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VIDEO STANDARDS AND FORMATS

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VIDEO STANDARDS AND FORMATS

FEBRUARY 1986

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NOTE

The definitions of television terminology formerly found in this document are contained in a separate RCC Document, 454-82, Glossary of Television Terms.

1.0 INTRODUCTION

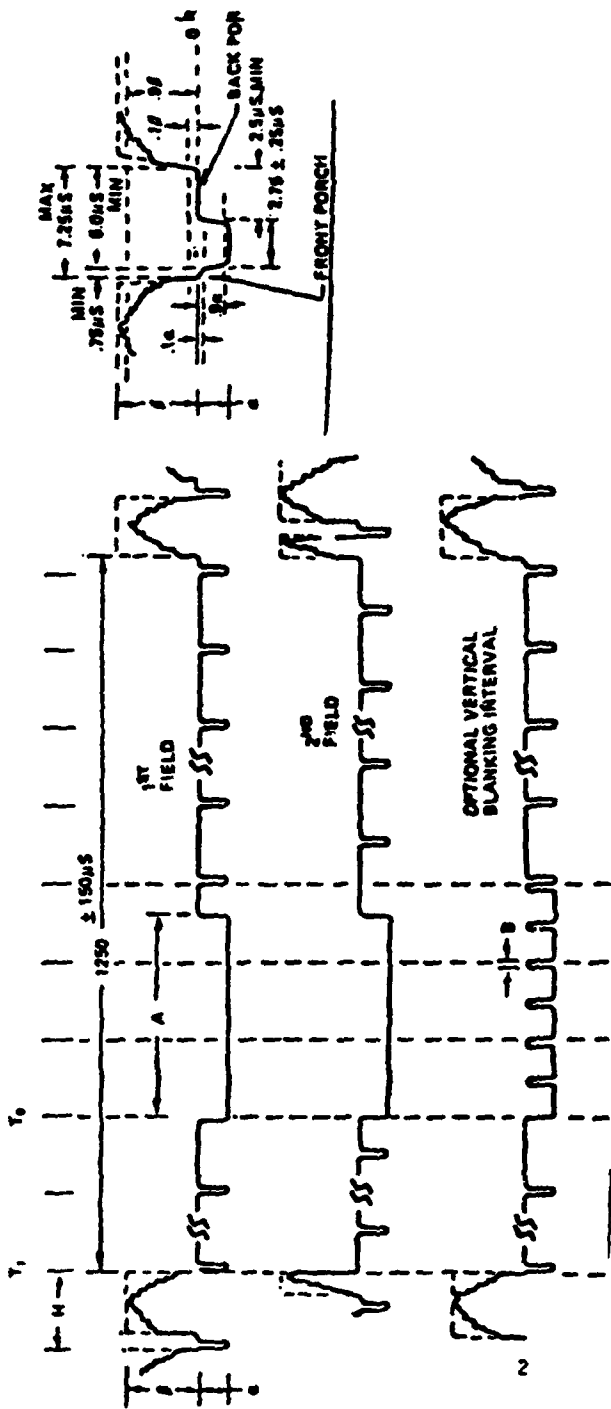
1.1 General

This standard is intended to clarify or augment existing standards where range applications are unique. Electrical performance standards for standard and high resolution monochrome and for color closed circuit television equipment are referred to in this document. These standards are those adopted by industry and associated professional groups which are applicable to test range use and are consistent with the rapidly developing state of the art. In addition, engineering considerations and practices used for automatic insertion of data into the video format and consequent retrieval for use are outlined.

The Army, Navy, and Air Force, including Department of Defense, Audio Visual Services, have regulations regarding television equipment and its use. The Electronic Industries Association (EIA), the Institute of Electrical and Electronic Engineers (IEEE), and the American National Standards Institute (ANSI) have published standards that are of high quality and usually adequate for technical guidance except for very specialized applications. Many of the standards are common between at least two of these groups. This publication contains a list of those available as of this document's publication date with a summary of most of them. Referral to the latest version is recommended.

1.2 Scope

The purpose of this document is to provide users of standard and high resolution monochrome and standard color closed circuit television equipment with the criteria essential for interchange and compatibility of equipment, tape recordings and live signals. These criteria are intended to apply not only to locally generated signals (that is, signals generated by the camera itself or at a nearby point where control can be exercised over picture quality), but also to ensure compatibility for metric video application, where video tape recorders, video disc recorders and data insertion equipment are used. This document is written primarily to encompass equipment which operates at a 525-line format, but does cover formats from 525 to 1023 lines with a 60-Hz field rate and 2:1 interlace. It is understood that special requirements may necessitate the use of formats of various numbers of lines, but it is recommended that one of the following formats be selected for use if at all possible: 525, 675, 729, 875, 945, 1023. This standard is not intended to encumber industry as to method of implementation of electronic designs and should be used to augment, not negate, other standards. See figures 1-1 and 1-2 and table 1-1 for details.



Notes:

1. $B = 0.714 \pm 0.1$ volts (100 IRE Units).
2. $\alpha = 0.286$ (40 IRE Units) nominal.
3. Sync to total signal ratio $\frac{B}{B + \alpha} = 28.6\%$.
4. Blanking = 7.5 ± 5 IRE Units (2.5% to 12.5% of B).
5. Horizontal Rise Times measured from 10% to 90% amplitudes shall be less than 0.1 μ s.
6. Overshoot on horizontal blanking signal shall not exceed 0.02 B at beginning of front porch and 0.05 B at end of back porch.
7. Overshoot on sync signal shall not exceed 0.05 B.
8. T_0 = start of vertical sync pulse.
9. T_1 = start of vertical blanking.
10. $T_1 = T_0 + 0$ -250 μ s
11. A - vertical sync pulse = 125 ± 50 μ s measured between 90% amplitude points.
Rise and fall times of vertical blanking and vertical sync pulse, measured from 10% to 90% amplitudes, shall be less than 5 μ s.
12. Tilt on vertical sync pulse shall be less than 0.1 \circ .
13. If horizontal information is provided during the vertical sync pulse it must be at 2H frequency and as shown in the optional vertical blanking interval waveform.
14. B - vertical serration = $2 \pm .5$ μ s measured between the 90% amplitude points. Rise time measured from 10% to 90% amplitudes shall be less than 0.1 μ s.
15. If equalizing pulses are used in the vertical blanking interval waveform they shall be 6 in number preceding and following the vertical sync pulse, be at 2H frequency and 1/2 the width of H sync pulse. It is recommended that for proper interlace the time duration between the leading edge of vertical sync and the leading edge of horizontal sync be a multiple of H/2.
- 16.
- 17.

Figure 1-1. Composite Video Waveform High Resolution Monochrome Television Camera.

THESE SIGNAL AMPLITUDES SHOULD BE HELD CONSTANT AT 100%
 0.0010 ± 0.0001 VOLTS
 0.0010 ± 0.0001 VOLTS
 0.0010 ± 0.0001 VOLTS
 0.0010 ± 0.0001 VOLTS

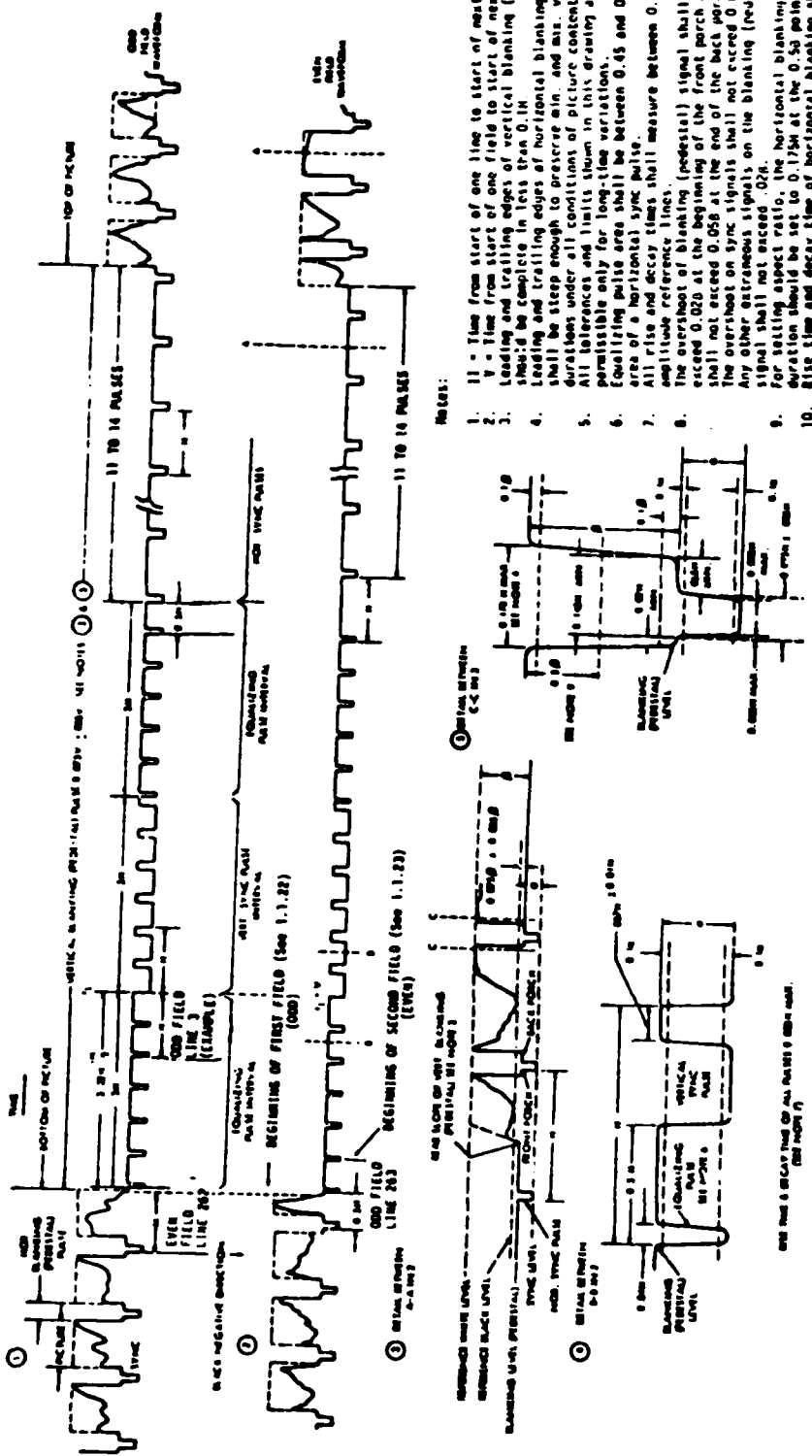


Figure 1-2. Standard Monochrome Video Signal Characteristics.

