John Watkinson

Convergence in Broadcast and Communications Media

The fundamentals of audio, video, data processing and communications technologies

Includes:

- MPEG transport streams
- Networks
- ADSL
- ATM
- DVB
- Telephony
- Firewire

Focal Press

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For Chrissie

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The fundamentals of audio, video, data processing and communications technologies

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Preface

There are two key inventions which have brought about this book, and neither of them are new. The digital computer is one of these, and turned from a curiosity into a powerful tool as early as the Second World War. The idea of pulse code modulation (PCM) which allows continuous signals to be handled by digital hardware is even older.

Digital video and audio are another form of data and so the convergence with computers and communications networks has always been inevitable, although it has taken 50 years to become an economic reality.

Now that convergence is a reality, products and systems combining audio, video, data processing and communications are emerging. Without adequate fundamental knowledge of the four core technologies, products could be flawed or even fail.

Traditional experience does not serve well in convergence. Computer engineers suddenly find they need to understand audio, imaging and data systems delivering with an accurate timebase. Audio and video engineers find they need to understand file servers and computer networks. This book is designed to meet those needs. Without assuming a background in any of them, the four core technologies of image reproduction, sound reproduction, data processing and communications are all treated here.

Specialist industries evolve their own buzzwords and acronyms in order to save time, but these terms have the side effect of making the technology incomprehensible to the outsider. Communications and networking are possibly the worst offenders in the acronym department, with MPEG and DVB close behind. In order to cross disciplines with any hope of success, the only approach which will work is to use plain

English first and to introduce the inevitable buzzwords and acronyms later.

Another important aspect of this book is that the reader is asked to take very little on trust. Instead of presenting facts which are as likely to be challenged as they are to be forgotten, this book gives reasons which can be followed, supported by references. For example, all the criteria involved in image and sound quality should be based on studies of the human senses and so it is here.

These studies have advanced our knowledge considerably, but this has not always resulted in parallel improvements in television and hi-fi equipment because these have become commoditized and riddled with tradition. The reader from a computer background should not make the mistake of thinking that current audio and television practice represents the best that can be done. This book does not simply describe current television and audio practice. Instead it goes far beyond that to the limits of what can be done and how to do it.

John Watkinson
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1

Introduction to convergent systems

1.1 What this book is about

The range of products and services which can be based on various combinations of audio, video and computer technology is limited only by the imagination. From the musical greetings card through videophones, digital photography, MP3 players, Internet video and video-on-demand to flight simulators, electronic cinema and virtual reality, the same fundamentals apply. The wide scope of this book has made it essential to establish some kind of order.

The purpose of this chapter is to show why binary coding and digital processing are so powerful, to introduce a number of key concepts and to give some examples of convergent systems and their far-reaching consequences. The explanations of this chapter are deliberately brief to avoid obscuring the overall picture with too much detail. Instead it will be indicated where in the book the in-depth treatment can be found. Figure 1.1 shows the key areas of convergent systems and how they interact. Figure 1.2 shows some of the systems which depend on the subjects treated here.

In the digital domain it is possible economically to perform any conceivable process on data. These processes can only be applied to audio and video if the sounds and images can be converted from their original form into the digital domain and back again. Realistic digital sound reproduction requires an understanding of the human hearing system, transducers such as microphones and loudspeakers as well as precision conversion techniques. Chapter 5 considers all these aspects of audio interfacing.

Image reproduction in Chapter 7 is based on a detailed study of the human visual system in Chapter 6 which shows how the eyeball's

