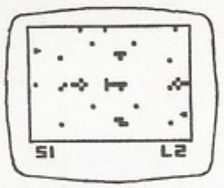

How to Design & Build Your Own Custom TV Games

Dedication

This book is dedicated to the growing number of young women who have the motivation and courage to join the ranks of skilled digital electronics technicians and engineers.

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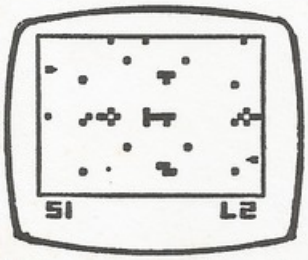

How to Design & Build Your Own Custom TV Games

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Preface

America is a nation accustomed to fads. Novel ideas and products catch on rather quickly, sweeping the country with new products and services. More often than not, these fads gradually change form or fade away with time.

TV games had all the earmarks of being one of these fads at first. Once the idea caught on, video game products captured the fancy of all sorts of people—people willing to put out $50, $60 or, in some cases, more than a $100 to play the fascinating little games in their own homes.

But it appears that TV games are here to stay. The games are becoming more sophisticated and diverse, and product sales skyrocket every Christmas. What's more, commercial, coin-operated versions have already transformed the game arcade industry into something totally new and different. It now seems that video games are replacing the pinball machine as America's number-one arcade game.

This is a book about TV games. It shows how they work and, more importantly, how to design and build custom versions. This book is not merely a collection of complete TV game circuits. To be sure, there are a number of complete game circuits presented as design examples; the real emphasis is on designing and building custom TV games. In fact the reader will loose much of the fun of the whole thing by simply copying the circuits shown here.

The whole idea of the book is to release the reader's creative instincts, transforming them into custom games that are a delight to

the designer as well as others who have an opportunity to enjoy them.

The game systems as they are presented here might seem rather cumbersome compared to the slick, cassette-programmed game systems on the market today. But how creative can one be with someone else's prescribed programs? Sure it is possible to get a dozen games on one program tape, but it really doesn't take long to want more. The game-design scheme presented in this book is wholly open-ended—there is no real limit to the number and types of games that can come from it. It's all a matter of learning how to design the games and exercising some degree of creativity and imagination.

It is not necessary to have a great deal of know-how concerning digital electronics to begin the work in this book. The first few chapters have been planned with the digital novice in mind. As the work progresses, however, the need for learning more about basic digital electronics becomes more apparent. Unfortunately, a book of this size cannot stand up as both a design manual for video games and a text book on basic digital electronics.

While the information regarding game design is thus adequate for building custom games of any sort, a reader not fully acquainted with basic digital electronics will eventually become lost without the aid of a good digital reference text. This, however, should not discourage a beginner in the digital business. Rather, it should provide some motivation and direction for learning more about digital electronics in general.

What better way to learn digital electronics than by seeing each newly learned fact transformed into moving image on the TV screen?

David L. Heiserman

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Special Notes to the Reader

- FCC regulations prohibit connecting the output of any rf source to an external antenna. The antenna must be completely disconnected from the TV receiver before any of the video circuits described in this book are connected to the set via rf modulators.

- While most of the circuits in this book have been orginated by the author, one or more circuits, techniques, and names of games may be covered by current U.S. patents and trademarks.

Chapter 1

Television and Television Games

Television has been an important part of home life in America for better than 25 years now, but television games, in their most popular forms, have been around for only a few years. It might seem that TV games could have been invented in the very early days of TV technology, but they were not. Why not? Because the right kind of game technology wasn't available at an affordable cost until recently.

This chapter describes the technologies of TV and TV games, showing in a very general way how modern TV games are interfaced with conventional TV receivers. Without at least a basic understanding of the interfacing problems, an experimenter can have little hope for designing custom TV games. One might be able to duplicate some of the specific game circuits shown in this book, but without that overall view of what the system is doing, the whole point of investing money in this book will be lost.