TABLE 1-1
HIGH RESOLUTION TV SYSTEM PARAMETERS

Lines/ Frame	(1) Active Lines	(2) Ver. Res R_v	(3) f_h KHz	(4) t_h μ secs	(5) t_{h_a} μ secs	Fundamental Generated Frequency (MHz) (8)							
						R_h MHz (5)		$R_h = R_v$ (9)		$R_h = 800$ lines		$R_h = 1000$ lines	
						4:3(7)	1:1	4:3	1:1	4:3	1:1	4:3	1:1
675	624	425	20.25	49.38	42.38	63.6	84.8	6.69	5.01	12.6	9.44	15.7	11.8
729	674	475	21.87	45.72	38.72	58.1	77.4	8.18	6.13	13.8	10.3	17.2	12.9
875	809	575	26.25	38.09	31.09	46.6	62.2	12.3	9.25	17.2	12.9	21.4	16.1
945	874	600	28.35	35.27	28.27	42.4	56.5	14.1	10.6	18.9	14.1	23.6	17.7
1023	946	650	30.69	32.58	25.58	38.4	51.2	16.9	12.7	20.8	15.6	26.1	19.5

Vertical Blanking = 1250 μ secs nominal.

Horizontal Blanking = 7 μ secs nominal.

Notes:

- (1) Active Lines = Lines/Frame less those occurring during vertical blanking.
- (2) Vertical Resolution = Active Lines times Kell Factor (0.7). Vertical Resolution rounded to nearest 25 lines.
- (3) f_h = Horizontal scanning frequency.
- (4) t_h = Total horizontal line time.
- (5) t_{h_a} = Total active horizontal line time ($t_h - 7$ μ secs).
- (6) R_h /MHz = Lines of horizontal resolution per MHz of bandwidth.
- (7) Aspect Ratio.
- (8) Fundamental generated frequency required to provide indicated resolution in lines per picture height.
- (9) Fundamental generated frequency required to provide horizontal resolution equal to vertical resolution.

2.0 TELEVISION REFERENCE MATERIAL AND GUIDANCE

2.1 The Television-Audio Support Activity (TASA), SEL-TVA, Sacramento Army Depot, Sacramento, California has the responsibility to design and procure administrative television and audio systems for the Department of Defense (DOD). TASA is an excellent source of information and procurement support for standard equipment and has in the past procured nonstandard equipment for Range Commanders Council (RCC) members.

2.2 DOD directives regarding television and its use are limited and contain mostly administrative guidance. They include: **DOD Directives 5100.81, 5120.20, and 5120.27**. Although television Military Standards (MIL-STDS) exist, they refer only to specific weapon systems.

2.3 Air Force and Navy publications relative to television are, in general, basic training documents and/or apply to specific systems. One exception is the Navy's **TP/5837, Transmission of Telemetry Data for Television** (NWC). Department of the Army (DA) publications other than those pertaining to specific weapon systems, are guidance oriented; for example, **AR 108-1, AR 108-6, AR 108-40, TB 108-1, TB 108-2, and TB 108-3**.

2.4 The following EIA standards have been recognized as providing the most help to RCC engineers:

a. **EIA Standard RS-170, Electrical Performance Standards - Monochrome Television Studio Facilities**, 1957. This standard outlines the signal polarity, amplitudes, and synchronization pulse format and duration which should be used for normal resolution (525 lines with 60-Hz field rate and 2:1 interlace) television. The composite picture signal provides a continuing horizontal synchronizing pulse thus facilitating the use of magnetic tape recording, magnetic disk recording, video processors, and microwave relay facilities. This standard provides or refers to standards for measuring and monitoring signal level, picture fidelity, transmission line characteristics, picture receiving power, and interference.

b. **EIA Industrial Electronics Tentative Standard N.1. and RS 170A EIA Tentative Standard, Color Television Studio Picture Line Amplifier Output Drawing**. An important part of the standard is the picture line amplifier output drawing, which defines the waveform and timing characteristics of the composite video signal at the output of a color television studio. This standard defines a four-field encoding scheme using color burst phase and horizontal-vertical relative synchronization to identify four distinct codes. Ranges may wish to deviate from this standard since it specifies a field rate of 59.94126 Hz, and a rate of 60.0 generally allows more useful synchronization to range timing systems and other range instrumentation.

c. **RS 189A, Encoded Color Bar Signal**. The EIA Standard Color Bar Signal is intended for use as a test signal for the following principal reasons: (a) adjustment of color monitors, (b) adjustment of

color encoders, and (c) rapid checks of color television transmission systems.

d. **RS-240-61, Transmitter (Broadcast) STD.**

e. **RS 250B (ANSI C16.50 - 1976), Electrical Performance Standards for Television Relay Facilities.** This standard specifies the minimum electrical performance characteristics of radio relay equipment for transmission of NTSC color television signals from a studio to its associated television broadcast transmitter or for similar applications. Pertinent parameters are defined, and standards and methods of measurement have been established for each where practical.

f. **RS-266-A-72, Television Screen STD.**

g. **RS 312A (ANSI C104.1 - 1968), Engineering Specifications Outline for Monochrome CCTV Camera Equipment.** This standard contains the recommended minimum specification formats that should be included in the published advertising items to provide the user with an adequate description of the equipment.

h. **EIA Standard RS 330 - November 1966 (ANSI C104.2 - 1968), Electrical Performance Standards for Closed Circuit Television Camera 525/60 Interlaced 2:1.** This standard should not be used for instrumentation purposes. It provides incompatibility with some classes of precision tape recorders, disk recorders and video processors and reduces available options in inserting data into the vertical interval. This standard does not require a continuously recurring horizontal synchronizing pulse. With presently available single integrated circuit television waveform generators there is very little economic incentive not to use a full broadcast standard such as RS-170.

i. **EIA Standard RS 343A, Electrical Performance Standards for High Resolution Monochrome Closed Circuit Television Camera, September 1969.** This standard is written to encompass equipment which operates in the range from 675 to 1023 scanning lines with a field rate of 60 Hz. It is understood that special requirements may dictate different line numbers. It is recommended that one of the following be considered to satisfy particular requirements: 675, 729, 875, 945, or 1023 lines.

j. **RS 375A (ANSI C16.54 - 1976), Electrical Performance Standards for Direct View Monochrome Closed Circuit Television Monitors 525/60 Interlaced 2/1.** These standards are intended to apply only to Direct View Monochrome Closed Circuit Television Monitors with video input; that is, signals generated at a nearby point where control can be exercised over picture quality. They are intended to apply with a video signal as described in RS 330. (See paragraph h. above.)

k. **RS 412A (ANSI C16.57 - 1976), Electrical Performance Standards for Direct View High Resolution Monochrome Closed Circuit Television Monitors.** These standards are intended to apply only to direct view high resolution monochrome closed circuit television monitors

with a video input; that is, signals generated at a nearby point where control can be exercised over picture quality.

1. **RS 420 (ANSI C16.58 - 1976), Electrical Performance Standards for Monochrome Closed Circuit Television Cameras 525/60 Random Interlace.** This standard is intended to apply only to locally generated signals; that is, signals generated in the camera itself or at a nearby point where control can be exercised over picture quality.

m. **RS 439, Engineering Specifications Format for Color CCTV Camera Equipment.**

2.5 IEEE Publications of Interest:

a. **201-1979 (SH07302), Terms Relating to Television, Standard Definitions of.**

b. **202-1954 (SH02548) (ANSI also), Television: Methods of Measurement of Aspect Ratio and Geometric Distortion.**

c. **205-1958 (SH01248) (ANSI also), Television: Measurement of Luminance Signal Levels.**

d. **206-1960 (SH01255), Television Measurement of Differential Gain and Differential Phase.**

e. **208-1960 (SH01263), Video Techniques: Measurement of Resolution of Camera Systems.**

f. **503-1978 (SH07062), Diode-Type Camera Tubes, Standard for Measurement and Characterization of.**

g. **511-1979 (SH07575), Video Signal Transmission Measurement of Linear Waveform Distortion, Standard on.**

2.6 Other Publications:

- a. **National Television Systems Committee's (NTSC), Television Standards and Practices, (McGraw-Hill)** is the NTSC standard adapted for commercial color broadcast in the United States. The term "NTSC compatibility" implies the use of standard American color television. The NTSC standard establishes the color subcarrier system to transmit color information and provides color video line, field and frame rates which are different from RS-170 monochrome.
- b. **Bell Laboratories, Transmission Standards for Communications.**
- c. **Industrial Publications, Television Operational Measurements-Video and RF for NTSC Systems, Tektronix Inc., March 1976.**

3.0 CAMERA OUTPUT - MONOCHROME VIDEO

3.1 Definition - Camera output terminals are defined as the junction between the camera or switching facilities and the line feeding either a transmission system or a visual display. The camera output signal is that signal which appears across the camera output terminals.

3.1.1 In this document any reference to camera output refers to the output of the camera channel whether it is a single unit or a multi-unit system.

3.1.2 The standard signal, which will be discussed below, is the signal which appears across the output terminals of the camera when they are connected to the standard load impedance.

3.1.3 The signal which appears across the line feeding either a transmission system or a visual display may be different from the standard signal. This is because the circuit may be equalized on an overall transmission basis and not with a view to keeping the input impedance of the line a specified value.

3.1.4 Under these conditions, monitoring measurements made at the output terminals of the camera must be properly interpreted.

3.2 Impedance

3.2.1 Definition - Couples ratio of voltage to current in a two-terminal network; expressed in ohms.

3.2.2 Minimum Standard - Standard load impedance of the camera output shall have a value of 75 ohms ± 5 percent over the frequency range of 0 to 10 MHz, and shall be connected for single-ended operation.

3.3 Direct Current in Output

Minimum Standard - Open-circuit dc voltage of the camera output shall not exceed 2 volts. The short-circuit dc current shall not exceed 2 milliamperes. These dc values are presumed to be independent of the output signal.

3.4 Polarity

Standard - The polarity of the output of the camera shall be black-negative.

3.5 Composite Picture Signal

Standard - The blanked picture signal with setup (noncomposite), as measured from blanking level to reference white level across the standard load impedance of the camera, shall be 0.714 ± 0.1 volt (100 Institute of Radio Engineers (IRE) units).

3.5.1 The synchronizing signal as measured across the standard load impedance of the camera shall be 0.286 ± 0.05 volts (nominally 40 + IRE units).

