Research on Typical System Platform of Mechanical and Electrical Equipment Based on Embedded Technology

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Abstract. Embedded technology is a new development of computer technology and has a wide range of applications and development prospects. The application of embedded technology has greatly promoted the development of the field of electromechanical control and improved the performance of electromechanical control equipment. Aiming at the problem that the mechanical and electrical products have low technical content and cannot meet the requirements of modern engineering, this paper uses DM642 as the core to build an embedded electromechanical device composed of video/audio signal processing modules, memory expansion modules, external interface modules, etc. A typical system platform proposes a motion detection method and an abnormal sound recognition algorithm based on the improved frame difference method. This paper introduces the composition of the system platform in detail, and also studies the application scheme of the embedded operating system for electromechanical equipment. Using this system platform can greatly improve the digitization, information and automation of mechanical and electrical products, and provide reference value for the technological upgrading of traditional manufacturing.

1. Introduction
In recent years, manufacturing companies have been slow to take off in the economy and technology [1-5]. The reason is that the most important point is that the product replacement cycle is too long and the technological content is too low, especially the degree of intelligence, information, digitalization, and automation. Failure to meet engineering needs, resulting in low added value and inability to cope with fierce market competition [6-9]. To make manufacturing enterprises out of the current predicament, policy support and system reform is an inevitable way. The product undergoes in-depth technical upgrades, so that the product itself has a stable place in the market, and the enterprise will inevitably get more opportunities and vitality for development [10-13].

With the rapid development of society, many advanced modern technologies have been applied to various production fields, which has greatly improved the productivity of various fields and promoted automation and intelligent upgrading in various fields [14-15]. Embedded system is an important technology in modern technology. Its application in various fields has significantly improved the level of industrialization [16-18]. Through the application of embedded systems, it can reduce the investment of human resources in enterprises and realize industrial automated production [19]. It can be said that industrial production applications supported by embedded systems have brought great convenience to our lives [20].
This article starts from the technical problems faced by electromechanical equipment, and starts from embedded technology, and integrates embedded technology into the typical system platform of electromechanical equipment. Specifically, it is to integrate the design and development concepts, related technologies and basic theories of embedded data into the design and development process of typical electromechanical system platforms, and to build a microprocessor-based, high-reliability, high-performance embedded This type of control system not only meets the complexity control requirements of mechanical and electrical equipment, but also improves the digitization, information and automation of mechanical and electrical products, and provides reference value for the technological upgrading of traditional manufacturing.

2. Application of embedded technology in electromechanical equipment

At this stage, there are two main types of RTOS used in embedded systems: free and commercial. The free RTOS mainly includes Linux and uC / OSII, and Linux is divided into RT-Linux and u Linux. Commercial RTOS mainly includes VX Work, Windows CE4.0 and Palm OS. These types of commercial RTOS have different application scopes. CE4.0 is applicable to consumer electronic devices, Palm OS is applicable to PAD products, and VX Work works on switching devices and networks. Based on the performance comparison of three platforms: VX Work, RT-LIMUX, and uC / OSII, including hardware platform, task switching, and interrupt response, this article treats uC / OSH as an RTOS developed for electromechanical control systems. uC / OSII has the following distinctive features:

(1) The RTOS contains the corresponding open source code, which enables it to provide favourable conditions for the migration of system software and its secondary development;

(2) RTOS is highly portable. Most of its open source code is compiled by ANSI C, and only a small part of its open source code is written in assembly language;

(3) RTOS has features that can be solidified, and its inner core is relatively small, which can be used to solidify the application in FLASHROM;

(4) RTOS is tailorable, which uses conditional compilation to perform software and hardware tailoring, thereby making RTOS more convenient;

(5) The pre-emptive type of RTOS is a reliable guarantee to ensure that it meets the requirements of real-time applications;

(6) RTOS can manage and control 64 tasks simultaneously;

(7) The certainty of RTOS is that it can know the functions and the execution time of its services during the application process;

(8) There are many RTOS services, such as semaphores and message queues. Ninth, RTOS can perform interrupt management services for 255 layers at the same time.

