New Challenge of the CPU for a Moving-Actuator type Total Artificial Heart

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Abstract

Intel's 80C196KD has been applied at the moving-actuator type total artificial heart (MA-TAH) from about early 1990th at our laboratory and it fulfilled its role successively. But the increased need of higher performance brought the other-type of the CPU, and the new challenge of ASIC to the application to the MA-TAH accelerated its need. So the new concept of the utilization of the DSP based CPU to the motor control was surveyed and analyzed deeply for about few months and the results were introduced and summarized in this paper.

I. Introduction

The present control system of the moving-actuator type total artificial heart (MA-TAH) being developed at Seoul national university hospital uses microcontroller for the CPU [1][2]. Intel's 80XC196 has been applied at the MA-TAH from about early 1990th at our laboratory and it fulfilled its role successively. But the increased need of higher performance brought the other-type of the CPU, and the new challenge of ASIC (Application Specific Integrated Circuit) to the application to the MA-TAH accelerated its need. So the new concept of the utilization of the DSP based CPU to the motor control was surveyed and analyzed deeply for about few months and the results were introduced and summarized in this paper.

As the integrated system of artificial heart - physiological control algorithm, hemodynamic variables estimation, fault processing, battery management, telemetry processing, etc. - requires the digital signal processor (DSP) characteristics, we selected the famous three classes of DSP based CPU for motor control and analyzed.

This paper is organized as follows. After this part of Introduction, the comparison results were stated in section II. In section III, conclusions and discussions are stated.

II. Comparisons among 80C196KD, ADMC330, ADMC300, and DSP56005

Table 1 shows the current status of the motor control system in the five major research groups which have developed electromechanical artificial heart. In Penn-State University, they made their artificial heart using one chip microcontroller (80C196, Intel) to control three phase BL DC motor, which made the number of parts and space less for CPU and peripheral circuit. Nevertheless, electrohydrolic artificial heart developed at Univ. of Utah uses 8 bit microcontroller, however complexity of peripheral circuit brought the need of hybrid. The system developed at our lab uses microcontroller 80C196 (Intel, On-Chip EPROM) and made control system for implantable artificial heart, which does not need hybridization. This system has advantage over Penn-State Univ. regarding the reduction of the space of EPROM. We minimized circuit space by using the function of the software such as velocity profile, PI (Proportional and Integral) compensator, timer, PWM (Pulse Width Modulation) generator etc. Since other logic circuit for motor control implanted in the EPLD (Erasable and Programmable Logic Device), which can make control system for artificial heart sufficiently implantable size. Furthermore, our system has various advantages like less energy consumption and more durability by reduction of the number of the parts over the control system of other research group [3].

Table. I. Current status of control system development at five major research groups of artificial heart.

	Univ. of Utah	Penn-State Univ.	CCF/ NIMBUS	ABIOMED	Seoul Nat. Univ. Hospital
Control System	68HC11 (Moto-rola)	80C196 (Intel)	Under Develop-ment	Under Devel-opment	80C196 (Intel)

2.1. Description of Control System

The hardware system of an internal controller consists of a microcontroller, a feedback circuitry of motor position, a motor drive circuitry, a motor current sensing circuitry, and a serial communication circuitry as shown in Fig. 1.

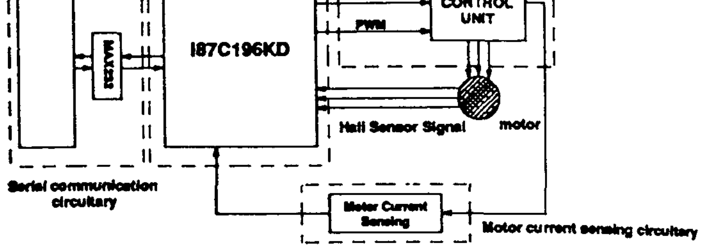

Fig. 1. A block diagram of the hardware of the internal controller.

The 87C196KD (Intel Co., USA), a high performance member of the 8096 microcontroller family, is a 16-bit microcontroller with 8 Kbytes of on-chip EPROM. Four highspeed capture inputs are provided to record times when events occur. Also provided on-chip are an 8 channel 10-bit A/D converter, serial port, watchdog timer, and a pulse-width modulated signal generator.