3.5.2 The setup shall be 7.5 ± 5 IRE units (2.5 percent to 12.5 percent of the blanked picture signal).

TECHNICAL NOTE

Measurement of signal levels shall be made in accordance with 58 IRE 23.S1, IRE Standards of Television: Measurement of Luminance Signal Levels, 1958 or latest revision. This standard defines the levels of a television signal in terms of IRE units. Reference white level is +100 IRE units; Blanking level is 0 IRE units; sync level is -40 IRE units. Thus, the peak-to-peak level of a signal extending from reference white to sync tip is 140 IRE units.

4.0 PICTURE FIDELITY

4.1 Geometric Distortion

4.1.1 Minimum Standard - It shall be standard that no picture element be displaced from its true position referred to the subject by more than 2 percent of the picture height. It is desirable that the distortion be held as much below this minimum standard as conditions permit. The instantaneous apparent scanning velocity, since it is a measure of the magnification of the system, shall vary from the mean velocity in a gradual fashion. Further study may more accurately define allowable variations in the instantaneous velocity.

4.1.2 The EIA Linearity Chart contains a rectangular array of circles whose radii are 1 percent and 2 percent of picture height. The electrical pattern generator provides an array of horizontal and vertical bars or dots to match the chart. The picture channel linearity controls are adjusted until the two superimposed patterns fall within the 2 percent tolerance circles of the chart as viewed on the picture monitor. Reasonable monitor geometric distortion will have negligible effect on the accuracy of measurement.

4.2 Resolving Power

4.2.1 Minimum Standard - It shall be standard that the resolving power of the overall studio facilities be at least 350 lines in the vertical direction and 400 lines in the horizontal direction; both measurements to be made near the center of the picture.

NOTE

The resolving power of a television system or a portion thereof is a measure of its ability to delineate picture detail. It is expressed in terms of a number of lines resolved on a test chart. For a number of lines N (normally alternate black and white lines) the width of each line is $1/N$ times the picture height.

4.2.2 Resolution Response - In television, the ratio of (1) the peak-to-peak signal amplitude, given by a test pattern consisting of alternate black and white bars of equal width corresponding to a specified line number, to (2) the peak-to-peak signal amplitude, given by large area blacks and large area whites having the same luminance as the black and white bars in the test pattern.

4.2.3 Line Number, Television - In measuring resolution, the ratio of the frame height to the width of each bar of a test pattern composed of alternate equal-width black and white bars as projected on the frame.

4.3 Performance

The picture signal is applied to a picture monitor properly adjusted per the IEEE Standard above for the measurement of limiting resolution. (For typical system performance refer to table 1-1, page 1-5.) The limiting horizontal and vertical resolution is determined by observing the point at which the individual lines of the graduated wedges are no longer distinguishable as separately defined images. For the measurement of horizontal resolution response, the picture signal should be applied to a line selector oscilloscope having a video bandwidth equal to or greater than the specified bandwidth of the television camera and a picture monitor. The picture monitor is used to observe which line number wedge is being displayed on the oscilloscope. The oscilloscope is adjusted to view the peak-to-peak amplitude of the camera video signal corresponding to the desired line number wedge. The ratio of this amplitude to the peak-to-peak reference video signal corresponding to the horizontal black bars and the white background is the horizontal resolution response.

4.4 Aspect Ratio

Minimum Standard - The standard aspect ratio of a frame in television shall be 4 to 3 on condition that the horizontal blanking interval be 17.5 percent of the line period and the vertical blanking interval be 7.5 percent of the frame period. No specific tolerances are assigned to this ratio, but it is understood that the tolerance allowed for geometric distortion will provide adequate limits for permissible variation in the aspect ratio.

4.5 Gray Scale

4.5.1 Definition - The ability of a camera to reproduce luminance variations in a scene. Usually expressed as the number of steps of gray discernible at the output of the camera.

4.5.2 The 10-step gray scales cover a contrast range of approximately 30 to 1. The reflectance of step #1 is determined by the reflection density of the chart material comprising the center circle. The nine-step gray scales cover a nominal contrast range of 20 to 1; step #2 having a reflectance of 60 percent and step #10 a reflectance of 3 percent. The steps are arranged in logarithmic decreasing values of reflectance such that the difference in reflection density between adjacent steps is equal to 0.16. Table 4-1 gives the reflectance and reflection density of the steps on the gray scales. The background reflectance of the outer useful area of the chart is 40 percent \pm 5 percent.

4.5.3 Shading

Shading may be checked by visual inspection of the picture monitor to determine if the background is an even gray, and if the same number of gray steps are discernible on all four gray scales. A waveform

monitor may also be used to determine if the average picture signal axis is parallel to the black level line at both line and field frequencies.

TABLE 4-1

SPECIFICATIONS FOR GRAY SCALES		
Gray Scale Number (Center (Percent) Circle)	Nominal Reflectance Relative to MgO	Nominal Reflection Density
1	>60.0	<0.22
2	60.0	0.22
3	41.7	0.38
4	28.2	0.55
5	19.5	0.71
6	13.5	0.87
7	9.3	1.03
8	6.3	1.20
9	4.4	1.36
10	3.01	1.52

4.5.4 Streaking

Streaking of horizontal black bars at the top or bottom of the large circle is an indication of low frequency phase shift or of poor dc restoration. The black bars are also very useful for adjusting the high peaking circuits which are used in camera chains to compensate for the high frequency roll off of the coupling network between the camera tube and first video amplifier.

4.5.5 Interlace

The four diagonal black lines inside the square formed by the gray scales may be used to check interlace. A jagged line indicates pairing of the interlaced lines.

4.5.6 Gray Scale Reproduction

The transfer characteristic of the camera, for given operating conditions, may be determined by using an oscilloscope with a line selector. The gray scale reproduction achieved will depend on the amount of gamma correction employed, the manner in which the camera tube is operated, and the adjustment of the picture monitor. The user will have to standardize these operating conditions if comparative subjective measurements are to be made.

4.5.7 Ringing

The two sections of single line widths located in the upper right-hand portion and lower left-hand portion of the square formed by the gray scale may be used to check ringing. These lines are included because the multiple lines in the wedges are confusing for checks of this type. The lines in the upper right-hand section have widths from 350-550 (350, 400, 450, 500, 550) and the lines in the lower left-hand section have widths from 100-300 (100, 150, 200, 250, 300).

4.5.8 Signal-To-Noise

Definition - The ratio of the value of the signal to that of the noise.

Note 1

This ratio is usually in terms of peak values in the case of impulse noise and in terms of the root-mean-square (RMS) values in the case of random noise.

Note 2

Where there is a possibility of ambiguity, suitable definitions of the signal and noise should be associated with the terms as, for example: peak-signal to peak-noise ratio, RMS signal to RMS noise ratio, peak-to-peak signal to peak-to-peak noise ratio, etc.

Note 3

This ratio is often expressed in decibels.

Note 4

This ratio may be a function of the bandwidth of the transmission system.

4.5.9 Sensitivity

Definition - A factor expressing the incident illumination upon a specified scene, required to produce a specified picture signal at the output terminals of a television camera.

5.0 SYNC SIGNAL TOLERANCE

5.1 Minimum Standard - It shall be standard that the time of occurrence of the leading edge of any horizontal pulse N of any group of 20 horizontal pulses not differ from NH by more than $0.001 H$, where H is the average interval between the leading edges of horizontal pulses as determined by an averaging process carried out over a period of not less than 20 or more than 100 lines.

5.2 It shall be standard that the rate of change of the frequency of recurrence of the leading edges of the horizontal sync pulses appearing in the picture line amplifier output be not greater than 0.15 percent per second, the frequency to be determined by an averaging process carried out over a period of not less than 20 or more than 100 lines; such lines not to include any portion of the vertical blanking signal.

5.3 It shall be standard that the frequency of horizontal and vertical scanning pulses not vary from the values established by the standards of frame frequency. The number of scanning lines shall not vary by more than ± 1 percent regardless of variations in frequency of the power source supplying the television station.

5.4 It shall be standard that the rate of change of frequency and the time interval between successive pulses that has been made standard for the horizontal synchronizing pulses appearing across the output of the picture line amplifier also be standard for the horizontal scanning of the pickup tube.

6.0 DATA IN VIDEO (DIV) ENCODING AND DECODING

6.1 Introduction

There is a growing use of video in instrumentation systems and control systems today. In some of these systems video is used as the primary sensor and not merely as an ancillary device. In other systems video is used in combination with transducers and other devices to form a sensing system. Usually it is desirable to time tag or otherwise correlate this data and the video images. The output of a typical sensing system then consists of a combination of video and data which is either digital or easily converted to digital. It is desirable in many if not most of these systems to merge some combination of digitized data, timing and identifiers into the video transmission format. Reasons for this are: (1) to reduce the number of transmission channels, (2) to accommodate a simple way of recording the video images and corresponding digital data on a low cost video recorder for archival purposes of transportation to a data reduction center, and (3) to facilitate a simple direct way of verifying the performance of many types of real-time image analyzers or image data extractors.

6.2 Alphanumeric Video Encoders

Alphanumeric video encoders have existed for a number of years and are in extensive use in the range community. However, they are not satisfactory for most video instrumentation systems because they require extensive manual translation of the data from the video to the data reduction equipment, and also they use up too much space on the video raster or picture area.

6.3 Data In Video (DIV) Encoders

6.3.1 The DIV systems of concern here are systems which can transfer data from the video signal to the data reduction system without human intervention. Such DIV encoder systems have been in use on various range instrumentation systems since about 1975. Although several approaches have been tried, those systems in use and on the market today employ some form of Time Division Multiplexing (TDM). This approach is natural because of unused time periods in the composite video format. Further, these systems also employ Pulse Code Modulation (PCM) for a number of reasons. Perhaps the strongest reason is that most of the data is of digital origin and most of the data ends up going into digital systems so PCM is natural throughout. Hardware simplicity also favors this approach. The time division multiplexer has traditionally been called an encoder and the time division demultiplexer has traditionally been called a decoder.

6.3.2 To be completely suitable, a DIV system used for general test range applications must be compatible with a number of types of video equipment and processes. Such things as processing amplifiers, time base correctors, and the various types of tape and disk recorders present a number of constraints to standardization. The dominant bandwidth limiter, noise source, and signal distortion source in video

instrumentation systems will be caused by the recording system. In regular playback mode, the recorder, considered as a transmission channel, differs significantly from a typical transmission channel. Video recorders introduce random noise and bandwidth limitations similar to a transmission channel, but in addition there is correlated noise, burst noise, and wow and flutter which are usually not significant or even detectable in a normal transmission channel.

