A MEDIUM RESOLUTION INTELLIGENT VIDEO CAMERA

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Abstract

The most popular method for abstracting visual information from video images is based around image grabbing techniques. This is expensive, bulky and quite often too slow. It also requires the use of large amounts of processing power.

There are a number of applications, ranging from intelligent toys to machine vision and security applications which need either low cost video images or ones that can be digitally manipulated.

The main criteria for the camera described was its manufactured cost - below $20. It had to be easily mass produced and small enough to fit into mobile toys, such as radio controlled cars. It also had to have good enough resolution so it could be used in a number of machine vision applications for mobile robots, industrial automation and security.

Introduction

The most popular method for abstracting visual information using video cameras is based around image grabbing techniques. This is expensive, bulky and quite often too slow. It also requires the use of large amounts of processing power. In its simplest form most of this effort is wasted.

Video cameras using these techniques usually use a ccd array as the image sensor. The information from that array is then converted to internationally accepted standards which is then available in a 1 Vpp composite video analogue format. The video processing system then has to grab each frame and convert each pixel into a binary code that can be stored in memory.

In many applications the camera is in close proximity to the processing unit. Thus the conversion to complex analogue form is not necessary. The camera described here takes the analogue information from the ccd array, processes it through a simple A-to-D flash converter and then uses an off-the-shelf 8-bit microcontroller to process the timing signals. To achieve a 1 Vpp composite video analogue signal, if required, a D-to-A converter can be used.

Although this is not too different from accepted techniques used in most commercially available camcorders, these have usually been designed to give near broadcast quality pictures, and in colour. For many applications low quality monochrome is all that is needed.

At the same time most video images are based on broadcast standard frame rates, usually 25 or 30 frames per second interlaced. In many applications a variable frame rate is necessar. Also the possibility of dynamically changing the resolution of the image is also very useful.

The second largest manufacturing industry in Hong Kong, after garments, is toys. Owing to the transfer of low technology manufacturing to Southern China the Hong Kong toy industry is moving towards toys with built in intelligence and further added-value functions. One of these is vision capability. For the toy industry such enhancements need to be low cost and easily mass produced.

The initial main criteria for the camera described was its manufactured cost - below $20. It had to be small enough to fit into mobile toys, such as radio controlled cars. A secondary criteria was that it also had to have good enough resolution so it could be used in a number of machine vision applications for mobile robots and industrial automation.

Taking into account the basic design criteria it was decided to use as many standard off-the-shelf components as possible. This would allow easy manufacture of a single-chip version using design automation techniques where many embedded sub-system designs are available. At the same time it would allow easy prototyping and testing.

The design also had to be video format independent, as well as having variable scan rate and pixel resolution.

General Description of Electronics

The two main applications of the camera, ie toys and machine vision, require the signals from the memory to be processed in different ways. The signals to generate the composite video for the former involve converting the digital data back to analogue. For the latter, the data needs to be kept in digital form and sent to whatever device will do the image processing.

The initial protoype, to be described first, produced the composite video signal. Another reason for building the composite video version first was so that the quality of the camera could be judged visually on a tv monitor. The second version, described later, was used for image processing.

Fig. 1 shows the general block diagram of the camera. It was decided to use an 'off-the-shelf' ccd array. The ccd array is configured as a 165 by 192 pixel array. The output from the array is passed to an analogue to digital converter, which converts the analogue levels from the ccd array into digital information which is the stored in RAM.

There are two sets of memories. One is used to store the picture information from the ADC, while the other provides data to the DAC. Their positions are changed after each 'page', so as to maintain data output during the two read write cycles. Data is switched between the two memories using a multiplexer switching circuit (MUX). The memory control unit (MMU) initialises each cycle as well as holding the memory addresses for the data.

The central control unit (CCU) provides all the handshaking signals for the ccd array, ADC, DAC and MMU. The digital to analogue converter (DAC) converts the data from the memory back into analogue form, where it is mixed with the complex sync signal generated by the CCU. This composite video signal is then fed to an amplifier to give the 1V pp standard video signal.

CCD Array

The TC211 is a full-frame charge-coupled-device image sensor, configured into 165 horizontal lines, each containing 195 pixels. Twelve additional pixels are provided at the end of each line to establish a dark reference and the line clamp. An antiblooming feature is activated by support clock pulses to the antiblooming gate. The charge is converted to a signal voltage of 4μV per electron. The signal is further buffered by a low noise two stage source follower amplifier to provide high output drive capability.

The output from the ccd array is then converted to ttl levels. In the original prototype the various voltage levels required by the ccd array were generated by complex analogue circuitry. This has recently been replaced by specialised integrated circuits. The complex timing signals for the ccd array were initially generated using standard oscillator circuits. However, to give the timing flexibility required for variable frame rate, these were replaced by signals generated by the microprocessor.

Other circuit elements

Because of the speed needed to convert the signal from the array a flash ADC was used. Experimentation with the acceptable resolution of the final picture, as well as the number of grey scales required, indicated that a 6 bit ADC was necessary. The CA3306, a CMOS parallel (flash) 6 bit ADC, has a clock speed of up to 10MHz, which was adequate for this application.

The function of the switch is to control the data flow between memory and ADC, and memory and DAC. Since the data from the ADC to memory, the writing process, and the data from the memory to DAC, the reading process, take place at the same time, the circuit is used to switch the channel for the data flow. The switch was constructed from two multiplexers, one analogue, the other digital.