THE TV RASTER

In the simplest terms, the TV raster is that pattern of fine horizontal lines that can be seen on the screen of a TV receiver. The set generates these lines whether it is tuned to a station or not. The raster generating process is built into the TV set itself.

As indicated in Fig. 1-1a, the raster is drawn on the screen, one horizontal line at a time, beginning near the upper left-hand corner and progressing toward the lower right-hand corner. Each horizontal line is drawn on the screen from left to right. As the beam reaches

the right-hand edge, it is first blanked off and then sent back to the left-hand edge to begin the next scanning operation.

This horizontal scanning operation continues until the beam reaches the lower right-hand edge, at which time it is blanked off and returned to the top to begin a new framing sequence.

The raster as it appears on the screen is thus a series of straight lines that result from two different kinds of operations: a relatively fast horizontal scan, combined with a relatively slow vertical scan. The horizontal scanning is responsible for moving the beam from left to right, and the vertical scanning is responsible for setting each line a bit below the previous one.

Figure 1-1b shows the sort of sawtooth waveform that is used for both horizontal and vertical scanning. As the sawtooth level rises with time, the beam responds by moving a proportional distance across the screen. Two such waveforms are required, one for the horizontal- and another for the vertical-scanning operations.

The only difference between the horizontal- and vertical-sawtooth waveforms is their frequency. The horizontal sawtooth waveform runs at a frequency on the order of 15,750 Hz, while the vertical version runs at about 60 Hz. It can be reckoned from these figures that there are 262.5 horizontal scan lines for each vertical scan. The American television scheme, however, uses an interlaced scanning technique calling for two complete vertical scans for one frame.

The framing rate is thus 30 Hz, and there are 525 horizontal lines (262.5 on the first field and another 262.5 on the interlaced field) in each complete frame.

None of the TV game schemes in this book use interlaced scanning, so the figures relevant to our purposes are the 15,750 Hz horizontal-scanning rate and the 60-Hz vertical-scanning rate.

The horizontal- and vertical-sawtooth waveforms are generated within the receiver by the horizontal and vertical oscillators. When receiving a TV signal from a broadcast station or TV game system, these oscillators must be synchronized in order to hold the picture together properly. Vertical rolling or horizontal tearing of a video signal are familiar signs of a loss of sync from the incoming video signal.

Figure 1-1c shows a typical video signal as it arrives from a conventional TV station. The horizontal-sync pulses ride in a piggyback fashion on the horizontal-blanking pulses. Since there are far more horizontal-scanning operations than vertical ones, it follows that the composite video signal is dominated by horizontal sync and blanking pulses.