6.4 Image Analysis

Most video instrumentation systems require image analysis using a Video Tape Recorder (VTR) in the pause/still mode. In the pause/still mode, the output of VTRs without time base correction is degraded more severely. Nearly all 3/4 inch U matic and 1/2 inch VHS format Video Cassette Recorders (VCRs) in pause/still mode alter the RS-170 video format. Due to the elimination of the forward motion of the tape in pause/still mode, the head-to-tape velocity is altered and the effective recorded scan line length is shortened. This format change normally eliminates one to two horizontal lines per field. Additionally, the vertical interval is usually corrupted due to synthetic sync reinsertion and guard band noise. Frequently this totally eliminates vertical interval serrations and may even blank an indeterminate number of "H" scan lines following the vertical sync period. Many of the vertical sync corruption problems eliminate any possibilities of identifying field count.

6.5 Dropout Compensation Circuits

Dropout compensation circuits located in most tape recorders can adversely affect DIV encoding. Ongoing research efforts by video tape and equipment manufacturers are seeking to totally eliminate the appearance of video dropouts due to head clogging, poor tape, environmental effects and contaminants. As technology develops more sophisticated techniques, it will become increasingly difficult to achieve high data reliability. Dropout compensation circuits may have to be bypassed on some recorders. These facts were taken into consideration when formulating DIV encoding standards.

6.6 DIV Encoding Standards

6.6.1 Introduction

The RCC OSG has elected to have two DIV encoding standards. Both encoding standards were designed to allow data decoding while a recorder is in pause/still mode and detailed analysis is being performed on the image. Of course, both standards are also completely compatible with line video or regular playback from a video recorder.

6.6.2 Left-Edge Encoding Standard

The first standard to be discussed is known as "left-edge" encoding or simply as "edge" encoding. The left-edge system is an outgrowth of the Horizontal Interval (HI) encoding system. It is called left edge because it occupies the left-most portion of the

picture area and can be seen on the left edge of a monitor. The left-edge standard is the product of work done at White Sands Missile Range (WSMR) and is sometimes referred to as the WSMR standard. Section 7 of this document defines the left-edge standard in detail.

6.6.2.1 The following improvements were made to the HI encoding system to create the left-edge system: (1) the pulse code position was moved from the back porch position of the horizontal interval to the left-edge of the picture area because use of the back porch is incompatible with several types of video equipment, (2) a 4-bit Hamming code was added to each byte of information to allow recovery from 1-bit errors during VTR playback, and (3) a start of message identifier was added. This identifier facilitates exchange of video data between ranges by providing a reference pattern on each field of video for optimizing decoding parameters. The left-edge system was selected for standardization for the following reasons:

a. It is a tried and proven technique with a large inventory of equipment in test range use. Further, it is an integral part of many systems either in use or under construction. To change from this system in most of these systems would not have been justifiable for any reason.

b. It has good noise immunity to VTR burst noise caused by dirt specks and dropouts on the video tape.

c. The encoding and decoding hardware is simple and inexpensive.

6.6.2.2 There are two aspects of left-edge encoding that limit its universal application.

a. The maximum number of information bits per video field is limited to 152. The use of Hamming error correction code and the start of message identifiers, which are necessary to achieve high data reliability with VTRs, reduces the capacity from the typical 216 bits per field of HI systems.

b. Although all known VTRs may be used to record left-edge encoding and all known recorders will support proper decoding in their regular playback mode, decoding from a recorder in the pause/still mode is more restrictive. Full message decoding cannot be done when there are noise bands or tearing (recorder dropout on consecutive video lines) in the active picture area. Good quality pause/still mode operation of the recorder used for analysis is necessary. Advancements in video tape recorder technology are eliminating noise and tearing in the pause/still mode and there is a growing number of lower cost recorders becoming available that will support pause/still mode decoding.

6.6.3 Scan Line Encoding

The second technique selected for standardization is called "Scan Line" (SL) encoding. Scan Line encoding is an outgrowth of "Vertical

Interval" (VI) encoding. At the time the standard was formulated, the best features of teletext encoding and other existing VI systems were combined into a consistent system. Scan Line encoding was selected for standardization because it has a high capacity of bits per video field (more than 1,000 bits per field are possible; see subparagraph 8.2, section 8), and it can be made compatible with the output of all known video recorders in their stop action or pause modes.

6.6.3.1 One major difference between SL encoding and VI encoding is that SL encoding can be located on essentially any video line (see figure 8-1, section 8) while the VI code, strictly speaking, can only be located in the vertical interval. Two things have to be considered when choosing which video lines to encode: (1) the content of the encoded lines must not be corrupted or lost by any part of the system before it is decoded, and (2) the encoded lines must not displace any essential part of the image.

6.6.3.2 The Scan Line encoding system uses the same Hamming code system as the left-edge encoding system. This provides for 1 bit of error correction per 8-bit data byte. The Scan Line encoding system is a nonreturn-to-zero binary format and the Hamming code is inserted in inverse polarity to ensure that there are always ample clock edges in the code for all possible data sets. The assurance of clock edges for all possible data sets makes the code self clocking and allows the decoding to be largely independent of horizontal sync. This in turn allows for decoding in the presence of burst noise and tearing in the near vicinity, but not over the code itself. In general, if the lines of the code haven't been corrupted by burst noise they can be decoded properly. Chapter 8 defines Scan Line encoding in detail.

6.6.3.3 Further ability to protect SL encoding from burst noise has been built into the system. Each line of code has a Longitudinal Redundancy Check Character (LRCC) at the end. This may be used to check data validity and/or to facilitate redundant encoding.

6.6.3.4 Redundant encoding will allow Scan Line encoding an increased degree of immunity from burst noise and recorder dropout compensators. (Dropout compensators affect scan line encoding more than left-edge encoding.) The LRCC provides a means of determining which of the redundant code lines to accept, that is, which code lines have a very high probability of no error. In most applications, redundancy encoding is not necessary, but Scan Line encoding is structured to facilitate its use if necessary.

6.6.3.5 Since the LRCC also provides an easy means of monitoring errors in decoding, an LRCC checker should be included in every decoder to provide quick-look assessment of performance. When the data sets are transferred into a computer system for analysis, the LRCC should be included so that it may be used along with other checks to assure that the data set transferred into the computer is error free. If redundant encoding is used, it is probably more appropriate to have the determination of valid code line data sets made in the computer rather than in the decoder.

7.0 LEFT-EDGE DATA ENCODING STANDARD FOR VIDEO SYSTEMS

7.1 Purpose

The purpose of establishing this standard is to ensure electronic compatibility among users for efficient binary encoding of data on video systems. The electrical format is necessarily separated from the data format because of the wide variety of data formats required by different users. The WSMR data format is included as a recommended data format, but is not an essential part of the encoding format. Use of the Hamming code, however, is an essential part of the standard.

7.2 Electrical Encoding Standard

7.2.1 Start-of-message line number. This is variable and is selected by the user; however, once the start-of-message line number is chosen, this value must remain fixed within ± 2 horizontal lines. The user should specify this number for each tape to facilitate decoding.

7.2.2 Horizontal interval data-bit position. There is 1 bit (sync or data) per horizontal line beginning with the start-of-message line. The bit cell center is positioned to occur 9.3 ± 0.1 microseconds after the falling edge of the horizontal sync (figure 7-1).

7.2.3 Bit cell duration. The duration of each bit is 3 ± 1 microseconds (figure 7-1).

7.2.4 Bit voltage values. Zeros are 0.25 ± 0.05 volt and ones are 0.65 ± 0.05 volt (figure 7-1).

7.3 WSMR Data Format

7.3.1 Start-of-message pattern. The message must begin with the start-of-message pattern. This pattern is $000B39_{16}$, which is $0000\ 0000\ 0000\ 1011\ 0011\ 1001_2$. The purpose of this pattern is to identify data to the decoder. This will initialize the decoding system for acceptance of valid data.

7.3.2 Error detection and correction. A Hamming code is used for error detection and correction. Four Hamming bits are combined with every 8 data bits for a total of 12 encoded bits per word. One-bit errors can be automatically detected and corrected (figures 7-2A and 7-2B). The use of the Hamming code in the standard is the only significant difference (with the exception of the data format) between the WSMR system and previous approaches to horizontal interval data encoding. This, however, is a significant change and precludes the use of earlier incompatible systems without modifications.

7.3.3 Sample rate. Sync, time, azimuth, and elevation are sampled at 60 samples per second.

7.3.4. Data capacity. There are 152 possible data bits (19 words x 8 bits of data per word), excluding sync bits, in each field. These