Embedded systems are more commonly used in mechatronics equipment as industrial equipment, especially in industrial control equipment, which can upgrade the application level of industrial-grade processors, achieve real-time monitoring and processing of equipment status information to ensure that applications can be improved effect. Especially under the background of 64-bit processors being gradually applied, while providing rich interface bus resources, it can ensure data collection and real-time summary processing, improve the effectiveness of communication and display functions, and also provide end users in the industrial field. Complete the corresponding processing work to create a good equipment platform.

Tracing back the robot technology system is closely related to the embedded system. The earliest control method did not reach the chip level. Only the logic circuit of the non-gate was used, and then the processor and intelligent control theory were gradually applied. Until the 1970s, the development of intelligent theory has driven the process of embedded processors, effectively achieving high reliability and high operability of the system, and can effectively create a more complete architecture and operating procedures.

The application of embedded control technology in mechatronics equipment is also reflected in the distributed control system. Because there are many measurement and control objects and high
requirements for production process automation, the use of embedded control technology can meet the operating efficiency requirements of distributed control systems. Speed up the application efficiency of DCS, and realize the integration and upgrade of the technical system.

3. Research on typical system platform of electromechanical equipment based on embedded technology

3.1. Hardware system architecture
The main processor is TI's 32-bit fixed-point high-performance chip DM642. It has rich video and audio hardware resources on the chip, and has a variety of interfaces such as network port, PCI interface, 1C interface, and serial port. In the fields of audio processing, network, signal analysis, etc., the main frequency of DM642 can reach 720MHz, and the number of executable instructions per second is 560Mbps. The width of its EMFA interface data bus is 64 bits, and its maximum data access frequency is 133MHz. Synchronous or asynchronous registers connect seamlessly. The system is mainly composed of video / audio signal processing module, memory expansion module, power conversion module, and external interface module. Figure 1 is a block diagram of the system.

![Figure 1. System structure block diagram](image-url)

(1) Video signal processing module
The video decoding chip uses TI's high-performance video decoding chip. TVP5150PS, it can convert the video signal in the format of PAL and NTSC into digital colour difference signal YCbCr. In the system, YCbCr is 4:2:2, and the video output format is ‘ITU-RBT. 656’, the chip is a 32-pin TQFP, with a small package and a power consumption of less than 150M W. It is a high-performance video signal processor. The DM642 processor supports BT. The input video data stream in 656 formats can be seamlessly connected with the data stream of TVP150.

The digital video signal processed by DSP can only be displayed after D / A conversion. The system video encoding and coding chip selects PHILIPS company's SAA7121H chip, its support Video coding in NTSC, PAL format, and the input supports BT. Data stream of 656 format; SAA7121H has one composite video (CVBS) output and one super video (S-Video, Q / C) output, which can be seamlessly connected to a DM64 processor with a VIP port.

(2) Audio signal processing module
The audio decoding chip uses TI's high-performance stereo audio chip TLV320AIC23B, which supports two types of input: LINEQIN or MIC. The built-in headphone output amplifier has programmable gain adjustment for the input and output. It is highly integrated inside and uses sigma-delta oversampling technology, which has low energy consumption and high signal-to-noise ratio.
The MC64 interface of the DM64 chip can be applied to multi-channel video and audio processing, and its data transmission and reception can be performed independently or synchronously. In this system, in order to ensure the synchronization of video and audio sampling and playback, a programmable phase-locked loop PL1708 is used, and the 27 MHz clock output of the video encoder TV510 is used as input. The clock input signal is provided by SCLK of TVP5150 through PL1708, and then divided by SCLOK3 (384fs) to AIC23B. In order to obtain proper frame synchronization and bit clock signals, DM642 are connected to SCKO2 (256fs) of PL1708 respectively.

(3) External storage module

The DM642 accesses off-chip memory through an external memory interface (EMIF). The EMIF consists of 4-bit select line CE3CE0, 8-bit enable line BE [7: 0], 20-bit address line A [22:0], and 64-bit data line D [63:00] and read / write control signals of various types of memory, each CEx space has 256 Mbytes of addressable space, and can be configured as various types of memory interfaces, such as SDRAM, Flash, SRAM, QBTRAM, etc. In addition, the CE1 pin is used as a chip select signal to expand a 1 M × 8-bit FLASH as a data buffer space. The external memory area address range is 0 × 9000.000 ~ 0 × 9001FFFF.

