TECHNICAL NOTE

THE OPPORTUNITIES AFFORDED BY EMBEDDED COMPUTER SYSTEMS FOR MONITORING AND CONTROL OF INDUSTRIAL PROCESSES IN LESS-INDUSTRIALISED COUNTRIES

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Abstract The dramatic changes in integrated-circuit technology over the last two decades have been of great benefit to countries such as Zimbabwe. High volume production of VLSI chips has produced a supply of intelligent, versatile electronic processing devices at very low cost. In particular the facilities of the microcontroller have steadily developed to the accompaniment of a reduction in price. Since, in essence, the microcontroller is a complete computer tailored to control and monitoring operations, one is now provided with a device capable of application to a great variety of industrial and domestic situations. The major challenges lie in the interfacing and programming of the devices, and these are cerebral skills with which many less-industrialized countries are well endowed. The paper examines the opportunities in the embedded-systems area by means of a number of case studies of real industrial problems, whose solution has been achieved through these techniques.

Key Words Embedded Computer, Picocontroller, Zimbabwe, Industrial Research

چکیده تغییرات عمده در فناوری مدار جمعی در دو دهه اخیر منافع فراوانی را برای کشورهایی مانند زیمبابوه به ارمغان آورده است. تولید پر حجم تراشه های VLSI، منبعی هوشمند و متنوع برای تامین تجهیزات الکترونیکی کم قیمت را باعث شده است. تسهیلات میکروکنترلر به ویژه به طور پیوسته توسعه ای همراه با کاهش قیمت را در بر داشته است. از آنجا که میکروکنترلر در اصل، به طور کامل توسط کامپیوتر بکار گرفته می شود، لذا ما را توانمند می سازد تا در گروه بزرگی از مسائل صنعتی و شهری آن را بکار بگیریم. چالش اصلی در این خصوص، نحوه مرتبط ساختن و برنامه ریزی است که خوشبختانه مهارت لازم در کشورهای کمتر صنعتی شده، به خوبی موجود است. این مقاله با طرح مثالهایی از مسائل واقعی صنعتی وحل آنها، موقعیتهای موجود در رابطه با سیستمهای رایانه دار را به مورد آزمایش می گذارد.

1. INTRODUCING EMBEDDED COMPUTER SYSTEMS

The way in which we analyze and control the world around us has radically changed since 1970. Resulting from parallel developments in computer architecture, integrated circuit fabrication and software techniques, the microprocessor has made computers available for the solution of a huge range of problems in industry and the home.

A by-product of microprocessor development is the microcontroller. The same fabrication techniques and programming concepts that made possible the general-purpose microprocessor also yielded this further intelligent device.

Microcontrollers are not as well known to the general public, or even the technical community, as the more glamorous microprocessors. The public is, however, very well aware that ‘‘something’’ is responsible for all the VCRS, clock radios, washers and dryers, video games,