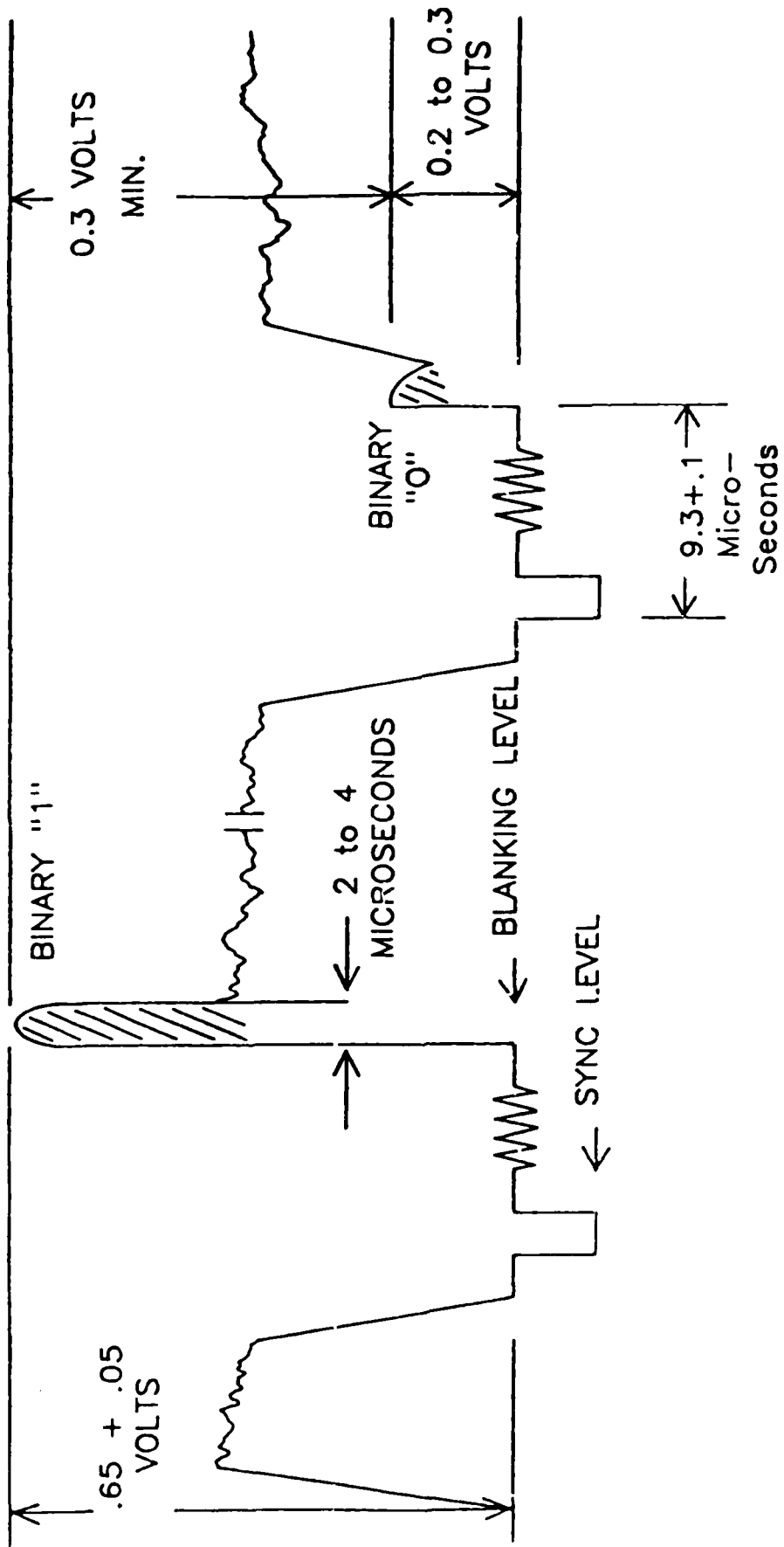


Figure 7-1. Video Signal Plus Binary Data.

FORMAT FOR EACH 12-BIT GROUP IN THE DATA BLOCK

D₇ D₆ D₅ D₄ D₃ D₂ D₁ D₀ H₃ H₂ H₁ H₀

WHERE: D₇ is encoded first in time, then D₆, D₅, etc.
D = Data Bit
H = Normal Polarity Hamming Bit (See Polarity, figure 7-1.)
H₀ = D₀ ⊕ D₁ ⊕ D₃ ⊕ D₄ ⊕ D₆
H₁ = D₀ ⊕ D₂ ⊕ D₃ ⊕ D₅ ⊕ D₆
H₂ = D₁ ⊕ D₂ ⊕ D₃ ⊕ D₇
H₃ = D₄ ⊕ D₅ ⊕ D₆ ⊕ D₇

EXAMPLES: Data Word 00000000 Hamming Code 0000
12-Bit Data Group Encoded as : 000000000000
Data Word 11101000 Hamming Code 1010
12-Bit Data Group Encoded as : 111010001010

* Note: ⊕ Represents the EXCLUSIVE OR Operation.

Figure 7-2A. Data Group Format and Hamming Code.

LET:

$$A = d_0 \oplus d_1 \oplus d_3 \oplus d_4 \oplus d_6 \oplus H_0$$

$$B = d_0 \oplus d_2 \oplus d_3 \oplus d_5 \oplus d_6 \oplus H_1$$

$$C = d_1 \oplus d_2 \oplus d_3 \oplus d_7 \oplus H_2$$

$$D = d_4 \oplus d_5 \oplus d_6 \oplus d_7 \oplus H_3$$

AND

$$D_n = \text{Data Bit } n \text{ Interpreted (Corrected if Necessary)}$$

$$d_n = \text{Data Bit } n \text{ Transmitted (Raw)}$$

$$D_0 = d_0 \oplus (A \bar{B} \bar{C} \bar{D}) \qquad D_4 = d_4 \oplus (A \bar{B} \bar{C} D + A B C D)$$

$$D_1 = d_1 \oplus (A \bar{B} C) \qquad D_5 = d_5 \oplus (\bar{A} B \bar{C} D)$$

$$D_2 = d_2 \oplus (\bar{A} B C + B C D) \qquad D_6 = d_6 \oplus (A B \bar{C} D)$$

$$D_3 = d_3 \oplus (A B C \bar{D}) \qquad D_7 = d_7 \oplus (\bar{A} \bar{B} C D)$$

Figure 7-2B. Hamming Decode.

data bits are located in words 3 through 21 (figure 7-3). Note that words 19 through 21 are spares reserved for future expansion.

7.3.5 Time and pointing data resolution. The resolution of timing data is 0.1 milliseconds. The resolution of the azimuth and elevation data is 0.0001 grad.

7.3.6 Field ID. Word 17 identifies the field so that station status bits can be properly identified by a video data reader.

7.3.7 Station status. Word 18 contains station status. Sixteen fields are required to provide station status (figure 7-4).

7.3.8. Hamming code format. Data and Hamming codes are formatted with the most significant digit first. It is recommended that decoding equipment be programmable to adapt to different data formats.

WORDS	1-2	3-9	10-16	17	18	19-21
FUNCTION	SYNC 000B39	TIME	AZ & EL	FIELD ID	STATUS	SPARES

DATA CAPACITY

USABLE LINES PER FIELD	252 LINES
DATA BITS PER WORD	8 BITS
HAMMING BITS PER WORD	4 BITS
WORD = DATA + HAMMING	12 BITS
WORDS PER FIELD	21 WORDS
MAX NO. OF IDENTIFIABLE FIELDS	256 FIELDS

Figure 7-3. WSMR Serial Data Format.

WORDS					
1-2	3-9	10-16	(BINARY) 17	(ASCII) 18	19-21
SYNC	TIME	AZ&EL	FIELD 0 FIELD 1 FIELD 2 FIELD 3 FIELD 4 FIELD 5 FIELD 6 FIELD 7 FIELD 8 FIELD 9 FIELD 10 FIELD 11 FIELD 12 FIELD 13 FIELD 14 FIELD 15	STATION STATION STATION STATION FOCAL LENGTH FOCAL LENGTH FOCAL LENGTH FOCAL LENGTH FOCAL LENGTH FOCAL LENGTH CAMERA # CAMERA # CAMERA # MISSION # MISSION # MISSION #	MSD 1 DIGIT 2 DIGIT 3 DIGIT 3 MSD 1 DIGIT 2 DIGIT 3 DIGIT 4 DIGIT 5 DIGIT 6 MSD 1 DIGIT 2 DIGIT 3 MSD 1 DIGIT 2 DIGIT 3
					SPARES

V I D E O F I E L D S

Figure 7-4. WSMR Capacity Usage.

8.0 SCAN LINE DATA-INTO-VIDEO ENCODING STANDARD

8.1 The line number of the first line of encoded data is variable but must be specified (written on the tape) within ± 1 video line for interrange or intergroup use. Data may be encoded in the vertical blanking interval outside of the vertical sync interval or on any line of video in the picture area. (See figure 8-1.)

PROCUREMENT NOTE

It is perfectly acceptable to procure encoders hardwired or prom-programmed to start encoding on a particular video line number and encode a fixed number of lines. Encoders in many cases may be built as part of the total data system. If an encoder has the possibility of being used on a variety of systems and projects over its lifetime, then it is probably wiser to buy it with flexibility in encoded line positioning.

It is less advisable to buy decoders hardwired to look for start of message on a particular line number plus or minus a few lines. Decoders will have a much greater probability of being used on a variety of systems and projects over their lifetime; therefore, decoders should probably have a means of entering the start-of-message line number via thumbwheels or a keyboard.

8.2 The number of lines of data is variable but must be specified (written on the tape) exactly to the number of lines of data for interrange or intergroup data exchange. It is suggested that users procure units with the following increments in maximum capacity:

Four Line: Up to 4 lines of data/field (that is, 288 data bits/field)

Eight Line: Up to 8 lines of data/field (that is, 576 data bits/field)

Sixteen Line: Up to 16 lines of data/field (that is, 1152 data bits/field)

8.3 Data lines must be contiguous.

8.4 Each video encoded line has the same format. The format of the encoded lines is shown in figure 8-2. There are 144 bits per encoded line. These are divided into 12 groups of 12 bits each. The first two groups are a start-of-message prefix. The next nine groups consist of data and Hamming bits, and the last group consists of a Longitudinal Redundancy Check Character (LRCC) and Hamming bits.