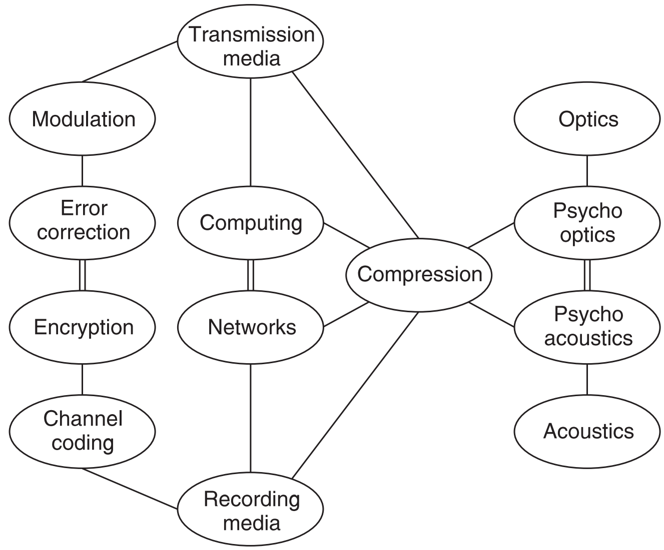

Figure 1.1 The enabling technologies of convergent systems are shown here. Combining these in various ways produces an infinity of information-related services and products.

Digital video broadcasting	Electronic cinema
Audio + video compression	Audio + video compression
Error correction	Networking
Encryption	Transmission
Modulation	Error correction
	Encryption
	Recording media
	Channel coding
	Optics
	Acoustics

Figure 1.2 Some examples of convergent systems and the technologies in them.

tracking ability has significant consequences. All good imaging systems should look the same, but today's film, television and computer images look different even to the casual bystander. The reasons for these differences will be seen to reside in a number of key areas. Colour accuracy is particularly difficult to achieve in convergent systems and familiarity with colorimetry is essential. Motion portrayal, the way that moving images are handled, is not well done in traditional systems, leading to a loss of realism. Chapter 7 also makes a detailed comparison of various scanning methods to see where progress can be made.

Imaging systems can only be as good as the transducers. Chapter 8 considers displays from the well-established CRT through LCDs up to modern display technologies such as micromirrors, plasma and lasers.

For a given quality, real-time audio and video require a corresponding data rate. Often this rate is not available for economic or practical reasons. This has led to the development of compression techniques such as MPEG which allow the data rate to be reduced. Chapter 9 looks at compression techniques and points out where quality can be lost by the unwary.

Once in the digital domain, audio and images can be manipulated using computer techniques. This can include production and post-production steps such as editing, keying and effects, or practical requirements such as resizing to fit a particular display. Although in principle any digital computer could operate on image data, the data rates needed by some imaging applications are beyond the processing power of a conventional computer and the data rates of its storage systems.

Moving-image processing needs hardware which is optimized for working on large data arrays. The general term for this kind of thing is digital signal processing (DSP). Chapter 2 explains how computers and digital signal processors work.

Data storage is a vital enabling technology and must be treated in some detail. Data can be stored on various media for archiving, rapid retrieval or distribution. The principles and characteristics of magnetic and optical recordings on tape and disks will be found in Chapter 11.

Data can be sent from one place to another in local or wide area networks, on private radio links or public radio broadcasts. Chapter 12 considers all principles of data transmission on copper, optical or radio links.

Whether for storage or transmission, the reliability or *integrity* of the data is paramount. Data errors cause computer crashes, pops and clicks in the audio and flashes on the screen. The solution is error checking and correction and this is the subject of Chapter 10. Encryption is related strongly to error correction and is important to prevent unauthorized access to sensitive or copyright material. Encryption is also treated in Chapter 10.

1.2 Why binary?

Arithmetically, the binary system is the simplest numbering scheme possible. Figure 1.3(a) shows that there are only two symbols: 1 and 0. Each symbol is a binary digit, abbreviated to *bit*. One bit is a datum and many bits are data. Logically, binary allows a system of thought in which statements can only be true or false.

What is binary?

(a) Mathematically:
The simplest numbering scheme possible, there are only two symbols:

1 and **0**

Logically:
A system of thought in which there are only two states:

True and **False**

(b) Binary information is **not** subject to misinterpretation

Black	**White**
In	**Out**
Guilty	**Innocent**

(c) Variables or non-binary terms:

Somewhat	**Undecided**
Probably	**Not proven**
Grey	**Under par**

Figure 1.3 Binary digits (a) can only have two values. At (b) are shown some everyday binary terms, whereas (c) shows some terms which cannot be expressed by a binary digit.