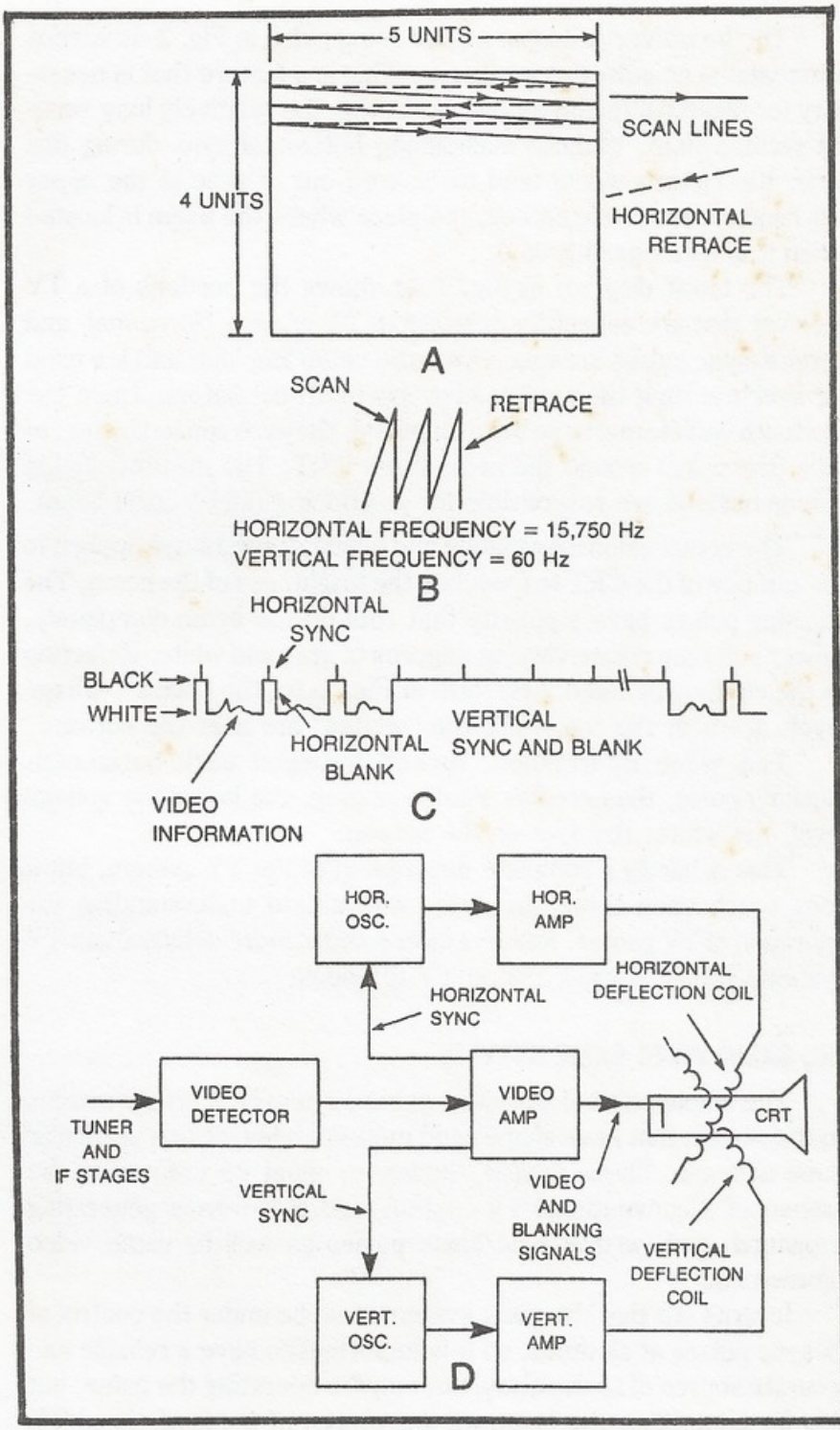

Fig. 1-1. Generating the TV raster. (a) The basic raster as it appears on the screen. (b) The sawtooth waveform characteristic of horizontal and vertical raster scanning. (c) A composite video waveform. (d) TV receiver block diagram showing sections relevant to TV games.

The broad vertical sync and blanking pulse in Fig. 1-1c carries horizontal-sync pulses along its top. This is a feature that is necessary for maintaining horizontal sync during the relatively long vertical retrace time. Without maintaining horizontal sync during this time, the picture would tend to be torn out of sync in the upper left-hand corner of the screen, the place where the beam is located when it is no longer blanked.

The block diagram in Fig. 1-1d shows the portions of a TV receiver that are especially relevant to TV games. Horizontal- and vertical-sync pulses are taken from the video amplifier and are used for synchronizing their respective sawtooth oscillators. Once the sawtooth waveforms have been amplified, they are applied to sets of coils (the yoke) around the neck of the CRT. The magnetic fields thus generated are responsible for positioning the electron beam.

The actual video information and blanking signals are applied to the cathode of the CRT to modulate the brightness of the beam. The blanking pulses have a polarity that cuts off the beam completely. Lower voltages create varying degrees of gray and white. Referring to the composite video waveform in Fig. 1-1c, the "black" voltage levels are near the top, while the "whites" are near the bottom.