EMI clock is generated on-clock based on the input clock of EMIF, ECLKIN is the clock input pin; ECLKOUT 1 is the input clock pin, and ECLKOUT 2 is the output clock pin, which can input and output 1x, 2x, and 4x CPU clocks, respectively. The SBSRAM controller is controlled by a more flexible programmable synchronization register, the storage space is CE0 to CE3, complete the effective selection of low level; and the enable signal of the signal receiving end is completed through BE0 to BE7; asynchronous memory The operation is realized and completed by signals such as pin ARDD (ready to signal), pin AOE (asynchronous enable), AWE (write signal), ARE (read signal). The RAM of the system adopts two symmetrically distributed HY547V283220F chips, which can simultaneously cooperate with the EMIF interface's fast output temporary storage data, and temporarily store the processed data.

(4) External interface module

The system selects TL16C752B to implement 2 asynchronous serial ports. In order to connect to TL16C752B, the DM6442 chip configures the CE1 subspace of EMI as an 8-bit asynchronous static memory interface, and each asynchronous serial port occupies 8 bit-memory cells.

The control signal is sent from the DM642 and reaches the controller via the asynchronous communication serial port (UART) TL16C752 and the FIFO buffer and level conversion chip. This system adopts 4-wire RS232 interface standard, and uses various logic in the CPLD device EP712128ETC control circuit to generate various control signals for serial communication in EP71228AETC, such as the chip selection signals CSA and CSB corresponding to the TI16C752B chip, chip reset Signal RESET etc. and the TL16C752B chip can convert the 8-bit parallel data from the DM642 into serial data that can be used by the RS232 serial chip, or convert the data from the serial chip into the parallel data that DM642 can operate.

(5) Circuit PCB simulation analysis

Because the data bus and address bus parts of the two SDRAM chips in the system have high transmission rates, their impedances are not easy to match. By looking up the data related to the IBIS model, the corresponding matching impedance value can be preliminarily calculated, and then from ZOUT = E/IO and RSERISE = ZO-Zout, we can get RSERISE = 53.15Ω. According to the components available on the market, select a 51Ω resistor when simulating the series termination matching resistor. The excitation signal is set to a 133 MHz square wave signal, and the quality of the signal is judged by observing the received signal from the receiving SDRAM.

Figure 2 and Figure 3 are the simulation comparison of transmit and receive waveforms of the address bus and the data bus after initial and matching. As shown in the figure, the unmatched termination resistance will have a large overshoot waveform; and by terminating a 51Ω resistor that matches the transmission line characteristic impedance, the source reflection coefficient is approximately zero, which basically eliminates reflection. The waveform overshoot is significantly reduced, and the noise margin is significantly increased, which meets the signal integrity requirements.
3.2. Monitoring methods and data processing

This system uses ZUV to process video signals in motion detection. On the display, the colour image signal can extract the luminance Y signal and chrominance signal, and the chrominance signal is also divided into a colour difference component U and a colour difference component V. The ZUV vector is converted into an RGB signal for display through matrix transformation. According to different algorithms, it can be applied to point arithmetic, geometric transformation, enhancement, and edge detection, encoding and decoding algorithms.

\[ D_k(x, y) = \begin{cases} 1 & |f_k(x, y) - f_{k-1}(x, y)| > T \\ 0 & \text{Others} \end{cases} \]  

(1)

It can be seen from the above formula that the threshold T plays a key role in the detection process, and its size determines the sensitivity of the entire detection system. When the value of T is small, there is more noise; on the contrary, it can filter out some noise to make the noise less, but at the same time, it is easy to destroy the continuity of the target. Because the threshold T lacks self-adaptability, it requires higher monitoring conditions and it is difficult to adapt to changes in the environment. For example, in the case of rainy weather, the monitoring effect will be greatly affected. To solve the above problems, this paper proposes an improved algorithm based on the frame difference method. Since the background environment is basically constant under the influence of weather changes, we have added an additional term to the judgment condition, namely the overall sensitivity. Amend the judgment conditions as follows:

\[ \text{Max}_{(x,y) \in A} |f_k(x, y) - f_{k-1}(x, y)| > T + \lambda \frac{1}{N_A} \sum_{(x,y) \in A} |f_k(x, y) - f_{k-1}(x, y)| \]  

