another manipulator was connected as DP-SLAVE station. The achieved computer stream flow structure in the lathe working center is fully sufficient to realize the autonomous work of the system in automatic cycle. All operations of mutual collaboration between SLAVE stations and superior DPM1 are set in "OPERATE" mode. Unfortunately, that solution requires that the main lathe working program must contain many subprograms for each machined element, so that the proper steering signal, coming from I/O robot system, will run the suitable lathe program by robot. That requirement is connected with the possibility of transfer information in zero-one mode. To make possible the dynamic main working program exchange in the working machine and to enable the full service of information flow in the whole flexible manufacturing system by using only one technical element, there was necessary to use PROFIBUS DP LAN [1, 2, 4, 10, 18, 19].

The automatic choice of the working program is realized by connecting the direct control bus of the DNC working program (Distribute Numerical Control) with the control lathe system of direct DNC computer with a PROFIBUS DP SLAVE card. To make it possible to create another computer connection between the direct FANUC robot RJ3iB (MASTER) controller and EMCO lathe, it was necessary to add to the lathe steering system another computer which has a PROFIBUS DP SLAVE card and installed DNC program in. To ensure the possibility of connecting additional systems to the computer robot manufacturing center LAN, during configuration the PROFIBUS DP LAN, it was predicted there would be a need for collaboration with an additional PLC FANUC VersaMax controller. The mutual information exchange between the PLC controller and direct FANUC robot RJ3iB controller is realized by feedbacks through DPM1 in "OPERATE" mode. Fig. 7. shows that computer structure in an analyzed lathe center. Worth notice is the redundancy of the information flow paths between CNC lathe and direct robot (MASTER).

This path was duplicated on purpose - to show the advantages and disadvantages of using a cheaper, zero-one system and more expensive connection – PROFIBUS DP industrial LAN. Using that kind of connection enables the working program exchange.