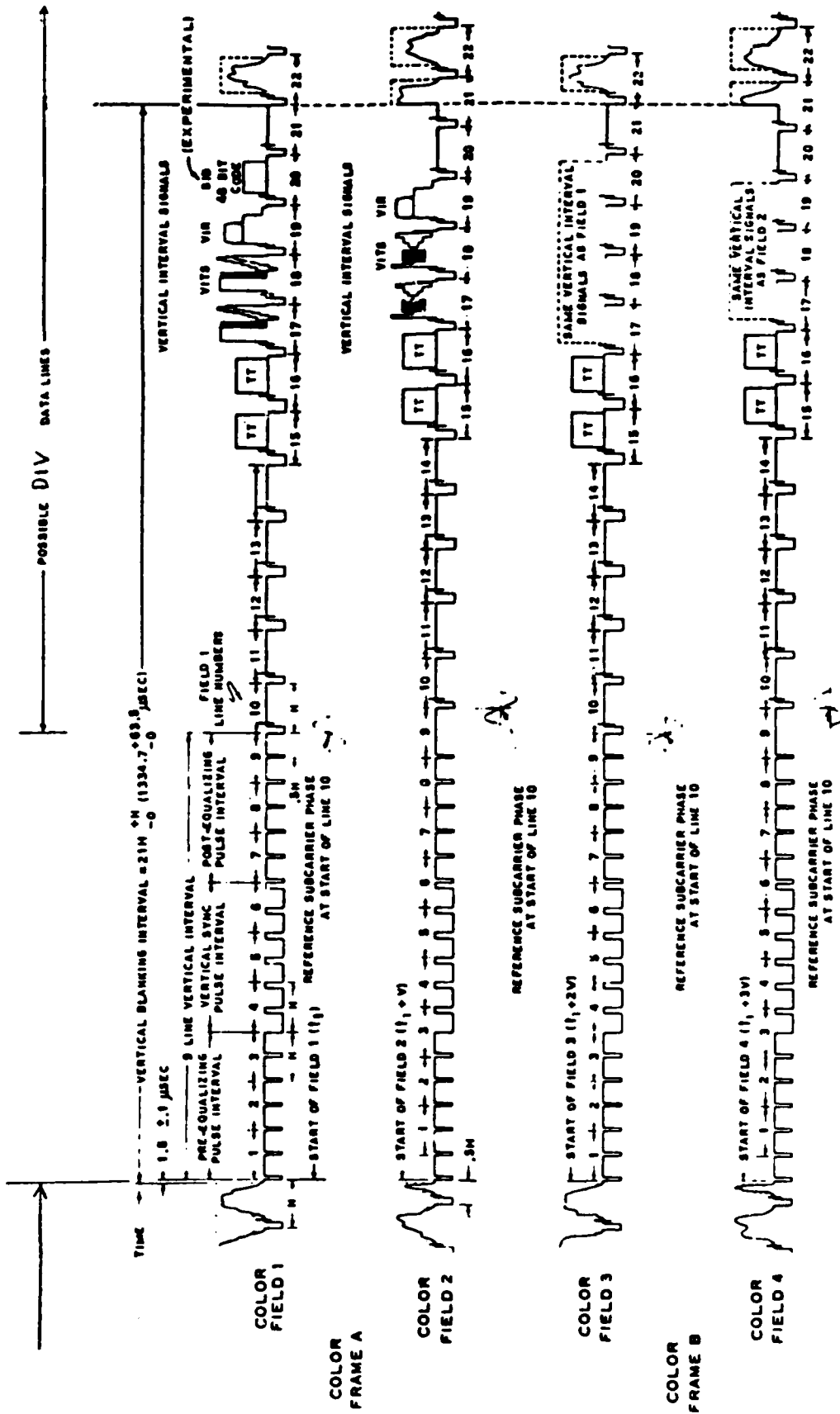


Figure 8-1. Composite Video Signal.

12 Blocks of 12 bits each

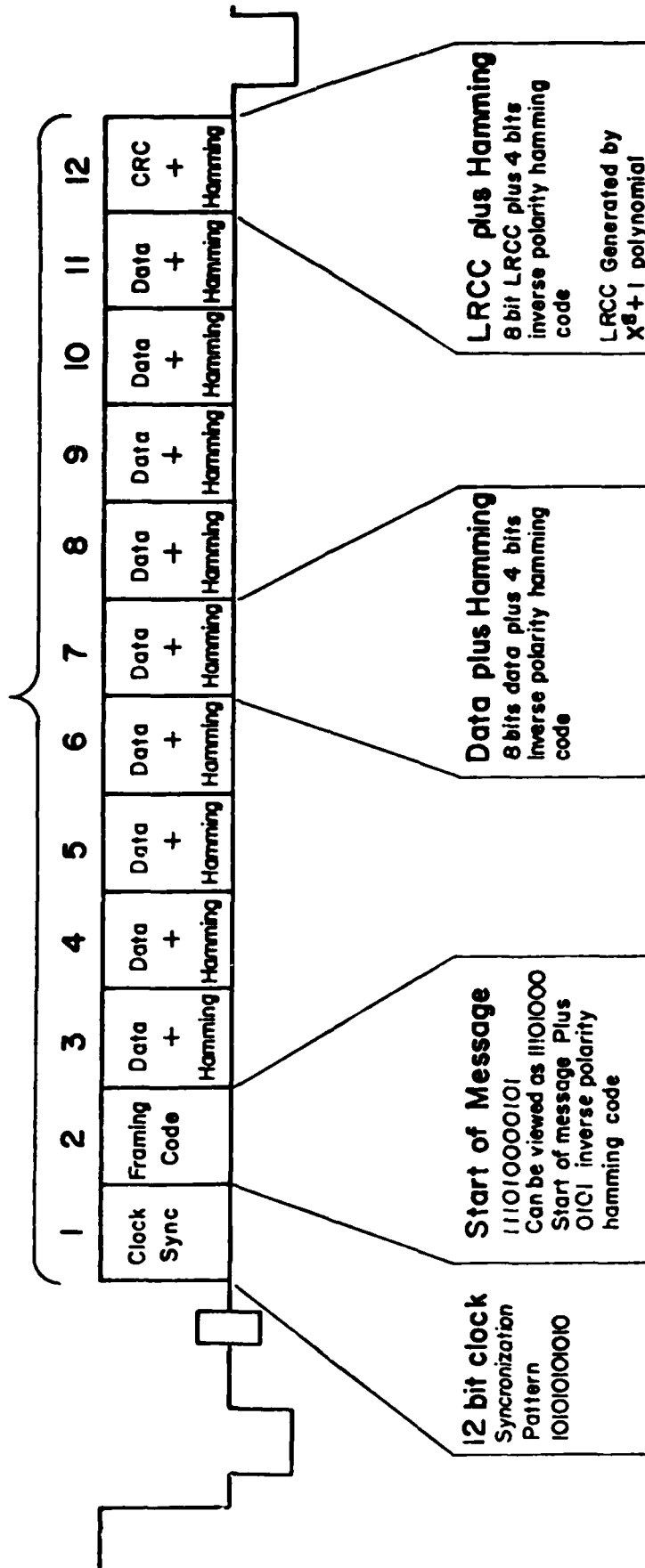


Figure 8-2. Encoded Line Format.

8.5 A data word logic high is encoded as a high in the DIV format (see figure 8-3). A data word logic low is encoded as a low in the DIV format.

8.6 The start-of-message prefix consists of a 12-bit clock sync pattern and a 12-bit word sync pattern for a total of 24 bits. The clock sync pattern is 101010101010. The word sync pattern is 111010000101. The word sync pattern may be viewed as a 11101000 pattern plus inverse polarity Hamming bits 0101. (See figure 8-2.)

8.7 Timing relationships of the DIV code relative to the video synchronization pattern are shown in figure 8-4. Timing relationships are shown in microseconds and in data clock cycles. Note that all timing relationships are an integral number of data clock cycles.

8.8 The data clock rate is either 2.8665 MHz or 182 times the video horizontal line rate. For monochrome encoding, 182 times the video horizontal line rate is exactly 2.8665 MHz. For color encoding, 182 times the video horizontal line rate is 2.8636 MHz. Either 2.8665 MHz or 182 times the video horizontal line rate is acceptable for encoding onto color video signals. The data clock shall have no more than ± 0.05 microseconds jitter per horizontal line period, and its long term rate shall be either 182 times the encoded video line rate or 2.8665 MHz ± 0.01 percent.

8.9 Amplitudes are expressed in terms of Institute of Radio Engineers (IRE) units. The amplitudes of the DIV waveform are shown in figure 8-3. One IRE unit equals 7.14 millivolts. Figure 8-3 also shows the maximum and minimum slopes of the leading and trailing edges of the DIV waveform.

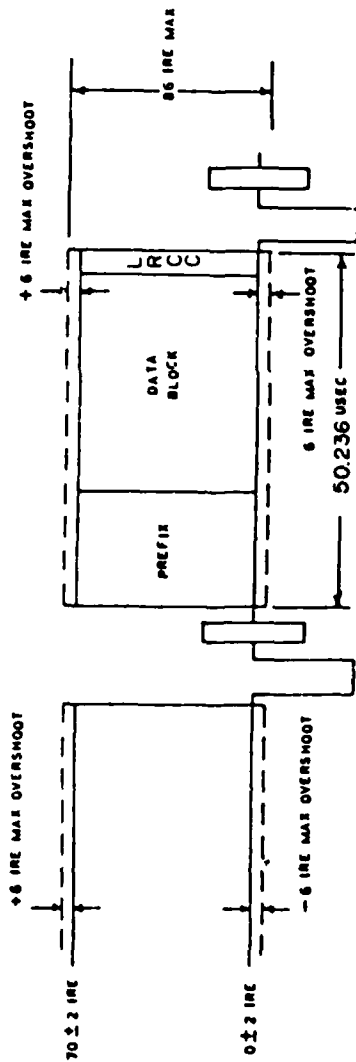
8.10 A Hamming error correction code is used in each data group and in the error detection (LRCC) group (see figure 8-2). Details of the Hamming code generation and format are shown in figure 7-2A and table 8-1. Details of the Hamming code interpretation upon decoding in the presence of noise are shown in figure 7-2B and table 8-2. The DIV encoder must generate a 4-bit Hamming code on each data byte (according to the rules given in figure 7-2A) and append it (in inverse polarity) to the end of the data byte to form a 12-bit data group, which is actually encoded onto the video. Random errors up to a density of 1 per each 12-bit data group can be automatically corrected by the DIV decoder (according to the rules given in figure 7-2B and table 8-2). It is very important to note before encoding that the Hamming code polarity is inverted from that shown in figure 7-2A. It must be inverted again in the decoder before interpretation. (See section 6.6.2.2 for an explanation of why inverse polarity is used for the Hamming code.)

8.11 An 8-bit LRCC is to be generated on the data (not data plus Hamming bits) contained in each line of data encoded. The 8-bit LRCC group has Hamming bits generated and attached to it exactly the same as 8-bit data groups. The DIV encoder, conversely, must first make a Hamming determination according to the rules given in figure 7-2B and

table 8-2 before doing an LRCC character check. The LRCC is generated using the polynomial $X^8 + 1$ (X to the 8th power plus 1).

8.12 The bandwidth required depends on the signal-to-noise ratio of the video recorder used and/or the transmission channel used. The system will have acceptably low error rates down to about 2 MHz of bandwidth if the signal-to-noise ratio is above 40 dB. (See figure 8-5.)