(2)
In the formula, $\lambda$ is the suppression coefficient; $N_A$ is the number of pixels in the detection area $A$, and $A$ can be the entire image. Add item as:

$$
\lambda \frac{1}{N_A} \sum_{(x,y) \in A} |f_k(x, y) - f_{k-1}(x, y)|
$$

(3)

Formula (3) represents the overall environmental change. When the environmental conditions change insignificantly, its value is close to zero. When the environmental conditions change significantly, its value increases with the conditions, which makes the conditions for formula (2) valid. As harsh, which reduces the cause.

During video processing, image acquisition is first converted into video data in the YUV format, and then the data frame is passed to the central processor for processing. After receiving the video data, the processor starts the monitoring task, and simultaneously converts the data in to the YUV format, and passes the starting address to the video processing program. After the program processes, it sends the YUV format image to the output device for display and moving objects. The edges will be highlighted on the screen.

The auditory part of the monitoring system is faced with abnormal sounds made under specific operating conditions. Using the DSP chip, high-speed collection of live sound can be performed, and abnormal sounds can be separated from normal audio and quickly recognized. The identified abnormal sound status is transmitted to the DM642 and a decision is finally made.

The test of audio input and output in this system mainly includes MCASP configuration and communication, AIC23B configuration, and exchange of audio data. When testing audio, it mainly includes initializing MCASP, setting Codec’s working mode through IIC, starting audio collection and playing back audio signals. The software implementation of abnormal audio recognition includes a core processor, digital signal pre-processing (pre-amplifier, gain, band-limit filter), a high-speed A / D interface, and an information transmission port.

In the detection, mean value calculation and FFT transformation are needed. Due to the large amount of calculation, in order to ensure real-time performance, the frequency range needs to be minimized. When a sound signal is taken at a frequency of 40ms and analysed every 10ms for frequency domain analysis, the effective frequency range of the loudspeaker can be set to 5000 Hz to 10125 Hz. Therefore, the basic algorithm is as follows:

$$
H(k) = \sum_{n=0}^{N-1} h(n) \cdot W(n) e^{-j2\pi nk/N}
$$

(4)

$$
W(n) = \left[ 0.42 - 0.5 \cos\left(\frac{2\pi n}{N-1}\right) + 0.08 \cos\left(\frac{4\pi n}{N-1}\right) \cdot W_k(n) \right]
$$

(5)

Let the sampled data sequence be $h(n)$, then perform the FFT operation of $N$ points plus the Blackman window as:

$$
W_k(n) = \begin{cases} 
1 & 0 \leq n \leq N-1 \\
0 & \text{Others}
\end{cases}
$$

(6)

Where $H(k)$ is the output sequence and $W(n)$ is the Blackman window function; therefore, the power spectrum $S(k) = |H(k)|^2$, and after the digital frequency $k$ is converted to the analogy frequency $f$, the power from 5000 Hz to 10125 Hz. The sum of the spectral values is $E$.

When $h(n)$ contains only the background sound input sequence, the above algorithm can determine $E$ when there is no abnormal sound; and when $h(n)$ contains abnormal sound, $E'$ can be calculated. Obviously, the two are not equal. A decision threshold $E$ can be determined. When $E' < E$, no abnormal sound occurs, and when $E' > E$, it indicates that there is abnormal sound.
3.3. Research results
The monitoring object is a manganese material boxer, which is mainly used to alert the abnormal working conditions in the process of manganese material boxing and identify the failure phenomenon. Figure 4 shows the overall structure of the manganese packer and the locations of the sensors. The sensor information in the system consists of visual information, auditory information, and internal sensor information. Most of the internal sensor information is switching values, such as limit switches, proximity switches, magnetic switches, which represent the travel limit of the robot. 0 means the switch is closed. 1 means open. Audio visual information is used for manganese motion detection and abnormal noise.

