IC Requirements for Multimedia TV

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Abstract: This paper describes the key technologies and trends for multimedia applications. The common use of digital processing has opened the door for new applications and new markets, from consumer products to communications and computing products. It also significantly re-invents traditional products from TVs to computers. Integrated Circuits and IC technologies have been the prerequisite for these multimedia products. This paper provides historical perspective of the multimedia systems. It also will provide some extrapolation to future needs in ICs.

Introduction

Digital technology has been in the market from the introduction of the computer. So why is there an explosive growth of products now? This growth is due to IC design and technology meeting the needs of the algorithms and of the customer's cost requirements. It is not a coincidence that computer products, digital video products, and digital communications products have migrated to the consumer in the 1990s. It is the epoch of sub-micron ICs that enables this trend.

ICs were necessary, but not sufficient, to drive this revolution. Nicholaus Negroponte's book "Being Digital" [1] describes the transition of signal processing (audio and video) from analog forms to digital. Even Digital Signal Processing alone was not enough to completely enable multimedia. The storage and transmission requirements of digitized video was beyond what was cost effective for mass products. The information theories pioneered by Claude Shannon at Bell Labs were necessary to meet this need. Shannon's seminal paper [2] describes the ideas of Source Coding and Channel Coding that are used in multimedia products.

Source Coding Fundamentals:

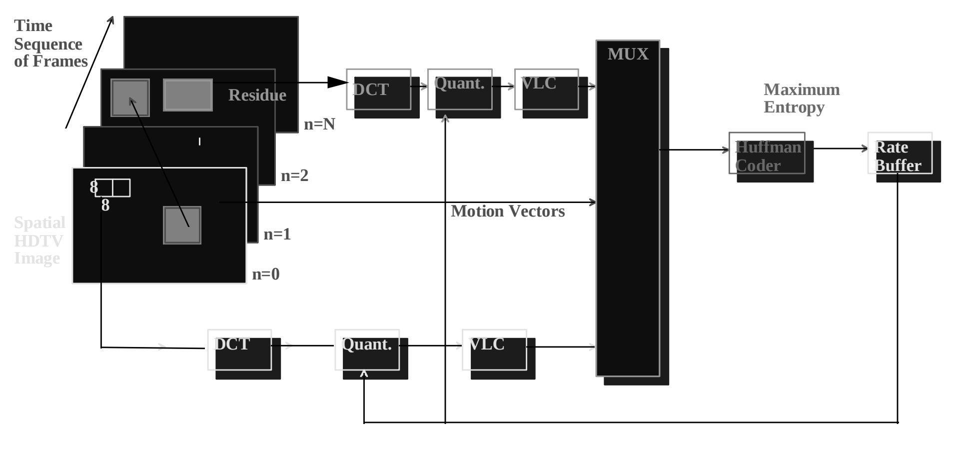
The source coding described by Shannon is the compression of data (or digital signals such as voice) to minimize redundant information. Shannon's contemporary, Huffman, describes a lossless compression technique based on the statistics of the data "words." This maximum entropy technique substitutes a short word-length "symbol" for a common "word", and uses a longer "symbol" for a rare "word." On average, the data is compressed and the output string of symbols has high entropy (approximates white noise). Shannon also describes lossy coding techniques and stresses the importance of matching the compression technique to the characteristics of the human perception in the cases of voice, audio, and video compression. The research on human perception fed the subsequent algorithm development in the 80s.

Source coding algorithms remained in research and university labs for many years. The first application of the research in video compression was video conferencing. This application suffers from a woefully low bandwidth channel (voice telephony) and continues to challenge compression algorithms. The important application to enable multimedia was the possibility of storing pictures and video on a CD. This launched Philips' CD-I product and also the Joint Picture Expert's Group (JPEG) the Motion Picture Expert's Group (MPEG). These committees were staffed by computer, consumer and IC companies as well as universities and research labs. They developed compression systems and syntax and proposed them to the International Standards Organization. MPEG2 is the standard upon which the multimedia revolution is based.

MPEG source coding has three parts: The still image coding uses the Discrete Cosine Transform. A block of an image is represented in frequency-like form through the transform. In this domain, bits are "quantized" from high frequency image data. This quantization (up to a point) is viewed with negligible impact on an observer, due to the human visual system properties of the coding. The second part of the coding process deals with the compression of moving images. Images contain much frame to frame redundancy. It is suitable to only update the portions of the image that change. In MPEG, blocks of previous (and future) frames are compared to the present frame blocks. The closest correlation provides a "Motion Vector" instruction for the decoder to do a block move in the present frame buffer.