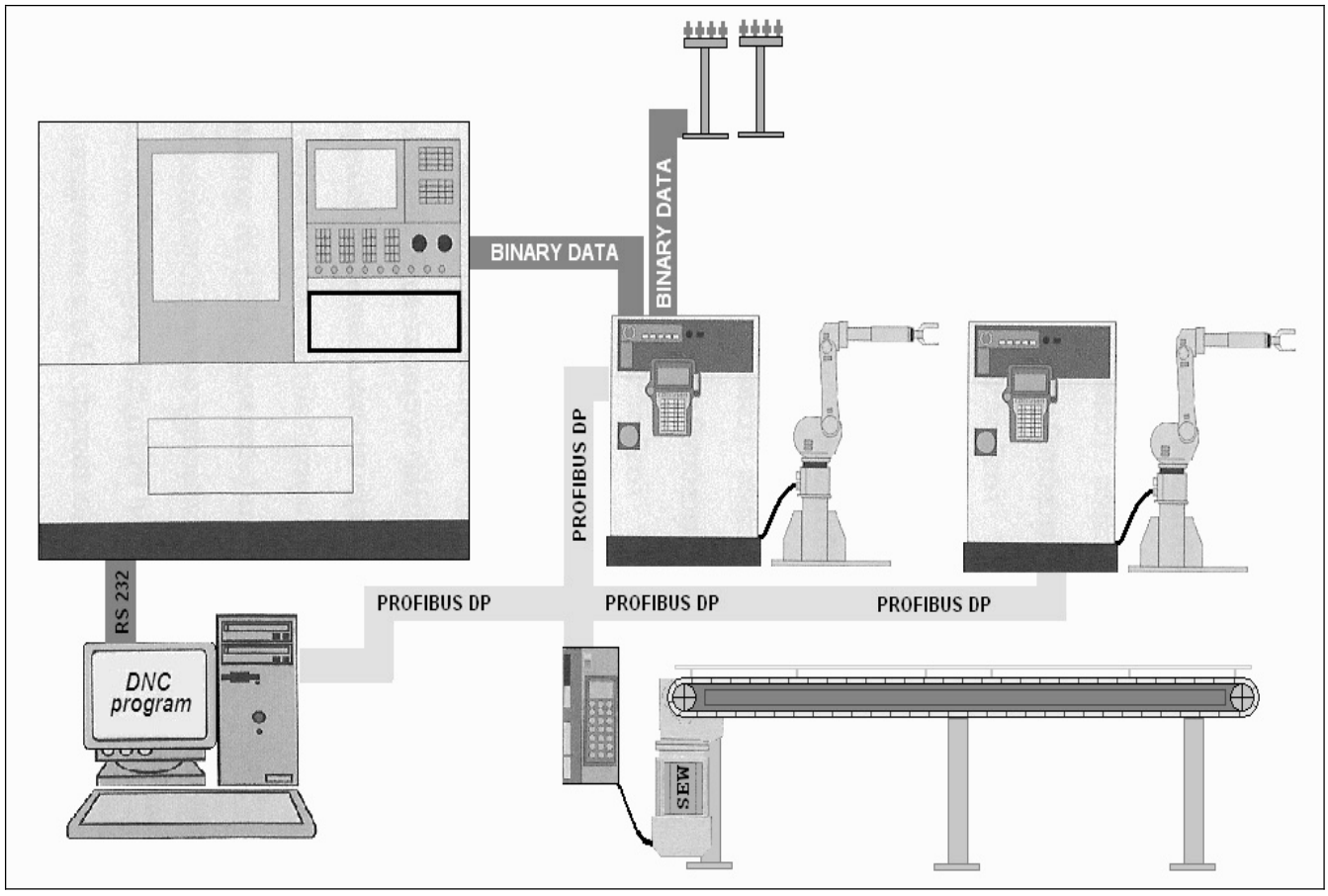

Fig. 7. Computer structure of all paths of information flow in robot lathe center

Moreover, there is obtained full application of memory registry of the RJ3iB controller. Memory registry permit to keep INTEGER values – 8 bits (using binary signal connection allows only 1 bit of memory – value zero or one).

3. Current and resistance parameters for the logical modules

For the safe use of a direct signal connection between control systems in EMCO Concept TURN 155 turning machine and FANUC RJ3iB robot, the input and output characteristics are shown in detail. The parameters of the current – tensional input modules are shown in table 1, whereas table 2 shown the parameters of output modules.

4. FANUC RJ3iB Controller main program algorithm

Because the configuration of the robot lathe center is based on the RJ3iB controller, which is used in that system as a MASTER, there was necessary to show a part of the lathe and robot integration algorithm (Fig. 8).

Table 1.
Statement of input modules in binary information flowing track [1, 2, 4, 9, 10]

Company	Type	High level voltage	Low level voltage	Resistance	Number of connections
FANUC Robotics	2xAID16D	20...28 V	0...4 V	3,3 kΩ	16
EMCO	integrated with EMCO Robot Interface main board	15...24 V	0...5 V	2 kΩ	44

Table 2.
Statement of output modules in binary information flowing track [1, 2, 4, 9, 10].

Company	Type	High level voltage	Low level voltage	Number of connections
FANUC Robotics	2xAOD16D	24 V	0,2 A	16
EMCO	integrated with EMCO Robot Interface main board	20...24 V	0,2 A	45

