

# INDUSTRIAL CONTROLLER FOR DISCRETE MANUFACTURE

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**Summary:** *The hardware and software solutions for industrial controller for discrete manufacture are discussed in this paper. The industrial controller is based on MC68HC11 single chip microcontroller. Thirty two digital inputs and thirty two digital outputs are provided. Eight channel ADC and two analog outputs are added. The system part of the software, designed on assembler and C, includes real time operating system, industrial network driver and routines and macro packages. The concrete application is described - control of machine for filling empty cassettes with desired length of tape.*

**Keywords:** *industrial controller, system software, discrete manufacture.*

## I. Introduction

Industrial controllers purposing for discrete manufacture have own specific features. At first, there is an intelligent control with microprocessors [1]. Relay digital inputs and outputs with two states - open/closed are mainly used and analog signals in input or for output are rarely used. Some of the digital inputs and outputs are able to work in higher frequencies for frequency control of electrical engines and are able to receive pulse sequences from sensors. The system security is very important, as well as the capability of saving the important data when critical situations occur. Modern industrial controllers support real time clock as well as hardware and software capability of connecting into industrial local area network together other industrial controllers or central control computer. The software for industrial controllers is designed using high level languages (C for example) [2] and only a small part is realised using Assembler.

## II. The hardware

The industrial controller, subject of this paper, is purposed to control a single machine in discrete manufacture. A single board realisation has been chosen with a MC68HC11 as a control processor. Because of single machine control there is possible to avoid galvanic decoupling.

The block diagram of the designed industrial controller is shown in fig.1. Microprocessor system consists of:

- single chip microcontroller MC68HC11;
- 32 Kbytes EPROM;
- 4 Kbytes RAM.

In the system is included a real time clock MC68HC68T1 with own separate 32 KHz generator, connected through SPI to the microcontroller. A separate battery supply for the real time clock is added.

For communication with an operator there is used a liquid crystal indication (two lines with 24 symbols) and a keyboard with 12 keys. Galvanic decoupled serial interface for specialised industrial local area network is added too. It uses the integrated in MC68HC11 serial communication port.

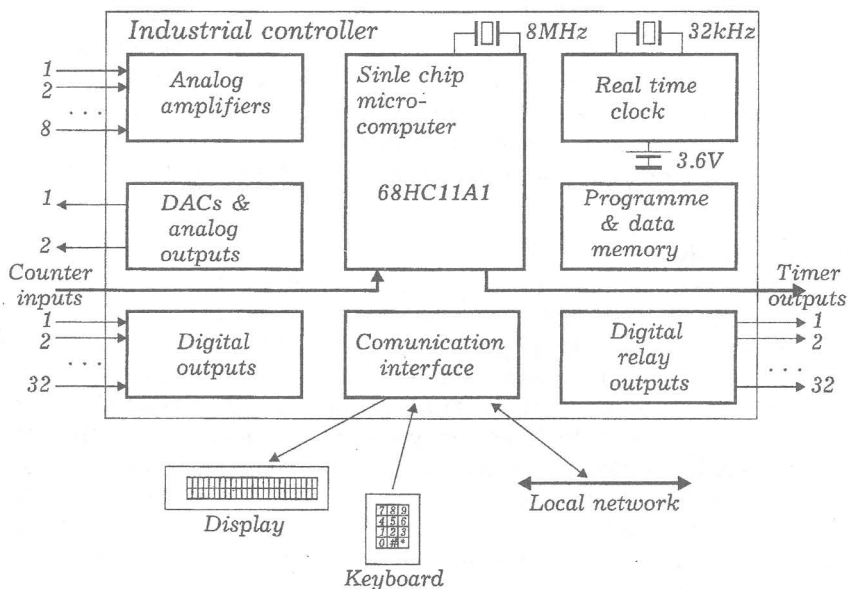


Fig. 1.

The industrial controller has eight analog inputs. The integrated in MC68HC11 eight channel analog to digital converter is used. The amplification ratio of each analog preamplifier (shown in fig. 2a) is defined by the input resistors R1 and R2 and by the feed back resistors R4 and R5. It is adjusted by the trimmer P. The resistor R3 define the analog offset.

In the industrial controller there are two analog outputs, realised

with two DAC08 as shown in fig. 2b. The external integrated DAC circuits are used because MC68HC11 does not have integrated DAC's. The trimmer P defines the output voltage amplitude, and the resistor R3 defines the output voltage offset. For analog inputs and outputs there is used single reference voltage source.