In addition, the difference between the original image ("Residue" in Figure 1) and the reconstructed motion vectored image is compressed with DCT quantization and sent to the decoder. The MPEG1 standard was expanded in MPEG2 to address interlaced images, among other improvements.

Figure 1. Block Diagram of MPEG Video Compression



The third part of the compression process is the Huffman coding explained earlier in this section. In addition to the basic compression, MPEG was developed to be very flexible so that the system is somewhat "future-proof." Many parts of the MPEG system are programmable (downloadable) to the decoder, and the decoder has the responsibility to follow the instructions from the encoder. The MPEG encoder can be designed with various levels of complexity in order to provide various price/performance points.

Channel Coding Fundamentals:

Channel coding is the matching of the compressed bits to the robustness (or lack thereof) in the noisy communications channel. The idea is to add redundancy in a controlled manner to the bitstream in order to correct for and survive errors caused by noise or distortions in the channel. Shannon described a theoretical bound of the maximum information bits to be transmitted in a particular noise environment. Two types of channel coding are typically used in multimedia products. The first, Block Coding (Reed-Solomon), adds bytes to a packet which will detect and correct errors. The second is a Convolutional Code, which controls the probability of symbol to symbol transitions, adding state transitions when necessary. The most common architecture for convolutional decoding is the Viterbi. The most probable transition is found by tracing back through a sequence of transitions, where Viterbi found the minimum hardware solution.

Multimedia Applications

A. Consumer Applications

Traditional Consumer Electronics has focused on entertainment products targeted at a large-screen experience with low interactivity. Since 1994, the multimedia products which have been introduced have a large downstream capacity for TV-type of programming, and a smaller return channel for limited interaction. This service is being offered or is under construction through all types of networks or media; cable, satellite, terrestrial, microwave terrestrial, fiber, telco and stored media such as disc and tape. Some of these are standards (international or national) and some are industry consensus standards. The following table summarizes the systems and status.

System/Standard	Video	Audio	Transport	Transmission	Network/Media	Status/Comments
US terrestrial HDTV	MPEG2-HLMP & MLMP	Dolby AC3	MPEG2 extended	8VSB	terrestrial	1998 deployment
US Telco	MPEG2	MPEG1 or Dolby AC3	MPEG2	Replaceable "NIM" module	Hybrid Fiber-Coax or Microwave	Telcos 1996 & 7 (long term FTTC)
US Cable	MPEG2-MLMP (Digicipher?)	Dolby AC3	MPEG2	??	Hybrid Fiber-Coax	Cable and EIA working standards, some RFP for 1997 product
Digicipher Satellite	Digicipher I	Dolby AC3	Digicipher	QPSK Conv. + RS	Satellite	800,000 Primestar 5/96
DSS Satellite	MPEG2-MLMP	MPEG1	nearly MPEG2	QPSK Conv + RS	Satellite	2,000,000 by 5/96
DVBS (Satellite)	MPEG2-MLMP	MPEG2 or MPEG1	MPEG2 extended	QPSK Conv. + RS	Satellite	ISO std. Europe products 1996,7 used in US - mid 96
DVBC (Cable)	MPEG2-MLMP	MPEG2 or MPEG1	MPEG2 extended	64, 256 QAM RS code	Cable or Hybrid	ISO std. Europe products 1996,7
dTTb (terrestrial)	MPEG2-HLSP	MPEG2	MPEG2	8000 COFDM-64QAM Conv. + RS	terrestrial	in standards process
DAVIC telco, sat, cable	MPEG2-MLMP	MPEG2 or MPEG1	MPEG2	QAM	ATM or switched	Protocol related- proposal by 12/95
DVD	MPEG2-MLMP	Dolby AC3 or MPEG1,2	PES layer with interactive commands	8 to 16 modulation RS code	disc	1996 introduction worldwide
DVC	DCT-based, no motion comp.	PCM	none	24 to 25 modulation RS code	tape	1996 introduction worldwide
Sega Nintendo Sony Playstation	Graphics, trend toward MPEG1	PCM or generated			game player w/ CD ROM	several million / yr.