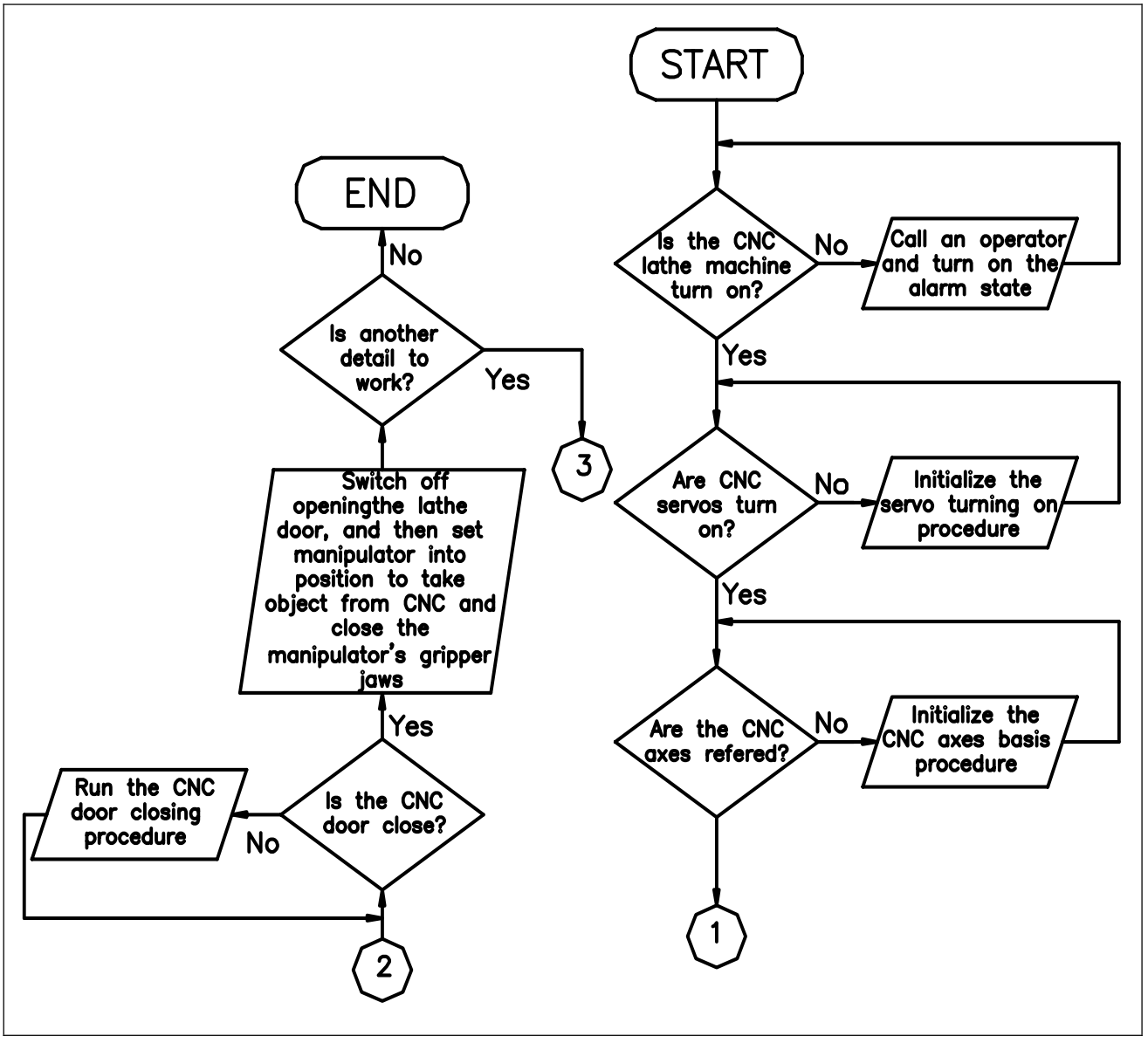

Fig. 8a. First part of manipulator and CNC lathe integration algorithm

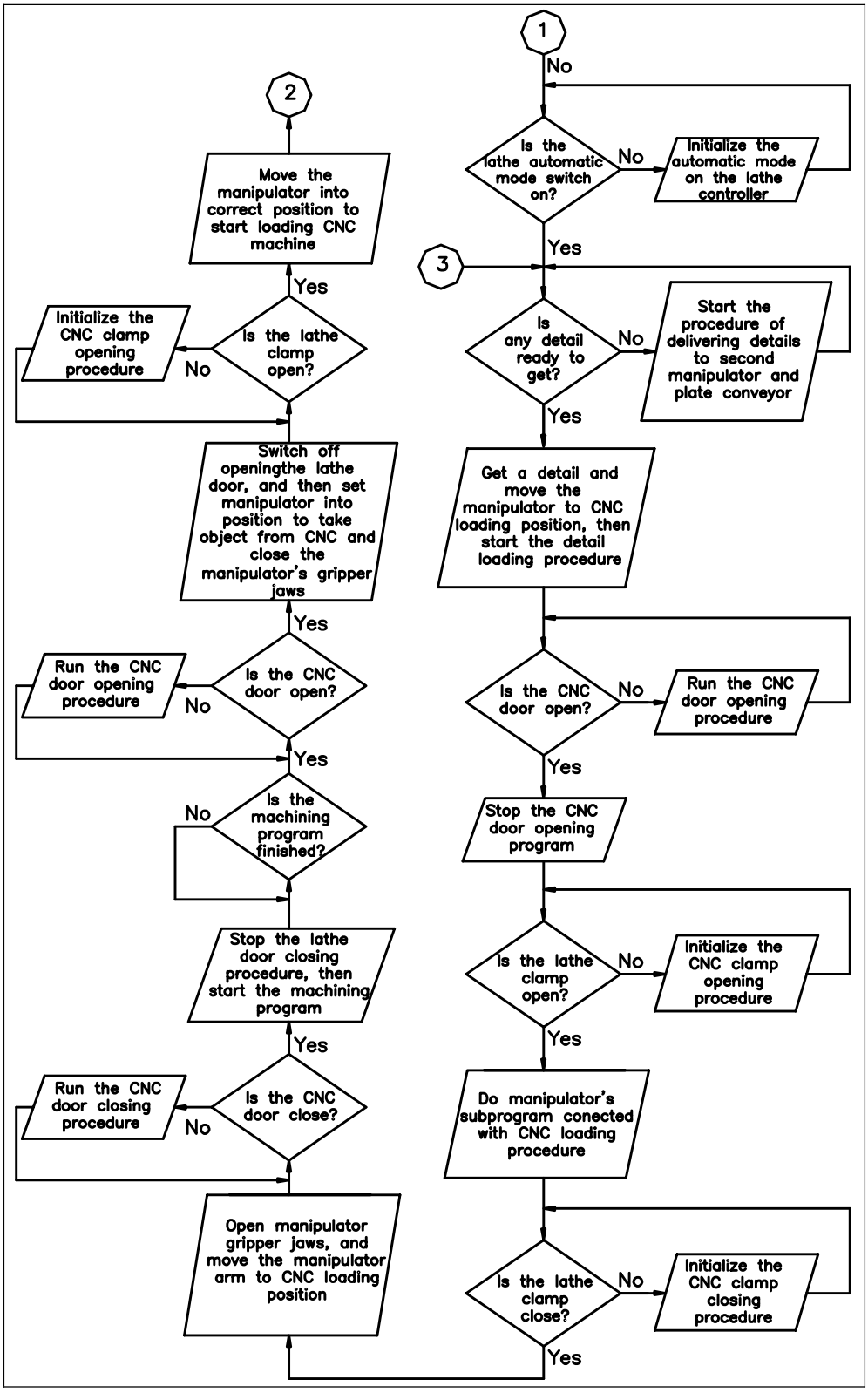

Fig. 8b. Second part of manipulator and CNC lathe integration algorithm

5. Conclusions

This paper deals with an example of a mutual communication solution between all of the components in a robot flexible integrated manufacturing system. This issue is complicated and it requires an individual approach, which depends on system flexibility. The typical solution of signal communication flow, based on binary outputs, is simple, easy to use and it doesn't require logical reorganization in algorithm to steering system. It happens so because of the solution simplicity. Unfortunately, using binary data exchange solution makes complicated tasks realization impossible through individual objects of robot integrated manufacturing system. Using advanced information exchange technology, based on industrial LAN, e.g. PROFIBUS DP, decreases the information sending incompatibility between all objects of robot integrated manufacturing system. It is also possible to use PROFIBUS DP to initialise the supportive operation and sending machining program or only its part to direct numerical computer DNC. To use all possible of LAN connections, it is necessary to change the steering system algorithm, in order to add another object (lathe) to manufacturing center.

References

[1] Machine Description. EMCO Concept Turn 155. Ref.-No. EN 1155. EMCO MAIER. Hallein-Taxach. 2003.
[2] Description of the DNC interface for machines with Sinumerik 840d PC control (Binary format), EMCO MAIER. Hallein-Taxach. 2003.
[3] EMCO Robotic Interface, Bedienungsanleitung, Operation Manual, EMCO MAIER. Hallein-Taxach. 2003.
[4] Software Descripction EMCO WinNC SINUMERIK 810D/840D Turning. Ref.-No. EN 1815. EMCO MAIER. Hallein-Taxach. 2005.
[5] Technical Data and Usage. MOVIDRIVE® MDX61B… (230 V-Value). SEW Eurodrive (in German).