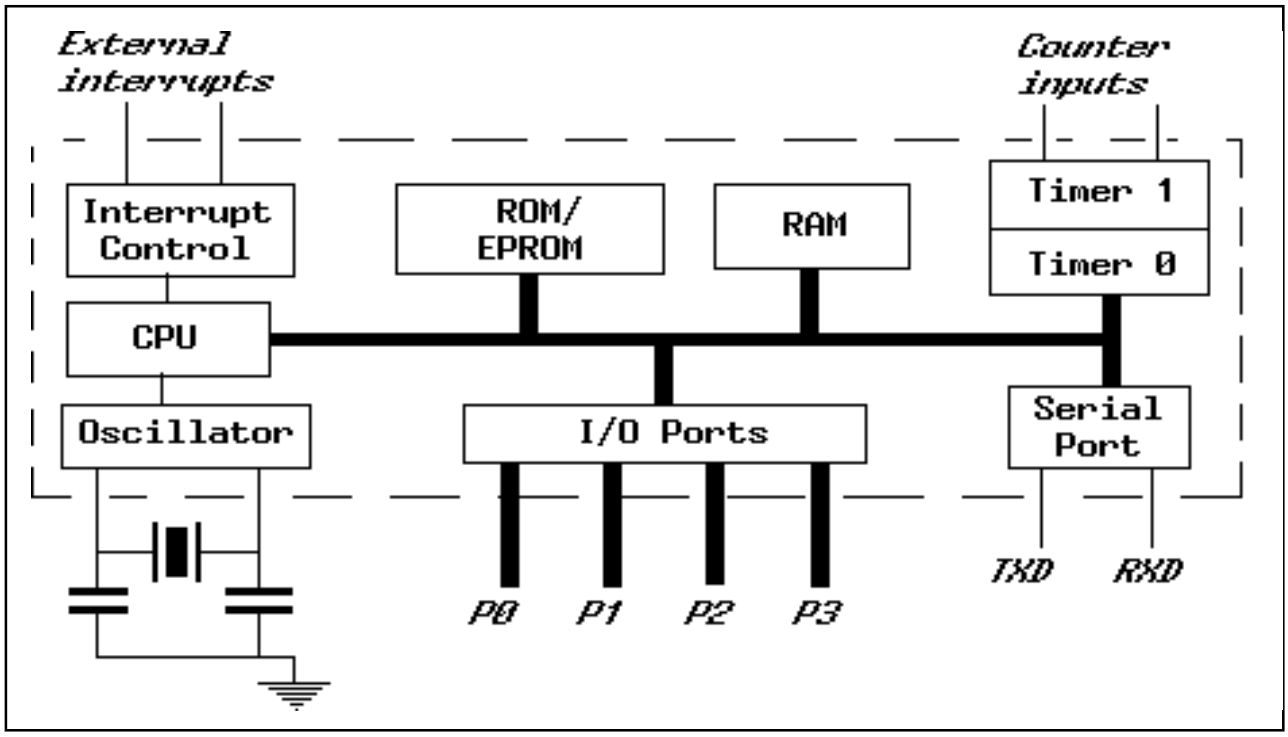

Figure 1. The 8051 microcontroller.

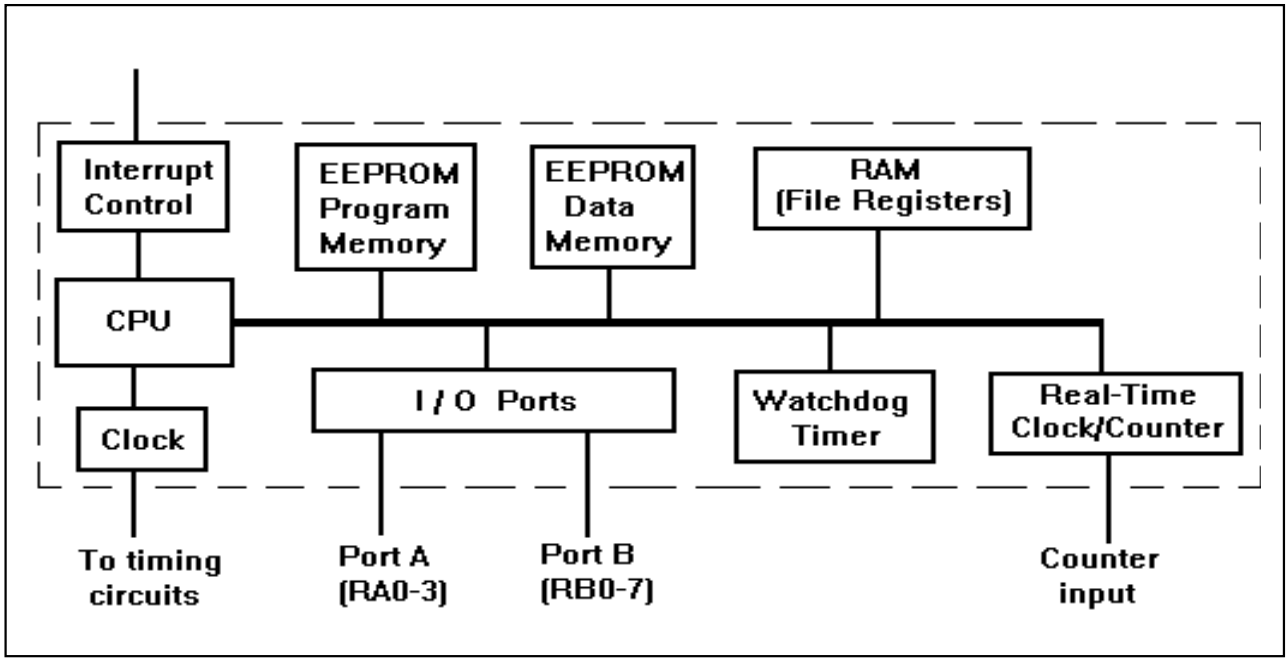

Figure 2. Architecture of the PIC 16F84.

telephones, microwaves, TVs, automobiles, toys, vending machines, copiers, elevators, irons, and a myriad of other articles that have suddenly become intelligent and ‘‘programmable’’. Companies are also aware that being competitive in this age of the microchip requires their products, or the machinery they use to make those products, to have some ‘‘smart features’’.