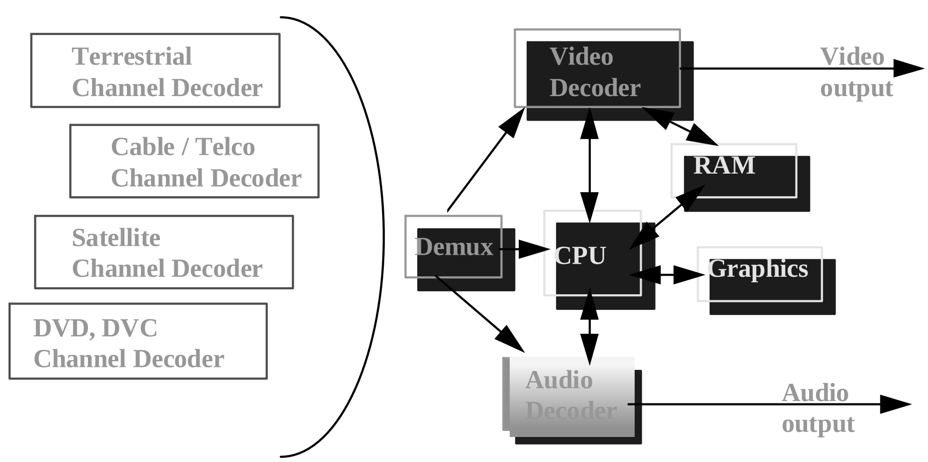
B. Computing Applications

In the last 2 years the computer has met the early 80s expectation of a "home computer" and has made significant sales into the consumer market. This consumer computer is truly a "multi-media" product with CD-ROM for video and games, and a high speed modem for access to the Internet. The market leader is a PC architecture, Intel microprocessor, and Windows 95 software. Today this equipped with 32Mbytes of RAM, 6-8x CD ROM, and SVGA graphics. The data compression for Video is not standardized (typically uploaded from storage media), but in many CD ROMs is MPEG1. This machine is a multi-purpose with the primary use in the home is games.

C. Predictions for the year 2000

Who wins the battle for the consumer? The computer or the TV? The answer is probably both. The consumer is asking for the ease of use and picture quality of a TV but the features such as internet access and game capability of a Computer. Is it a Compuvision or a Teleputer? The focus today is on the "$500 set-top box." This is the most likely parent of the dream product of the year 2000. Figure 2. shows the block diagram of the functions in this set-top.

Figure 2. Block Diagram of Multimedia "set-top"



The common functions in this set-top for the IC development will depend on the features. It seems clear that the “killer application” is access to the Web. The Web browser feature will require graphics, text, sound (probably compressed), and compressed video. MPEG 1&2 video are a must. Dolby AC3 and MPEG 1&2 audio are required. Good graphics is required for stored or downloaded games. A large amount of RAM (or other storage) is required for Web access.

Are Intel processors and Windows-95 software requirements? Many companies are now developing or have announced other processor solutions, all involving some kind of RISC architecture. It is very likely that other processors or software can gain market share in the “$500 set-top” concept, since the “killer application” of Web access is truly processor independent. When will general processors have enough power to handle MPEG2 decoding? This can be predicted by Moore’s law for CPUs: processor power doubles every 2-3 years. Today, Intel is showing 1/4 (CIF) resolution MPEG1 on the latest processors. For Main Level Main Profile (MLMP), the CPUs should be capable by 2000, for HDTV (4-8x resolution) it will be 2004.

The set-top will need for ICs for Channel decoding. However, there is no clear prediction is which network will dominate the connection to this set-top. ICs will need to be developed for all network or media interfaces.

Integrated Circuits for Multimedia

A. DRAM requirements

DRAM price per bit has been following Moore’s law (cost per bit reduces by 68% per year) in the long term, with the recent fall in DRAM prices bringing the market back to the curve. The continuation of this trend will allow competitive diskless solutions (such as the set-top). The minimum requirement for quality MPEG2 MLMP 60Hz images is 16Mbit (2MBytes). 16Mbit RAM peak volume years are 1997-99 according to the Integrated Circuit Engineering Report for 1996 [3]. The price per bit in 1996 is forecast at 0.24 millicents, translating to $38 for this part. For high volume products by the year 2000, this size RAM may be embedded. For HDTV Video decompression the system needs 96Mbits (12MBytes).

RAM will also be required, as in computers, for program buffering. In the case of Web applications this buffer may be large (32MBytes).