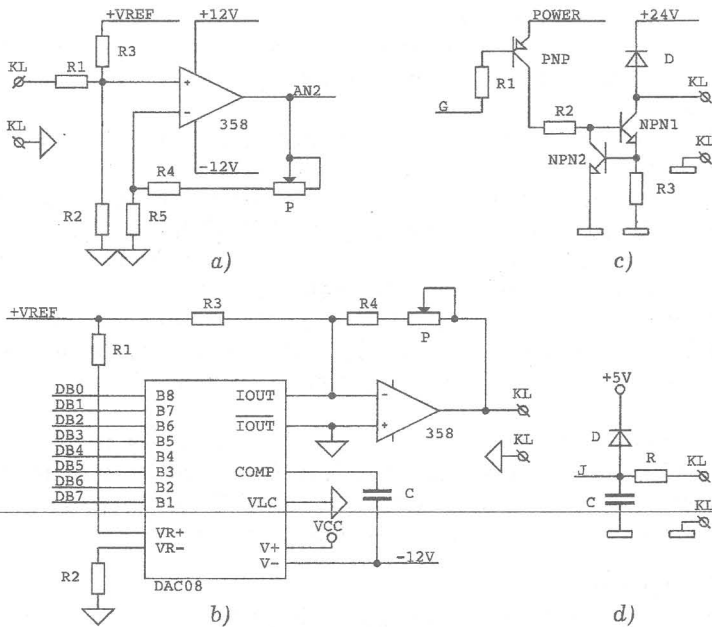


Fig. 2.

There are 32 digital inputs, realised as shown in fig. 2c. RC circuit increases noise reduction capability of the inputs, together with integrated in input buffers Smith triggers. The diode D protects the inputs from the positive voltages, and the integrated in the input buffer diodes protect from the negative input voltages. Additionally, in the industrial controller are realised four digital inputs for higher frequency input sequences.

There are 32 digital outputs, realised as shown in fig. 2d. They have load capability of 24 V/200 mA. The protection from preloading and over voltages presents in case inductance load is provided. The supply of driver transistors is controlled by the microcontroller and in the initialisation time all outputs are in inactive state. Additionally, three outputs are provided for high frequency pulse sequences.

### III. The system software

A system software for the presented industrial controller has been designed. It consists of:

- real time operating system;
- local area network driver;
- macro and subroutines packages for communication between the tasks under the control of real time operating system, users data structures, flag and queue;
- keyboard and display drivers, providing direct using from high level language C;
- procedures package for interrupt servicing and real time clock access, including clock's battery supplied CMOS RAM;
- subroutine packages using integrated in MC68HC11 EEPROM memory, 'watch dog' and analog to digital converter;
- subroutine packages for access to the digital inputs and outputs of the industrial controller and to the digital to analog converters.

All subroutines in the packages are accessible from high level language C.

The system software is developed in C and Assembler. The packages of macros, subroutines and heading files provide fast developing of the custom layer of the software. The IBM PC and cross assembler and cross C compiler are used as a development system.

### IV. Application

One application of the designed industrial controller and system software is to control a machine, purposed to fill the empty cassettes with tape. The machine works using pneumatic cylinders and the industrial controller must control the electromagnetic vents and read the sensors of the pneumatic cylinders' state. The velocity of filling with tape engine depends on one analog voltage. The quantity of filled tape is measured by a sensor with pulse sequence output.

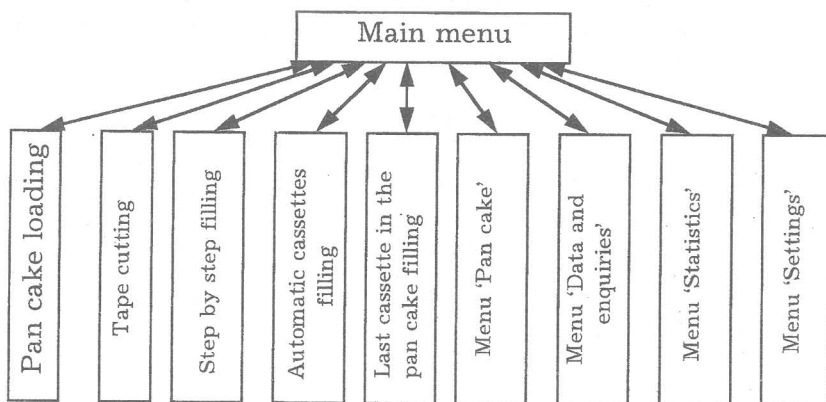
#### 1. Phases of the filling process

The process of filling with tape consists of the following phases:

- loading and opening the empty cassette from the empty cassettes container;
- cutting the leads and pasting with the begin of the tape;
- filling the cassette with necessary length of tape (fluently acceleration, supporting of needed speed and fluently decreasing the speed to zero);
- cutting the tape and pasting to the end back of the lead;
- exporting the filled cassette to the filled cassettes container.