The area of electronics responsible for designing and implementing products containing microcontrollers is known as Embedded Computer Systems. Techniques in this field employ a large amount of real-time software, often with a sizeable safety-critical feature. Hardware design includes the interfacing of microcontrollers to a huge variety of sensors and actuators. The analysis of total system performance involves software, electronics, mechanical, hydraulic and environmental factors. The microcontroller has spawned a smaller, cheaper type of processor called the picocontroller. This device has fewer interfacing lines, does not allow the use of external memory, and contains a more limited amount of internal RAM.

2. THE RELEVANCE TO THE DEVELOPING WORLD

Many less-developed countries are rich in cerebral power though poor in hardware and import opportunities. A number of cases have indicated that software development is a viable industry for developing countries. Most of this currently entails high-level programming, but embedded systems offer a similar opportunity in the production of chip-level software. Since microcontrollers are relatively cheap, mass-produced integrated circuits, the raw material is affordable. By programming and interfacing these devices a significant value-added component is introduced, utilizing local resources. A further benefit is that products resulting from this process can be maintained, customized and updated in the local situation. The overall result is increased independence from import constraints.

3. INDUSTRIAL CONTROL WITH MICROCONTROLLERS

Industrial control can be implemented with either analogue or digital electrical signals. Traditionally the former have been processed by analogue electronic circuitry involving operational amplifiers connected to sensors and actuators. Operations are usually described mathematically in terms of differential equations in time. In contrast, the processing of digital signals is usually undertaken by logic circuits, which, in all except the simplest of cases, would comprise microprocessors or microcontrollers. However, an interesting development has been the processing of analogue signals by digital means using analogue/digital converters at the inputs and outputs. This has necessitated a different mathematical approach. While it may seem logical to program the microcontroller to obey the same equations that the analogue controller would have used, there are difficulties in implementing these practically. Whereas op-amps can conveniently differentiate and integrate with respect to time, these mathematical operations are cumbersome in a microcontroller since they are time-consuming and memory-hungry.

A method involving fuzzy-logic concepts is providing a more elegant way of solving real engineering control problems by microcontrollers [1].

To illustrate some features of available microcontrollers, two typical offerings are considered. The first is the 8051 microcontroller produced by the Intel Company [2] for which the basic architecture is shown in Figure 1.

The cheaper, simpler PIC16C84 from Microchip [3,4] has the architecture shown in Figure 2.

4. CASE STUDIES IN EMBEDDED SYSTEMS WITHIN ZIMBABWE

For several years the graduates in electrical and electronic engineering from the University of Zimbabwe and the National University of Science and Technology have been emerging with skills in the design of embedded systems. Final-year projects, post-graduate research and industrial consultancy have provided an interesting spectrum of microcontroller applications for industrial and

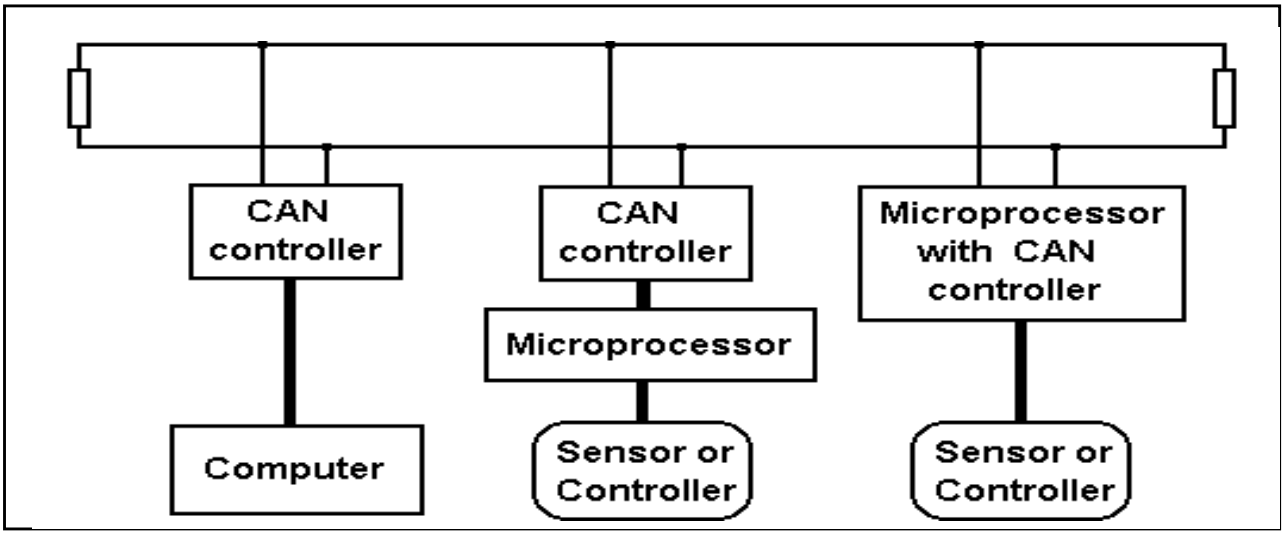

Figure 3. Types of connection to a CAN.

domestic needs. The following is a summary of projects carried out in the last few years.