A high speed 8 bit current output DAC, the DAC0800, was used to convert the data. This has a conversion speed of 10MHz. As the digital signal had only 6 bits, the spare two were used to provide reference negative and positive DC bias voltages.

The signal from the DAC, as well as the complex video sync signal generated by the microprocessor, were then mixed. This was kept very simple - a single 2N3904 transistor - as the input signals had a Vpp of around 5V, whilst the output had a Vpp of 1V.

As the speed for accessing the memory is high, 4MHz, it was not possible to generate the addresses by the micro-controller as the controller needed would be very expensive. Therefore it was necessary to construct a dedicated address counter. In fact, two counters were used, one each for the vertical and horizontal addresses.

An 8031 microcontroller was used as the central control unit. As this does not have internal memory and external EPROM was required.

Software

The main function of the central control unit is to generate the control signasl for the components such as CCD and DAC. With the configuration of the prototype another important role is the generation of the complex video sync signal (CVS). Since the timing of the CVS is very important - it will directly affect the signal displayed on the television, the video syncs were generated before the control signals. The camera was designed to operate using PAL or NTSC formats. As no colour information was required, the only criteria was to make sure that the sync signals could be generated under program control to give both signals.

Experimental results

For the prototype, the camera was built to NTSC format, with software compensating for the difference between that and PAL. Consequently, the image displayed in NTSC format was same as the 'original'.

For the initial prototype built with discrete components and wire wrapped, the resulting picture was very noisy, although the image was quite clear. The second version, on single sided pcb, was much less noisy. A final version, using 4-layer pcb and smt components is currently being constructed.

Conclusions

The prototype showed that the basic concept was valid, especially as the total component cost was under US$50. Estimated cost for the smt version is around US$40. Elimination of the external memory, by using a microprocessor with internal memory is the next stage of development. This will reduce the cost even further. Finally, using EDA techniques, a fully integrated version, using just four main chips, is the final goal. This should then reach the US$20 cost that was the original aim.

Since the initial development of the camera was for toy and domestic uses, a number of other applications have arisen. In the field of machine vision, for example, expensive frame grabbers are used to take the composite video signal and convert it into a digital one.

As the original signal coming from the ccd array is easily converted to a digital one by the use of just an ADC, most of this intervening circuitry is really unnecessary. A concurrent programme is investigating whether image processing techniques, such as Hough Transform edge detection, can be integrated into the camera so that only needed information goes to the computer, thus lowering the cost of such applications.

With this type of application the signal processing takes place directly after the 'MUX B' stage. Thus composite video signal is not required, making the camera even less costly. Without the need to generate the timing signals for the complex video stage, the cpu can be used for other activities, as mentioned above.

Similarly, another application is in the security area. As it is possible to selectively scan the image, resolution enhancement can be integrated into the software, thus providing an intelligent camera that can eliminate the need for expensive control equipment.

With the recent introduction of higher resolution ccd arrays it should be possible to develop an even better camera for the same price.

Acknowledgement

I would like to thank Mr Gary Wong Sing and Ms Zhu Bei Min, who did the construction and programming of the prototypes.

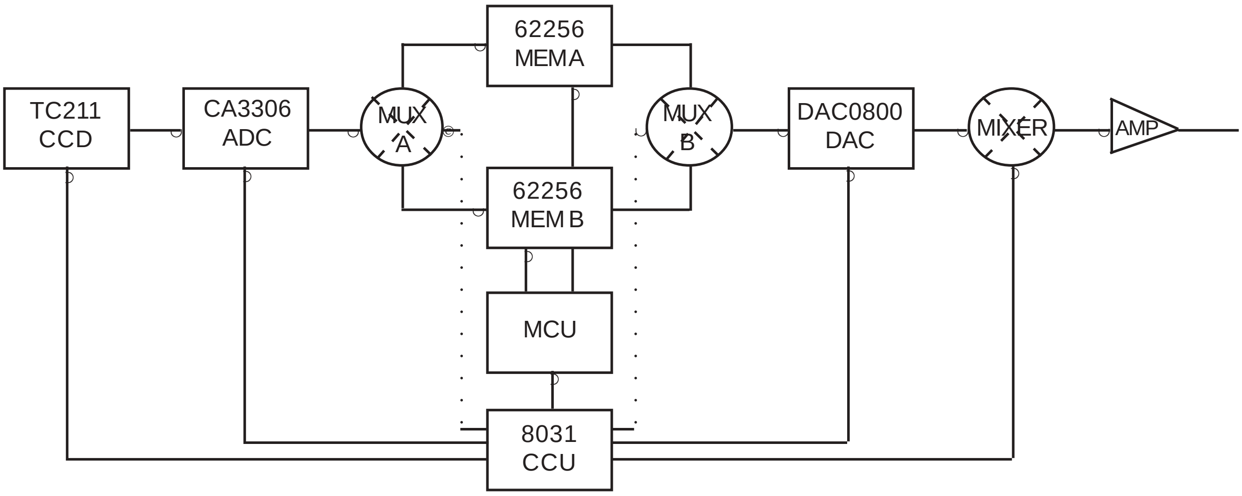

Fig1: Block diagram of prototype camera