The video information, tucked between each horizontal-blanking pulse, thus creates shades of gray, the lower the voltage level, the whiter the spot on the screen.

This is hardly a complete description of the TV system, but it does touch upon those principles relevant to understanding the operation of TV games. Readers interested in more details about TV systems should consult a good TV textbook.

THE BASIC VIDEO GAME SYSTEM

The whole point of the video game system is to create images on the screen that have shapes and motions relevant to a particular game scheme. These images, however, must be created in the context of a conventional TV system, and that means generating horizontal- and vertical-sync/blank pulses as well as game video information.

It turns out that the game system must be under the control of its sync pulses at all times, so it is important to have a reliable and accurate source of such pulses, not only for operating the game, but also for controlling the beam on the screen of a conventional TV receiver.

The whole game system is ultimately synchronized by a crystal oscillator. In this particular case, the oscillator runs at 14 MHz. The

14-MHz pulses from the oscillator operate a 9-bit binary counter that ultimately yields the 15,750-Hz pulses required for horizontal synchronization. During the counting interval, however, the horizontal-count circuit generates a distinctive pattern of binary numbers that actually indicate the horizontal position of the beam on the screen. See Fig. 1-2.

The 15,750-Hz output of the horizontal-counting circuit clocks yet another 9-bit binary counter, the vertical-count circuit. This circuit utlimately produces the necessary 60 Hz vertical-sync pulse, but in the meantime, it also generates a 9-bit binary code that indicates the vertical position of the beam on the screen.

In a manner of speaking, then, the TV game system always knows exactly where the beam is situated on the CRT screen. A pair of 9-bit binary numbers indicate the coordinates in a manner quite similar to the x, y coordinates of a conventional graphing scheme.

Since the game system knows where the beam is located at any given moment, it is possible to generate white or black video levels to create images on the CRT.

Notice in Fig. 1-2 that the sync pulses, blanking pulses, and game video information are combined to create the composite video signal. The only step remaining after that is to place the signal onto an rf carrier that will feed it through the tuner section of a conventional receiver. The rf modulator, incidentally, can be omitted from the system if the composite signal is applied directly to the video amplifier in the TV set. This calls for some surgery on the receiver circuitry, and many experimenters are unable or unwilling to do that sort of job.

As far as this book is concerned, the bulk of the circuits blocked out in Fig. 1-2 is the same for every game. Only the game video generator and external game controls change. Most of the circuitry is thus built into a permanent unit called the Sourcebox unit. This particular part of the system is described in great detail in Chapter 2. The remainder of the book deals with experiments, examples, and design hints for the game video generator and external game controls, units that are plugged into the standard Sourcebox.

HOW TO USE THIS BOOK

This book leads the prospective TV game designer through a series of experiments, examples, and hints that are all intended to make game design possible and fun for just about anyone willing to make the effort. Generally speaking, the material (or "lessons," if you will) are presented in order of importance. It would be difficult,