DATA AMPLITUDE



POLARITY: A data "1" is recorded as a High ($70 \pm 2 \text{ IRE units}$)
 A data "0" is recorded as a Low ($0 \pm 2 \text{ IRE units}$)

HORIZONTAL SYNC & BLANKING

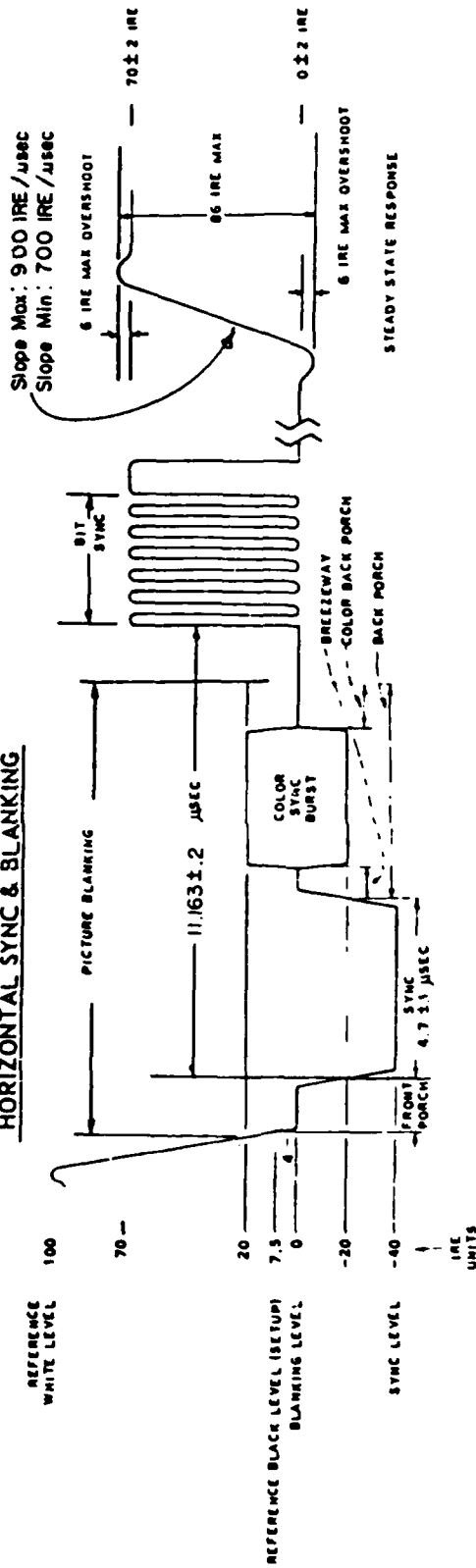
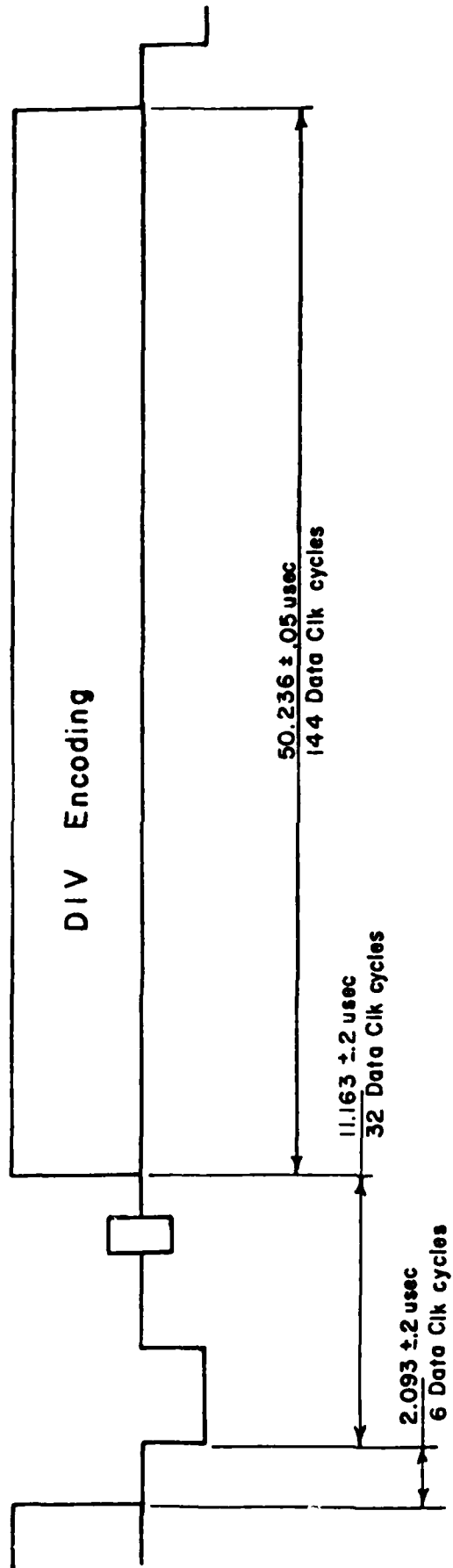


Figure 8-3. Amplitude and Slopes.



Bit Rate (Data Clk) = $182 \times$ the video horizontal line rate = 2.8665 MHz for monochrome.
 For color, either $182 \times$ the horizontal line rate (i.e., 2.8665 MHz) or 2.8665 MHz is acceptable.

Figure 8-4. Timing Detail.

TABLE 8-1

HAMMING ENCODING LIST

DECIMAL DATA	BINARY DATA	HAMMING CODE				INVERSE CODE			
		H 3	H 2	H 1	H 0	H 3	H 2	H 1	H 0
0	0 0 0 0 0 0 0 0	0	0	0	0	1	1	1	1
1	0 0 0 0 0 0 0 1	0	0	1	1	1	1	0	0
2	0 0 0 0 0 0 1 0	0	1	0	1	1	0	1	0
3	0 0 0 0 0 1 1 1	0	1	1	0	1	0	0	1
4	0 0 0 0 1 0 0 0	0	1	1	0	1	0	0	1
5	0 0 0 0 1 0 1 1	0	1	0	1	1	0	1	0
6	0 0 0 0 1 1 1 0	0	0	1	1	1	1	0	0
7	0 0 0 0 1 1 1 1	0	0	0	0	1	1	1	1
8	0 0 0 0 1 0 0 0	0	1	1	1	1	0	0	0
9	0 0 0 0 1 0 0 1	0	1	0	0	1	0	1	1
10	0 0 0 0 1 0 1 0	0	0	1	0	1	1	0	1
11	0 0 0 0 1 0 1 1	0	0	0	1	1	1	1	0
12	0 0 0 0 1 1 1 0	0	0	0	1	1	1	1	0
13	0 0 0 0 1 1 0 1	0	0	1	0	1	1	0	1
14	0 0 0 0 1 1 1 0	0	1	0	0	1	0	1	1
15	0 0 0 0 1 1 1 1	0	1	1	1	1	0	0	0
16	0 0 0 1 0 0 0 0	1	0	0	1	0	1	1	0
17	0 0 0 1 0 0 0 1	1	0	1	0	0	1	0	1
18	0 0 0 1 0 0 1 0	1	1	0	0	0	1	1	1
19	0 0 0 1 0 0 1 1	1	1	1	1	0	0	0	0
20	0 0 0 1 0 1 0 0	1	1	1	1	0	0	0	0
21	0 0 0 1 0 1 0 1	1	1	0	0	0	1	1	1
22	0 0 0 1 0 1 1 0	1	0	1	0	0	1	0	1
23	0 0 0 1 0 1 1 1	1	0	0	1	0	1	1	0
24	0 0 0 1 1 0 0 0	1	1	1	0	0	0	1	1
25	0 0 0 1 1 0 0 1	1	1	0	1	0	0	1	0
26	0 0 0 1 1 0 1 0	1	0	1	1	0	1	0	0
27	0 0 0 1 1 0 1 1	1	0	0	0	0	1	1	1
28	0 0 0 1 1 1 1 0	1	0	0	0	0	1	1	1
29	0 0 0 1 1 1 1 1	1	0	1	1	0	1	0	0
30	0 0 0 1 1 1 1 0	1	1	0	1	0	0	1	0
31	0 0 0 1 1 1 1 1	1	1	1	0	0	0	0	1
32	0 0 1 0 0 0 0 0	1	0	1	0	0	1	0	1
33	0 0 1 0 0 0 0 1	1	0	0	1	0	1	1	0
34	0 0 1 0 0 0 1 0	1	1	1	1	0	0	0	0
35	0 0 1 0 0 0 1 1	1	1	0	0	0	1	1	1
36	0 0 1 0 0 1 0 0	1	1	0	0	0	0	1	1
37	0 0 1 0 0 1 0 1	1	1	1	1	0	0	0	0
38	0 0 1 0 0 1 1 0	1	0	0	1	0	1	1	0
39	0 0 1 0 0 1 1 1	1	0	1	0	0	1	0	1
40	0 0 1 0 1 0 0 0	1	1	0	1	0	0	1	0
41	0 0 1 0 1 0 0 1	1	1	1	0	0	0	0	1
42	0 0 1 0 1 0 1 0	1	0	0	0	0	1	1	1
43	0 0 1 0 1 0 1 1	1	0	1	1	0	1	0	0
44	0 0 1 0 1 1 1 0	1	0	1	1	0	1	0	0
45	0 0 1 0 1 1 1 1	1	0	0	0	0	1	1	1
46	0 0 1 0 1 1 1 0	1	1	1	0	0	0	0	1
47	0 0 1 0 1 1 1 1	1	1	0	1	0	0	1	0
48	0 0 1 1 0 0 0 0	0	0	1	1	1	1	0	0
49	0 0 1 1 0 0 0 1	0	0	0	0	1	1	1	1
50	0 0 1 1 0 0 1 0	0	1	1	0	1	0	0	1
51	0 0 1 1 0 0 1 1	0	1	0	1	1	0	1	0
52	0 0 1 1 0 1 0 0	0	1	0	1	1	0	1	0
53	0 0 1 1 0 1 0 1	0	1	1	0	1	0	0	1
54	0 0 1 1 0 1 1 0	0	0	0	0	1	1	1	1

