Sborník vědeckých prací Vysoké školy báňské - Technické univerzity Ostrava
číslo 1, rok 2005, ročník LI, řada strojní
článek č. 1446

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HIGH SPEED MICROCONTROLLER AS CONTROL SYSTEM OF LINEAR ACTUATORS

RYCHLÝ MIKROKONTROLÉR JAKO ŘÍDICÍ SYSTÉM LINEÁRNÍCH POHONŮ

Abstract:

This paper describes the design of the powerful control system based on the High Speed 8051 microcontroller C8051F120. This Control system is designed for control of the linear hydraulic cylinder regulated with a pair of the separated proportional valves.

Abstrakt

Příspěvek popisuje návrh výkonného řídicího systému založeného na vysokorychlostním mikrokontroléru C8051F120. Řídicí systém je určen pro řízení hydraulického válce regulovaného dvojicí proporcionálních ventilů.

Preface

The task of the presented control system is to control of the position of the linear hydraulic cylinder. Pressures before and behind of the cylinder there are actuated by a pair of the independent modified proportional valves. For reasons of the request on high computing power – two dependent PSD controllers with 1 ms cycle – microcontroller is based on C8051F120 chip. Other reason for choice of this chip is , we have disposition of the developing system KEIL. This circuit is derived from x51/52 family microcontrollers and it is completed with others peripherals and managed 100times higher computing power compared to the standard x51 core. From analysing this task the control system must have readings of the actual position of the hydraulic cylinder (analogue signal), actual pressures (analogue signals), and the desired value of the position (analogue and/or digital signal). Outputs are analogue actuating signals for two proportional valves.

Control System

The desired control system is based on C8051F120 microcontroller. At present - March 2005 - it is the most powered microcontroller based on X51/52 family in the world, witch managed 100times higher speed in comparison to standard x51 microcontroller running on 12MHz oscillator.

The C8051F120 device is the member of family of 8 microcontrollers and disposes the highest power and equipment:

Analog Peripherals

12-bit SAR ADC

- ± 1 LSB INL
- Programmable Throughput up to 100 ksps
- Up to 8 External Inputs; Programmable as Single Ended or Differential
- Programmable Amplifier Gain: 16, 8, 4, 2, 1, 0.5
- Data-Dependent Windowed Interrupt Generator
- Built-in Temperature Sensor

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8-bit SAR ADC

- ❑ Programmable Throughput up to 500 ksps
- ❑ 8 External Inputs (Single-Ended or Differential)
- ❑ Programmable Amplifier Gain: 4, 2, 1, 0.5

Two 12-bit DACs

- ❑ Can Synchronize Outputs to Timers for Jitter-Free Waveform Generation

Two Analog Comparators

Voltage Reference

VDD Monitor/Brown-Out Detector

On-Chip JTAG Debug & Boundary Scan

- ❑ On-chip debug circuitry facilitates full-speed, nonintrusive in-circuit/in-system debugging
- ❑ Provides breakpoints, single-stepping, watchpoints, stack monitor; inspect/modify memory and registers
- ❑ Superior performance to emulation systems using ICE-chips, target pods, and sockets
- ❑ IEEE1149.1 compliant boundary scan
- ❑ Complete development kit

Temperature Range: -40°C to +85°C

High Speed 8051 µC Core

- ❑ Pipelined Instruction Architecture; Executes 70% of Instruction Set in 1 or 2 System Clocks
- ❑ **100 MIPS** Throughput with On-chip PLL
- ❑ 2-cycle 16 x 16 MAC Engine

Memory

- ❑ 8448 Bytes Internal Data RAM (8k + 256)
- ❑ 128k Bytes Banked FLASH; In-System programmable in 1024-byte Sectors
- ❑ External 64k Byte Data Memory Interface (programmable multiplexed or non-multiplexed modes)

Digital Peripherals

- ❑ 8 Byte-Wide Port I/O (100TQFP); 5V tolerant
- ❑ Hardware SMBus™ (I2C™ Compatible), SPI™, and Two UART Serial Ports Available Concurrently
- ❑ Programmable 16-bit Counter/Timer Array with
- ❑ 6 Capture/Compare Modules
- ❑ 5 General Purpose 16-bit Counter/Timers
- ❑ Dedicated Watchdog Timer; Bi-directional Reset Pin

Clock Sources

- ❑ Internal Precision Oscillator: 24.5 MHz
- ❑ Flexible PLL technology
- ❑ External Oscillator: Crystal, RC, C, or Clock

Voltage Supples

- ❑ Range: 2.7-3.6V (50 MIPS) 3.0-3.6V (100 MIPS)
- ❑ Power Saving Sleep and Shutdown Modes

With on-chip VDD monitor, Watchdog Timer, and clock oscillator, the C8051F120 is truly stand-alone System-on-a-Chip solutions. All analogue and digital peripherals are enabled/disabled and configured by user firmware. The FLASH memory can be reprogrammed even in-circuit, providing non-volatile data storage, and also allowing field upgrades of the 8051 firmware.