The great advantage of binary systems is that they are the most resistant to misinterpretation. In information terms they are *robust*. Figure 1.3(b) shows some binary terms and (c) some non-binary terms for comparison. In all real processes, the wanted information is disturbed by noise and distortion, but with only two possibilities to distinguish, binary systems have the greatest resistance to such effects.

Figure 1.4(a) shows an ideal binary electrical signal is simply two different voltages: a high voltage representing a true logic state or a binary 1 and a low voltage representing a false logic state or a binary 0. The ideal waveform is also shown at (b) after it has passed through a real system. The waveform has been considerably altered, but the binary information can be recovered by comparing the voltage with a threshold which is set half-way between the ideal levels. In this way any received voltage which is above the threshold is considered a 1 and any voltage below is considered a 0. This process is called slicing, and can reject significant amounts of unwanted noise added to the signal.

The signal will be carried in a channel with finite bandwidth, and this limits the slew rate of the signal; an ideally upright edge is made to slope. Noise added to a sloping signal (c) can change the time at which the slicer judges that the level passed through the threshold. This effect is also eliminated when the output of the slicer is reclocked. Figure 1.4(d) shows

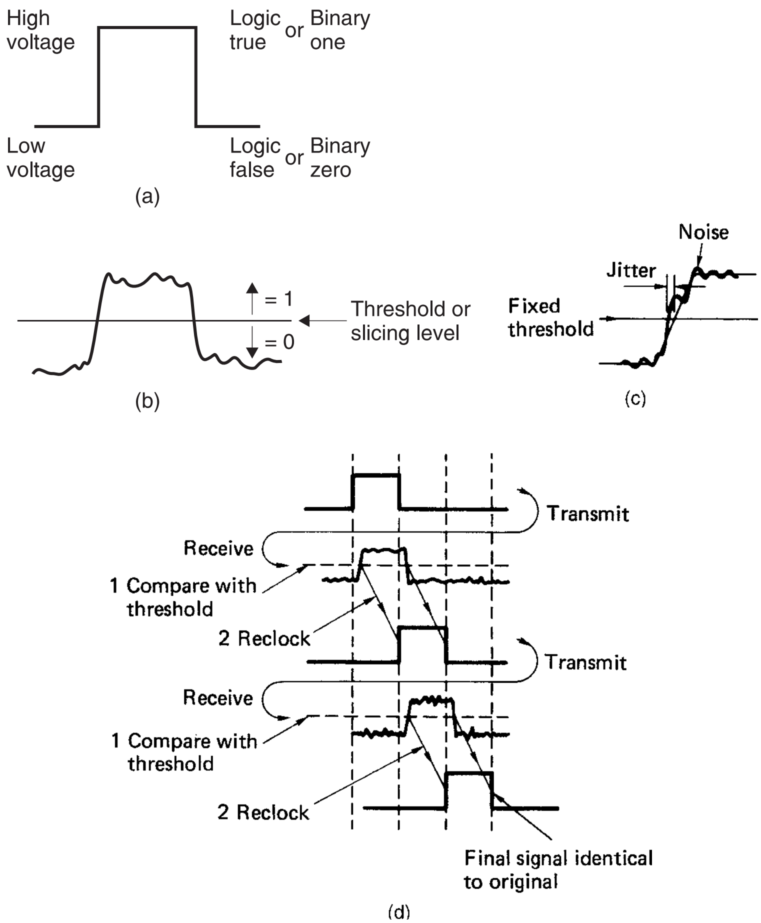

Figure 1.4 An ideal binary signal (a) has two levels. After transmission it may look like (b), but after slicing the two levels can be recovered. Noise on a sliced signal can result in jitter (c), but reclocking combined with slicing makes the final signal identical to the original as shown in (d).

that however many stages the binary signal passes through, the information is unchanged except for a delay.

Of course, an excessive noise could cause a problem. If it had sufficient level and the correct sense or polarity, noise could cause the signal to cross the threshold and the output of the slicer would then be incorrect. However, as binary has only two symbols, if it is known that the symbol is incorrect, it need only be set to the other state and a perfect correction has been achieved. Error correction really is as trivial as that, although determining which bit needs to be changed is somewhat more difficult.

Figure 1.5 shows that binary information can be represented by a wide range of real phenomena. All that is needed is the ability to exist in two