4.1 Drilling Machine Control System A Harare company was seeking the repair of the electronic controller for an automated drilling machine. Instead of importing expensive spares from the manufacturer, a completely new embedded system has been designed around a Motorola microcontroller. The result is a locally produced controller, which under test conditions gives performance and versatility superior to the original circuitry [5].

4.2 Temperature Control with Fuzzy Logic A thermistor sensor has been interfaced to a picocontroller through an analogue-to-frequency converter. The frequency of the input signal is measured and used to implement a temperature-control system, using fuzzy logic principles.

The parameters of the fuzzy logic terms are adjusted to meet the user's requirements for the system [6].

4.3 Furnace Temperature Control A Bulawayo company has used a single 8031 microcontroller to automate a heat-treatment process involving up to five furnaces simultaneously. The readings of the thermocouple are relayed from the microcontroller to a personal computer for graphical display on the screen. Parameters can be changed from the keyboard, and the resulting control of the furnaces is carried out by the microcontroller [7].

4.4 Multi-Channel pH Meter A system for the measurement of acidity in a number of chemical samples has been constructed around a picocontroller. The project is aimed at evaluation of water treatment processes, but is applicable to industrial pH measurements in general [8].

4.5 Microcomputer Implementation Using Parallel Microcontrollers A prototype microcomputer has been designed in which processing is carried out by two 8751 microcontrollers operating in parallel. The necessary inter-process communication is implemented, and an operating system and user interface provided. While not commercially viable as a microcomputer, the machine has potential as an industrial process controller [9].

4.6 Controller Area Network development A network has been developed for interconnection of microcontrollers providing sensing or control information in an industrial process. The system uses the international CAN protocol, and Figure 3 shows the various ways in which computers and microcontrollers can be interfaced onto the CAN bus. The novel feature of the system is the production of the packet protocols and timing entirely in software, thereby eliminating the need for special protocol-generating integrated circuits. A prototype network of this type was installed in a large chemical processing company in Harare for initial tests [10].

4.7 Hospital Patient Communications System A system for patients to call nurses in a military hospital has been designed around a PIC16C84 picocontroller, which provides the necessary multiplexing and remote identification features [11].

4.8 Telephone Switching Applications A PABX using an 8031 microcontroller has been developed as a way of obtaining communications switching for small enterprises. Connections between extension telephones and outside lines are implemented by the software of the embedded system [12].

4.9 Portable Telephone Testing Unit An 8031 microcontroller is used as the processing center for a portable system to test all the functions of a standard telephone handset. The unit can check the operation of both DTMF and pulse dialing systems, and provides facilities to test the bell, cradle switch, transmitter and receiver. Performance is comparable with imported testing units of the same type, but the local product is significantly lower in price [13].

5. THE LOCAL MAY BE MORE APPROPRIATE CONCEPT

The term “appropriate technology” has sometimes been used to imply a low level of design reliability and maintenance in countries where the benefits of sophisticated engineering are not available. However, there can be advantages in utilizing products whose origin is in the same continent, where the designers may be only a phone-call away, and where maintenance can be obtained without the need to ship equipment across international borders. The cases cited above illustrate that digital control equipment can be designed and fabricated in Zimbabwe to meet a range of industrial and domestic needs. The recurrent question about the reliability of locally produced artifacts may to some extent be answered by the fact that the basic integrated circuit processing units are produced by international companies with a fine track record of robust devices. The local value-added element comprises electronic interfacing, software design and mechanical housing, in all of which areas the country has considerable expertise. While not expecting that local products can substitute all imports, it is felt that for a number of applications, especially non-critical ones, the local designers should be given a chance to show and develop their abilities.

6. CONCLUSION

It is suggested that several industrial monitoring and control needs within the country could be met by local design of embedded systems. Benefits would be the reduction of imported items, lower forex requirements, and the opportunity to harness the skills of local electronic engineers.

The syndrome of “imported is always best” needs to be broken, and replaced with a concept of “local may be more appropriate”. In this way expertise in Zimbabwe will be enhanced and the country's dependence on outside factors reduced.

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