[6] MOVIDRIVE® MDX61B Engineering Specifications DIP11B SEW Eurodrive. Handbook. 2004 (in German).
[7] SEW Eurodrive 1125 2901 / DE Catalogue, SEW Eurodrive, 2006 (in Polish).
[8] T. Legierski, PLC Controllers Programming, Jacek Skalmierski Publishing, 1998 (in Polish).
[9] Tutorial materials from FANUC 100iB technical operators training, Astor, 2006.
[10] P. Lecyk, SINUMERIK 840D Manual. Lathe operations, FESTO. 2004 (in Polish).
[11] K. Sacha, PROFIBUS local connections, Mikom, Warsaw, 1998 (In Polish).
[12] G. Kost, R. Zdanowicz, Modeling of manufacturing systems and robot motions, Proceedings of the 12th Scientific International Conference „Achievements in Mechanical and Materials Engineering" AMME'2003, Gliwice-Zakopane, 2003, 347-350.
[13] A.W. Colombo, R. Carelli, B. Kuchen, A temporised Petri Net Approach for design, modelling and analysis flexible production systems, International Journal of Advanced Manufacturing Technology 13 (1997) 214-226.
[14] A.J. Alvares, J. C. Espindola Ferreira, WebTurning, Teleoperation of a CNC turning center through the Internet, Journal of Materials Processing Technology 179 (2006) 251-259.
[15] G. Yasuda, Distributed autonomous control of modular robot systems using parallel programming, Journal of Materials Processing Technology 141 (2003) 357-364.
[16] S.F. Chan, R. Kwan, Post-processing methodologies for offline robot programming within computer integrated manufacture, Journal of Materials Processing Technology 139 (2003) 8-14.
[17] A. Klimpel, A. Lisiecki, A.S. Klimpel, A. Rzeźnikiewicz, Robotized GMA surfacing of cermetal deposits, Journal of Achievements in Materials and Manufacturing Engineering 18 (2006) 395-398.
[18] J. Balic, Model of automated computer aided NC machine tools programming, Journal of Achievements in Materials and Manufacturing Engineering 17 (2006) 309-312.
[19] J. Świder, G. Wszołek, D. Reclik, Didactic model of the high storage system, Journal of Achievements in Materials and Manufacturing Engineering 16 (2006) 199-206.