Debug system supports inspection and modification of memory and registers, setting break-points, watch-points, single stepping, run and halt commands. All analogue and digital peripherals are fully functional while debugging using JTAG.

MCU is specified for operation over the industrial temperature range (-45° C to +85° C). The Port I/O, /RST, and JTAG pins are tolerant for input signals up to 5 V. The device is available in 100-pin TQFP packaging.

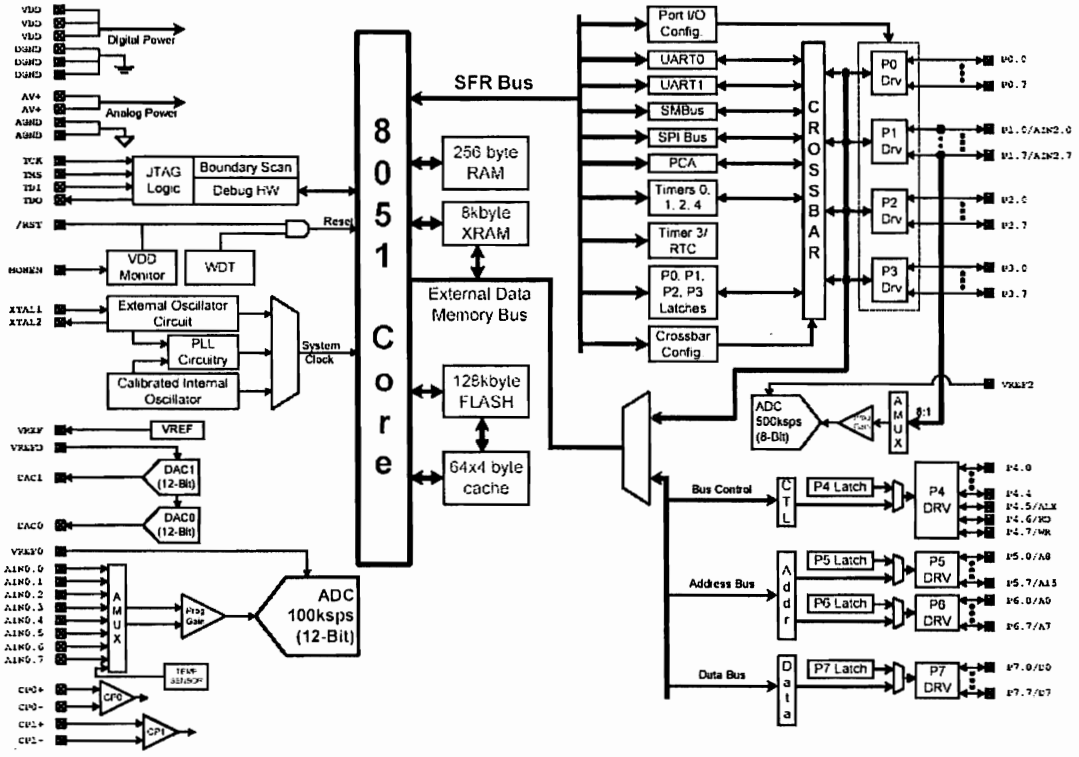


Fig. 1 C8051C120 Block Diagram

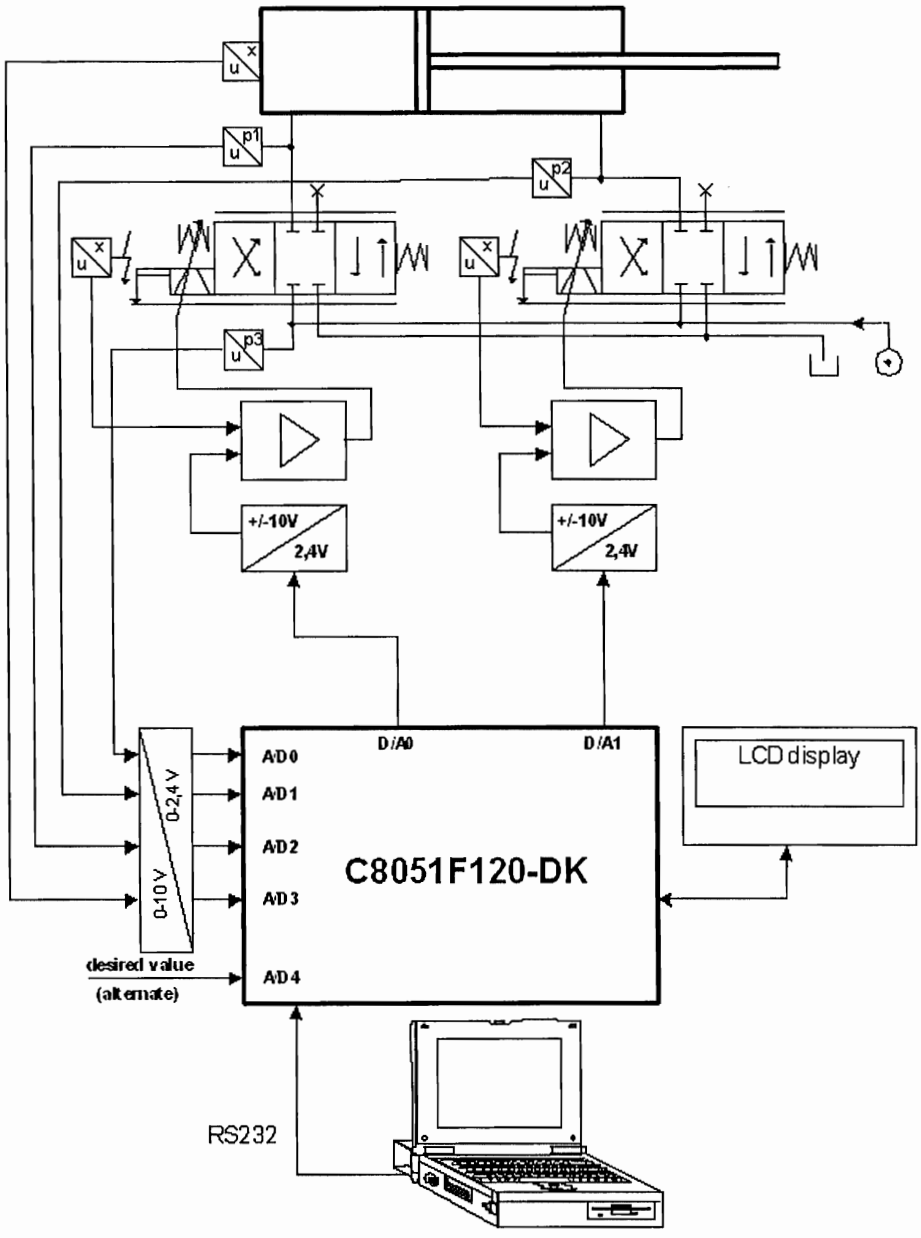


Fig. 2 The block diagram of connecting of the control system to linear hydraulic drive

The designed control system is based on the Development Kit C8051F120 DK which is directly programmed via JTAG connector by PC. This kit consists of the C8051F120 Target board (see Fig. 3), RS232 Serial Adapter, AC to DC Power Adapter, documentation on CD and evaluation Development environment.

Program debugging is made directly within the microcontroller with help of the JTAG interface. Due to it , all subsystems can be watched during debugging software. Microcontroller includes very complicated subsystems (including pipelined instruction architecture) and producers of developing systems (as KEIL, TASKING, IAR ...) doesn't offer common software simulators as in cases of easier standard chips.