#### 2. The custom layer of the software

The custom layer of the software is developed fully by high level language C. The previously developed system software has been used. The small package for primary control of the pneumatic cylinders has been written (go forward, go back etc.). The interacting with the operator is based on the system of menus as shown in fig. 3.



**Menu 'Pan cake':**

New pan cake  
Minutes in the pan cake  
Cassettes in the pan cake  
Minutes in the last cassette

**Menu 'Data and enquiries'**

Enquiry 'Minutes in a cassette'  
Enquiry 'Cassettes in the job'  
Enquiry 'Cassettes to do'  
Set minutes in a cassette  
Set the number of cassettes

**Menu 'Settings':**

Set the time T1  
Set the time T2  
Set the time T3  
Set the time T4  
Set the time T5  
Set the power P1  
Set the power P2

**Menu 'Statistics'**

Enquiry 'Number of pan cakes'  
Enquiry 'Number of filled cassettes'  
Enquiry 'Number of last cassettes'  
Clear the data  
Change the password

Fig. 3.

The most interesting part of the software is control of the filling speed. The acceleration must be fluent and cosinusoidal low of acceleration is chosen:

$$V(t) = \frac{V_{max}}{2} - \frac{V_{max} \cdot \cos\left(\frac{4\pi t}{T}\right)}{2}, t = 0 \dots T$$

where T is time for acceleration.

The time of decreasing the speed depends by the weight of the pan cake - from 6 kilograms for full pan cake to 0.5 kilograms for empty pan cake. The maximal negative acceleration depends by the maximal power of electric motor (which is constant), which mean that the decreasing of the speed must begin early for more weight pan cake. The identification of the weight must be done in the time of acceleration using the delay of real speed. The time diagram of required and real velocities is shown in fig. 4.

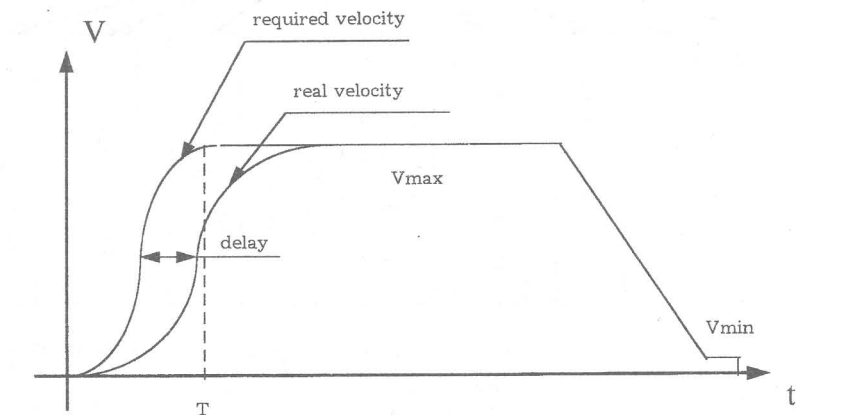


Fig. 4.

After the moment  $T$ , the output analog voltage (required velocity) is constant. The time between pulses from the tape sensor (real velocity) is measured in the time of acceleration. The delay between a real and a required velocity is proportional of the pan cake weight. On its base the time for decreasing the speed is calculated. From the necessary moment, the output voltage decreases the velocity from  $V_{\max}$  to  $V_{\min}$ . With this velocity the process of filling continues to the reaching of the needed length of tape.

## V. Conclusion

Presented in this paper industrial controller for discrete manufacturing with its system software has wide field of application. Practical using for control of real objects demonstrate its stable and reliable working.

## VI. References

1. MC68HC11 - reference manual. Motorola Inc., 1991.
2. Луканчевски, М., Системно програмиране за едночипови микрокомпютри, С., Техника, 1993.