B. Source Decoding

Single chip MPEG2 Video Decoding ICs have been described [4] in 1994 and MPEG Audio chips [5] have been described in 1995, both in 0.5 micron CMOS. This year these two functions are available on a single chip. Looking forward, IC manufacturers have forecasted in the trade press that all the source decoding functions will be available on a single IC in 97/98 in 0.35 micron CMOS. These proposed solutions typically have an on-chip RISC. Some of the decoding process can be shared on this processor, while high bandwidth MPEG tasks use dedicated hardware. The next step in technology (0.25 or 0.18 micron CMOS) should make software decoding feasible. This technology will be at consumer cost targets around 2000. The successful IC designs in the near term will be the ones that make the best choices of hardware and software to maximize flexibility and minimize cost.

C. Channel Decoding

Channel Decoding chips for satellite and cable have been presented [6-8] which are 1-2 chips for each specific channel in 0.5 to 1.0 micron CMOS. Single chip solutions per channel are feasible in 0.35 micron in the near term. The next step in technology would allow the combination of various channel solutions on a single chip. The difficult task in the channel decoding is to optimize the design for the channel which has the highest volume. Prediction of this trend today is impossible.

D. Encoding

The consumer will need low-cost encoding solutions for recordable media. The chips available for encoding require 10x the operations per second of a decoder function. The solutions reported in 1995 [9-13] in 0.5 micron CMOS required several chips for the MPEG2 MPML encoding. Even if the requirement for compression is less on recorded media, the solutions still requires more than one IC and are large chips. There is much work yet to bring these chips to consumer price levels.

Conclusions

The "$500 set-top" with the "killer application" of Web access was presented as the product of the future. In this concept the integration of the source decoding functions (MPEG2 Video, AC3 audio, MPEG audio, transport decoding) and the system processor (some form of RISC) in the lowest cost manner is imperative. The Channel decoding must be kept as separate chips until the dominant network emerges, or when all channel decoding functions converge. Low-cost source encoding (primarily MPEG Video) is also required for recording products in the future multimedia.

References

[1]. Nicholas Negroponte, "Being Digital," Alfred A. Knopf, New York, NY, 1995

[2]. ed. J.J.A Sloane and Aaron D. Wyner, "Claude Elwood Shannon Collected Papers," IEEE Press, Piscataway, NJ, 1993

[3]. "Status 1996, a Report on the Integrated Circuit Industry," Integrated Circuit Engineering Corporation, Scottsdale, AZ, 1996

[4]. Tatsuhiko et al., "A Single Chip MPEG2 Video Decoder LSI," 1994 IEEE International Solid State Circuits Conference Proceedings, IEEE 1994, pp 72-73

[5]. Berger et. al., " MPEG Audio Decoder for Consumer Applications," 1995 IEEE Custom Integrated Circuits Conference Proceedings, IEEE 1995, pp 413-416

[6]. Christopher et. al., "A Fully Integrated Digital Demodulation and Forward Error Correction IC for Digital Satellite Television," 1995 IEEE Custom Integrated Circuits Conference Proceedings, IEEE 1995, 281-284

[7]. Luthi et. al., "A Single Chip Concatenated FEC Decoder," 1995 IEEE Custom Integrated Circuits Conference Proceedings, IEEE 1995, pp 285-288

[8]. Robindra Joshi, Henry Samueli., "A 100MHz, 5MBaud QAM Decision-Feedback Equalizer for Digital Television Applications," 1994 IEEE International Solid State Circuits Conference Proceedings, IEEE 1994, pp 68

[9]. Matsumura et. al., " A Chip Set Architecture for Programmable Real-Time MPEG2 Video Encoder," 1995 IEEE Custom Integrated Circuits Conference Proceedings, IEEE 1995, pp 393-396

[10]. Nakagawa et. al., " A Single Chip, 5GOPs, Macroblock-Level Pixel Processor for MPEG2 Real-Time Encoding," 1995 IEEE Custom Integrated Circuits Conference Proceedings, IEEE 1995, pp 397-400.

[11]. Armer et. al., " A Chip Set for MPEG2 Video Encoding," 1995 IEEE Custom Integrated Circuits Conference Proceedings, IEEE 1995, pp 401-404.

[12]. Ohtani et. al., " A Motion Estimation Processor for MPEG2 Video Real-Time Encoding at Wide Search Range," 1995 IEEE Custom Integrated Circuits Conference Proceedings, IEEE 1995, pp 405-408.

[13]. Hayashi et. al., " AA Compact Motion Estimator with a Simplified Vector Search Strategy Maintaining Encoded Peicture Quality," 1995 IEEE Custom Integrated Circuits Conference Proceedings, IEEE 1995, pp 409-412.