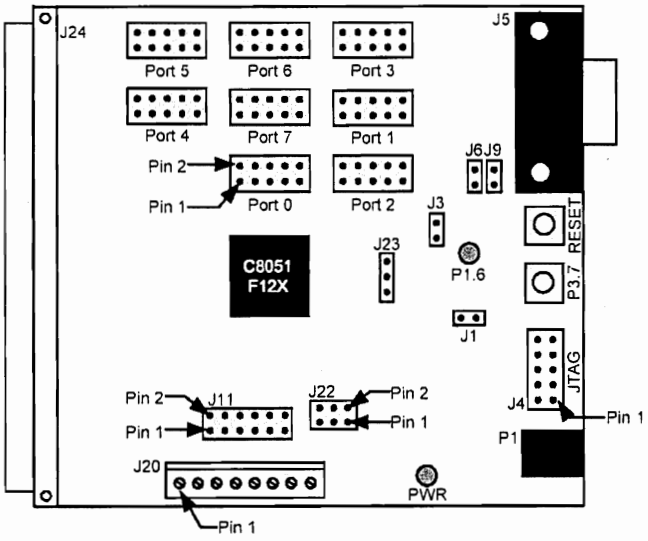
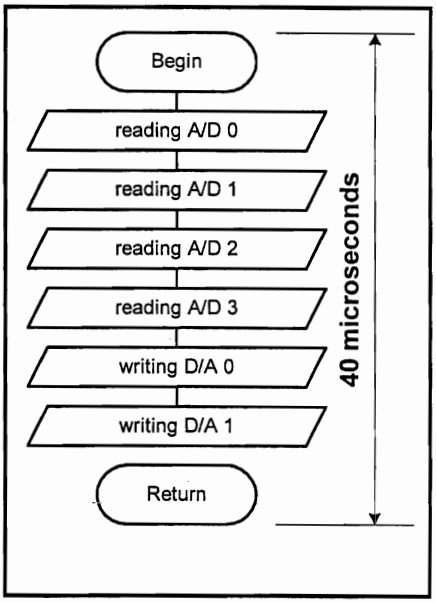


Fig. 3 C8051F120 Target Board

Analogue data acquisition

The important part of algorithm is the analogue – digital conversation. The chip offers a pair of 12-bit and 8-bit A/D converter, both with frond-end multiplexers. This application uses four A/D inputs – two pressures in hydraulic cylinder (p1 and p2) and working pressure (p3). The fourth A/D input is the desired value of position. This value can by entered via serial link by higher-level control system (on Fig. 2 it is notebook). The speed of A/D conversation can be set with help of the dedicated pre-divider of the system clock. The minimal conversation time is about 10 microseconds including the short time for throwing of multiplexer and sample/hold circuits.

```
void T3_ISR (void) interrupt 14   // Interrupt service sub-
routine
{
static unsigned int da1=0;
char SFRPAGE_SAVE = SFRPAGE;          // Save Current
SFR page
SFRPAGE   = TMR3_PAGE;
TF3 = 0;                              // clear TF3
SFRPAGE = ADC0_PAGE;
// measuring input No: 0
AMX0SL = 0x00;  // connect  AIN0.0
AD0INT=0; // start conversation
AD0BUSY=1;
while (AD0INT==0) ; // wait while  = 0 i.e.  converter is
working ..
result_0=ADC0;  // reading  and saving result of conversation
```




```
// measuring input No: 1
AMX0SL = 0x01;
AD0INT=0;
AD0BUSY=1; // start
while (AD0INT==0);
result_1=ADC0;
// measuring input No: 2
AMX0SL = 0x02;
AD0INT=0;
AD0BUSY=1;
while (AD0INT==0);
result_2=ADC0;
// measuring input No: 3
AMX0SL = 0x03;
AD0INT=0;
AD0BUSY=1;
while (AD0INT==0);
result_3=ADC0;
// writing to D/A {void DAC(unsigned char ch, unsigned int
value);}
if(da1++ == 4095) da1=0;
if (SW2==1)
{DAC(1,da1);}
else
{DAC(1,0x0fff);}

SFRPAGE   = SFRPAGE_SAVE;
if(count++ == 1000)
{LED = ~LED;   // change state of LED for visualisation pur-
poses
count=0;}
} // end of ISR
```

Listing 1 The Interrupt service subroutine of Timer 3 – reading and writing analogue data

The Listing 1 above contains the testing service subroutine of Timer 3 which generates the interruption every 1milisecond. In this subroutine there are analogue data read and written. The total time of this subroutine is about 40 microseconds. In comparison to the period of calling this subroutine (1000 microseconds) is only 4 % computing time of the microcontroller, thus the main program has enough time capacity for computing in real numbers.

Conclusion

The article describes the design of the control system for control of the linear actuators based on the hydraulic cylinder equipped by a pair of proportional valves. The Control system is built on the highest-rating microcontroller family x52 – C8051F120 with computing power 100 MIPS.

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This article was compiled as part of "GAČR" projects 101/03/0648 ("Digital control of linear actuators of mechatronic systems").

Opponent: Doc.Ing. Bohuslav Pavlok, CSc.