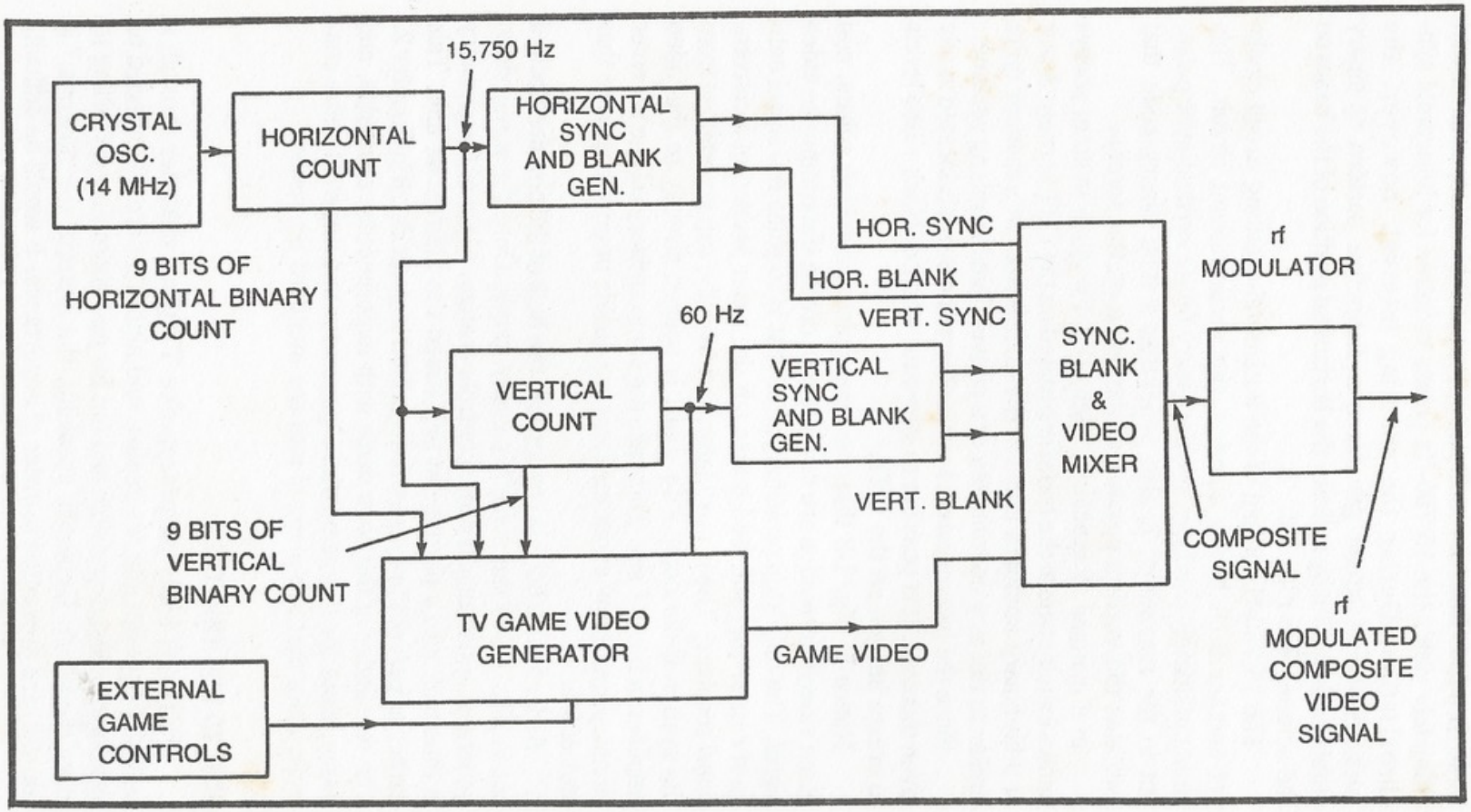

Fig. 1-2. The basic TV game system block diagram.

for instance, to begin your study of TV games in the middle of the book, because each chapter assumes an understanding and some experience with the ideas presented in all the previous chapters.

Build up the systems one step at a time, performing the suggested experiments and trying some of your own. Hands-on experience is the key to designing games of your own, and the only way to get that kind of experience is by doing the work suggested here.

LOCATING PARTS

Most of the parts specified in this book are available from stores such as Radio Shack. In many instances, Radio Shack part numbers are specified for the benefit of experimenters who are not fully acquainted with other sources and substitution procedures.

Not all parts are available from Radio Shack, but it is not difficult to locate them from the many mail-order houses advertising surplus in newsstand electronics magazines.

ASSEMBLING THE SYSTEMS

There are few specific notes in this book concerning the final assembly of game circuits. It is left to the experimenter to devise clever assemblies of his or her own, thereby removing the limitations on fun and imagination that characterize commercially available TV game systems.

Of course this approach puts something of an extra burden on the beginner, but what better way to learn than by doing?