To commutate a brushless DC motor three Hall effect sensors are utilized and activated in the form of rectangular pulse signal by the flux of the rotor magnet. These sequential pulses of Hall sensors, which are fedback to the high-speed capture input ports of the microcontroller via a motor position feedback circuitry that is composed of low pass filtering circuitry for rejecting high frequency noise and schmitt trigger circuitry, are also used for the position and speed control as well as the motor commutation.

And also, the motor current signal detected in the drive circuitry is converted to digital data by an embedded A/D converter in the microcontroller and transmitted to the external controller for external monitoring through an RS-232C serial protocol [4].

2.2. Comparisons among Four CPUs

Summarized results are shown in Table II. The major difference points of the DSP based CPU compared with 80C196KD are listed below.

- Many mathematical operations are possible.
- Real time processing is possible.
- Signal is a discrete form.

As the integrated system of artificial heart - physiological control algorithm, hemodynamic variables estimation, fault processing, battery management, telemetry processing, etc. - requires the above characteristics, we selected the famous 3 classes of DSP based C:PU for motor control.

Among listed features, the most important factors for artificial heart motor control are like following:

- Embedded A/D converter
- High speed inputport which can generate interrupt request
- PWM signal generator
- Serial Port

Considering these points, we decided the ADMC300 for the future main CPU!

DSP56005 requires peripheral devices such as A/D converter which prevents the possibility of implantable artificial heart system and has problem with high clock frequency which has the potential of heat during operation.

ADMC330 has similar features with ADMC300. It is cheaper than ADMC 300 but the overall performances are lower. ADMC300 has special merit. It is very small size, which gives very possibility for the implantability combined with ASIC system. It is about one quarter size compared with 80C196KD which is current CPU in our lab [5].

III. Conclusions and Discussions

The present control system of the moving-actuator type total artificial heart (MA-TAH) being developed at Seoul National University Hospital uses microcontroller for the CPU. Intel's 80C196KD has been applied at the MA-TAH from about early 1990th at our laboratory and it fulfilled its role successively. But the increased need of higher performance brought the necessity of changing CPU, and the new challenge of ASIC to the application to the MA-TAH accelerated its need. So the new concept of the utilization of the DSP based CPU for the motor control was surveyed and analyzed deeply for about few months and the results were introduced and summarized in this paper.

As were stated in section II, the ADMC300 satisfies our need and outperforms than other kinds of CPUs. Furthermore it is very small size, which gives very possibility for the implantability combined with ASIC system. It is about one quarter size compared with 80C196KD which is current CPU in our lab. Considering. these points, we believe that the decided ADMC300 will carry out the future needs successfully.

References

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Table II. Classfication of the features of the four major CPUs

Classes / Features	80C196KD	ADMC300	ADMC330	DSP56005
ROM	EEPROM (32K)	2K×24 bit (Program) External EEPROM (64K)	2K×24 bit (Program) External EEPROM (64K)	96×24 bit bootstrap two 256×24 bit on chip data
RAM	1000 byte (data)	4K×24 bit program, 1K×16 bit data	2K×24 bit program, 1K×16 bit data	4K×24 bit program, two 256×24 bit data
Clock Frequency	20 MHz	25 MHz	20 MHz	50 MHz
Single Cycle Instruction Execution	62.5 nsec	40 nsec	50 nsec	40 nsec
Timer/Counter	2 Hardware 4 Software	2		
Interrupt Source	28	26	13	6
Interrupt Vector	18	19	11	
Serial Port	1 (Full Bidirectional)	2	2	5 (1 SCI, 4 SSI)
IO Port	5 (8 bit)	12 (12 bit)	8 (8 bit)	25
PWM Port	3 (8 bit)	(12 bit)	(12 bit)	5 (12 bit)
A/D Converter	One 10 bit 5.12 V ref.	Five 16 bit 2.5 V ref.	Seven 12 bit	None
Watchdog Timer	16 bit	16 bit	16 bit	16 bit
External Bus	8/16 bit	None	None	16 (address) / 24 (data) bit
Package	PLCC (68 pin) QFP (80 pin)	TQFP (80 pin)	PLCC (68 pin) QFP (80 pin)	TQFP (144 pin)
Trend of Version Up	80C196JQ and 80C296	ADMC 302	ADMC 300	.
Year of Publication	1990	1996. 8	1997. 6	1995
Corporation	Intel	Analog Device	Analog Device	Motorola
Nation	U. S. A.	U. S. A.	U. S. A.	U. S. A.