![Figure 4. Top view of the sensor position of the boxer](image-url)

For the description of the working state of the system, no matter the state or the fault, usually only a few of all the sensing information are needed. For example, the description of the blanking phenomenon can be completed by using the robot's proximity switch information and visual information; using visual information and the sound information of the servo motor can determine whether the robot has stayed for a certain time out; using visual information, the sound information of the screw rotation, and the yoke The magnetic switch information of the upper limit of the cylinder and the packing position can judge the movement speed of the robot. The detailed analysis is shown in Table 1.
Table 1. Analysis of fault status and diagnosis results

| Internal sensing information | Vision sensor key frame | Explanation of failure phenomenon |
|-----------------------------|-------------------------|-----------------------------------|
| A: 1-0                      | Detect aggressive movement | Z axis cylinder (Z axis) running speed is too fast |
| A: action before 5s (back), B: 1-0 |                         |                                   |
| D1: 1-0                     | Detect aggressive movement | Cylinder (X axis) running speed is too fast / slow |
| D1: action before 7s (back), D2: 1-0 |                         |                                   |
| B: 1-0                      | Detect aggressive movement | Cylinder (Z axis) running speed is too fast / slow |
| B: action before 3s (back), C: 1-0 |                         |                                   |
| A: action (1-0) 3s back     | No sharp movement detected | Manganese material stays overtime in the gripping area |
| B: action (1-0) 2s back     | No sharp movement detected | Manganese stays over time at the beginning of the screw |
| D1: action (1-0) 2s back    | No sharp movement detected | Manganese stays overtime in the middle area of the screw |
| D2: action (1-0) 2s back    | No sharp movement detected | Manganese stays overtime at the beginning of the packing area |
| C: action (1-0) 3s back     | No robot motion detected | Robot stays overtime at the end of the packing area |
| A: 1                        | Blank detected           | Blanking occurs                   |
| A: 1                        | No blank detected        | A failed                           |

During the experiment, a total of 60 typical faults were artificially created. The accuracy of the system's judgment of whether the equipment is in a fault state when operating is 98.3%, and the accuracy of identifying the fault phenomenon is 91.6%. The results show that the system works. Status can be effectively monitored.

In order to verify the accuracy of the designed energy consumption monitoring system, a HIOKI3390 broadband power analyser manufactured by a Japanese company was used as a calibration instrument. At the same time, the data acquisition module HIOKI3390 broadband power analyser of the monitoring system was installed at the air switch of the CK6136 main power supply of the CNC machine tool. The curve record is shown in Figure 5. It can be seen that the relative error of the measured power values is relatively small.

![Figure 5. Energy consumption monitoring results](image-url)
The actual energy consumption analysis of the CNC machine tool during the machining process. The machine tool energy consumption information such as total machine tool energy consumption, machine tool effective energy, machine tool energy utilization rate, and machine operating time are displayed by the human-machine interactive interface, which is convenient for the staff to better analyse. And understand the working process of CNC machine tools and their real-time energy consumption. Provide reliable data support for subsequent improvement of energy saving and emission reduction effects in the production process.

Transfer the successfully read back data from the USB port provided by rk3399 to the PC. Through data analysis software processing, the original data is separated according to the data frame header of each channel, and finally 7 channels of data are output. View and process with HEXEDIT and MATLAB software to get the corresponding data source and waveform diagram. Of the first 8 bytes of each channel of data, 4 bytes are the data frame header and 4 bytes are the frame count, which can be seen intuitively in the original data.

The switching and analogy test results are shown in Figure 6. Data frame header F1F20000, frequency 100Hz, frame counting interval is 2.

![Figure 6](image_url)

Figure 6. Raw data of switching value and analogy quantity

Figure 7 shows the analogy waveform after MATLAB processing. It can be seen that the voltage value basically coincides with the system operating voltage of 28.0V.
4. Conclusion
According to the requirements of the condition monitoring of electromechanical equipment, an embedded audio-visual sensor system based on DM642 was built. The system was tested on the manganese packing production line to verify the reliability of the system. The DSP chip is used as a processor to process multi-source information. It runs fast, is compatible with other digital devices, and has a high degree of system integration. To respond to different operating conditions and use requirements, you only need to change the algorithm and adjust the digital sampling rate. The software and hardware are flexible in construction and easy to promote.

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