55	0 0 1 1 1 1 1	0 0 1 1	1 1 0 0
56	0 0 1 1 1 0 0 0	0 1 0 0	1 0 1 1
57	0 0 1 1 1 0 0 1	0 1 1 1	1 0 0 0
58	0 0 1 1 1 0 1 0	0 0 0 1	1 1 1 0
59	0 0 1 1 1 0 1 1	0 0 1 0	1 1 0 1
60	0 0 1 1 1 1 0 0	0 0 1 0	1 1 0 1
61	0 0 1 1 1 1 0 1	0 0 0 1	1 1 1 0
62	0 0 1 1 1 1 1 0	0 1 1 1	1 0 0 0
63	0 0 1 1 1 1 1 1	0 1 0 0	1 0 1 1
64	0 1 0 0 0 0 0 0	1 0 1 1	0 1 0 0
65	0 1 0 0 0 0 0 1	1 0 0 0	0 1 1 1
66	0 1 0 0 0 0 1 0	1 1 1 0	0 0 0 1
67	0 1 0 0 0 0 1 1	1 1 0 1	0 0 1 0
68	0 1 0 0 0 1 0 0	1 1 0 1	0 0 1 0
69	0 1 0 0 0 1 0 1	1 1 1 0	0 0 0 1
70	0 1 0 0 0 1 1 0	1 0 0 0	0 1 1 1
71	0 1 0 0 0 1 1 1	1 0 1 1	0 1 0 0
72	0 1 0 0 1 0 0 0	1 1 0 0	0 0 1 1
73	0 1 0 0 1 0 0 1	1 1 1 1	0 0 0 0
74	0 1 0 0 1 0 1 0	1 0 0 1	0 1 1 0
75	0 1 0 0 1 0 1 1	1 0 1 0	0 1 0 1
76	0 1 0 0 1 1 0 0	1 0 1 0	0 1 0 1
77	0 1 0 0 1 1 0 1	1 0 0 1	0 1 1 0
78	0 1 0 0 1 1 1 0	1 1 1 1	0 0 0 0
79	0 1 0 0 1 1 1 1	1 1 0 0	0 0 1 1
80	0 1 0 1 0 0 0 0	0 0 1 0	1 1 0 1
81	0 1 0 1 0 0 0 1	0 0 0 1	1 1 1 0
82	0 1 0 1 0 0 1 0	0 1 1 1	1 0 0 0
83	0 1 0 1 0 0 1 1	0 1 0 0	1 0 1 1
84	0 1 0 1 0 1 0 0	0 1 0 0	1 0 1 1
85	0 1 0 1 0 1 0 1	0 1 1 1	1 0 0 0
86	0 1 0 1 0 1 1 0	0 0 0 1	1 1 1 0
87	0 1 0 1 0 1 1 1	0 0 1 0	1 1 0 1
88	0 1 0 1 1 0 0 0	0 1 0 1	1 0 1 0
89	0 1 0 1 1 0 0 1	0 1 1 0	1 0 0 1
90	0 1 0 1 1 0 1 0	0 0 0 0	1 1 1 1
91	0 1 0 1 1 0 1 1	0 0 1 1	1 1 0 0
92	0 1 0 1 1 1 0 0	0 0 1 1	1 1 0 0
93	0 1 0 1 1 1 0 1	0 0 0 0	1 1 1 1
94	0 1 0 1 1 1 1 0	0 1 1 0	1 0 0 1
95	0 1 0 1 1 1 1 1	0 1 0 1	1 0 1 0
96	0 1 1 0 0 0 0 0	0 0 0 1	1 1 1 0
97	0 1 1 0 0 0 0 1	0 0 1 0	1 1 0 1
98	0 1 1 0 0 0 1 0	0 1 0 0	1 0 1 1
99	0 1 1 0 0 0 1 1	0 1 1 1	1 0 0 0
100	0 1 1 0 0 1 0 0	0 1 1 1	1 0 0 0
101	0 1 1 0 0 1 0 1	0 1 0 0	1 0 1 1
102	0 1 1 0 0 1 1 0	0 0 1 0	1 1 0 1
103	0 1 1 0 0 1 1 1	0 0 0 1	1 1 1 0
104	0 1 1 0 1 0 0 0	0 1 1 0	1 0 0 1
105	0 1 1 0 1 0 0 1	0 1 0 1	1 0 1 0
106	0 1 1 0 1 0 1 0	0 0 1 1	1 1 0 0
107	0 1 1 0 1 0 1 1	0 0 0 0	1 1 1 1
108	0 1 1 0 1 1 0 0	0 0 0 0	1 1 1 1
109	0 1 1 0 1 1 0 1	0 0 1 1	1 1 0 0
110	0 1 1 0 1 1 1 0	0 1 0 1	1 0 1 0
111	0 1 1 0 1 1 1 1	0 1 1 0	1 0 0 1
112	0 1 1 1 0 0 0 0	1 0 0 0	0 1 1 1
113	0 1 1 1 0 0 0 1	1 0 1 1	0 1 0 0
114	0 1 1 1 0 0 1 0	1 1 0 1	0 0 1 0

115	0 1 1 1 0 0 1 1	1 1 1 0	0 0 0 1
116	0 1 1 1 0 1 0 0	1 1 1 0	0 0 0 1
117	0 1 1 1 0 1 0 1	1 1 0 1	0 0 1 0
118	0 1 1 1 0 1 1 0	1 0 1 1	0 1 0 0
119	0 1 1 1 0 1 1 1	1 0 0 0	0 1 1 1
120	0 1 1 1 1 0 0 0	1 1 1 1	0 0 0 0
121	0 1 1 1 1 0 0 1	1 1 0 0	0 0 1 1
122	0 1 1 1 1 0 1 0	1 0 1 0	0 1 0 1
123	0 1 1 1 1 0 1 1	1 0 0 1	0 1 1 0
124	0 1 1 1 1 1 0 0	1 0 0 1	0 1 1 0
125	0 1 1 1 1 1 0 1	1 0 1 0	0 1 0 1
126	0 1 1 1 1 1 1 0	1 1 0 0	0 0 1 1
127	0 1 1 1 1 1 1 1	1 1 1 1	0 0 0 0
128	1 0 0 0 0 0 0 0	1 1 0 0	0 0 1 1
129	1 0 0 0 0 0 0 1	1 1 1 1	0 0 0 0
130	1 0 0 0 0 0 1 0	1 0 0 1	0 1 1 0
131	1 0 0 0 0 0 1 1	1 0 1 0	0 1 0 1
132	1 0 0 0 0 1 0 0	1 0 1 0	0 1 0 1
133	1 0 0 0 0 1 0 1	1 0 0 1	0 1 1 0
134	1 0 0 0 0 1 1 0	1 1 1 1	0 0 0 0
135	1 0 0 0 0 1 1 1	1 1 0 0	0 0 1 1
136	1 0 0 0 1 0 0 0	1 0 1 1	0 1 0 0
137	1 0 0 0 1 0 0 1	1 0 0 0	0 1 1 1
138	1 0 0 0 1 0 1 0	1 1 1 0	0 0 0 1
139	1 0 0 0 1 0 1 1	1 1 0 1	0 0 1 0
140	1 0 0 0 1 1 0 0	1 1 0 1	0 0 1 0
141	1 0 0 0 1 1 0 1	1 1 1 0	0 0 0 1
142	1 0 0 0 1 1 1 0	1 0 0 0	0 1 1 1
143	1 0 0 0 1 1 1 1	1 0 1 1	0 1 0 0
144	1 0 0 1 0 0 0 0	0 1 0 1	1 0 1 0
145	1 0 0 1 0 0 0 1	0 1 1 0	1 0 0 1
146	1 0 0 1 0 0 1 0	0 0 0 0	1 1 1 1
147	1 0 0 1 0 0 1 1	0 0 1 1	1 1 0 0
148	1 0 0 1 0 1 0 0	0 0 1 1	1 1 0 0
149	1 0 0 1 0 1 0 1	0 0 0 0	1 1 1 1
150	1 0 0 1 0 1 1 0	0 1 1 0	1 0 0 1
151	1 0 0 1 0 1 1 1	0 1 0 1	1 0 1 0
152	1 0 0 1 1 0 0 0	0 0 1 0	1 1 0 1
153	1 0 0 1 1 0 0 1	0 0 0 1	1 1 1 0
154	1 0 0 1 1 0 1 0	0 1 1 1	1 0 0 0
155	1 0 0 1 1 0 1 1	0 1 0 0	1 0 1 1
156	1 0 0 1 1 1 0 0	0 1 0 0	1 0 1 1
157	1 0 0 1 1 1 0 1	0 1 1 1	1 0 0 0
158	1 0 0 1 1 1 1 0	0 0 0 1	1 1 1 0
159	1 0 0 1 1 1 1 1	0 0 1 0	1 1 0 1
160	1 0 1 0 0 0 0 0	0 1 1 0	1 0 0 1
161	1 0 1 0 0 0 0 1	0 1 0 1	1 0 1 0
162	1 0 1 0 0 0 1 0	0 0 1 1	1 1 0 0
163	1 0 1 0 0 0 1 1	0 0 0 0	1 1 1 1
164	1 0 1 0 0 1 0 0	0 0 0 0	1 1 1 1
165	1 0 1 0 0 1 0 1	0 0 1 1	1 1 0 0
166	1 0 1 0 0 1 1 0	0 1 0 1	1 0 1 0
167	1 0 1 0 0 1 1 1	0 1 1 0	1 0 0 1
168	1 0 1 0 1 0 0 0	0 0 0 1	1 1 1 0
169	1 0 1 0 1 0 0 1	0 0 1 0	1 1 0 1
170	1 0 1 0 1 0 1 0	0 1 0 0	1 0 1 1
171	1 0 1 0 1 0 1 1	0 1 1 1	1 0 0 0
172	1 0 1 0 1 1 0 0	0 1 1 1	1 0 0 0
173	1 0 1 0 1 1 0 1	0 1 0 0	1 0 1 1
174	1 0 1 0 1 1 1 0	0 1 1 0	1 1 0 1

175	1 0 1 0 1 1 1 1	0 0 0 1	1 1 1 0
176	1 0 1 1 0 0 0 0	1 1 1 1	0 0 0 0
177	1 0 1 1 0 0 0 1	1 1 0 0	0 0 1 1
178	1 0 1 1 0 0 1 0	1 0 1 0	0 1 0 1
179	1 0 1 1 0 0 1 1	1 0 0 1	0 1 1 0
180	1 0 1 1 0 1 0 0	1 0 0 1	0 1 1 0
181	1 0 1 1 0 1 0 1	1 0 1 0	0 1 0 1
182	1 0 1 1 0 1 1 0	1 1 0 0	0 0 1 1
183	1 0 1 1 0 1 1 1	1 1 1 1	0 0 0 0
184	1 0 1 1 1 0 0 0	1 0 0 0	0 1 1 1
185	1 0 1 1 1 0 0 1	1 0 1 1	0 1 0 0
186	1 0 1 1 1 0 1 0	1 1 0 1	0 0 1 0
187	1 0 1 1 1 0 1 1	1 1 1 0	0 0 0 1
188	1 0 1 1 1 1 0 0	1 1 1 0	0 0 0 1
189	1 0 1 1 1 1 0 1	1 1 0 1	0 0 1 0
190	1 0 1 1 1 1 1 0	1 0 1 1	0 1 0 0
191	1 0 1 1 1 1 1 1	1 0 0 0	0 1 1 1
192	1 1 0 0 0 0 0 0	0 1 1 1	1 0 0 0
193	1 1 0 0 0 0 0 1	0 1 0 0	1 0 1 1
194	1 1 0 0 0 0 1 0	0 0 1 0	1 1 0 1
195	1 1 0 0 0 0 1 1	0 0 0 1	1 1 1 0
196	1 1 0 0 0 1 0 0	0 0 0 1	1 1 1 0
197	1 1 0 0 0 1 0 1	0 0 1 0	1 1 0 1
198	1 1 0 0 0 1 1 0	0 1 0 0	1 0 1 1
199	1 1 0 0 0 1 1 1	0 1 1 1	1 0 0 0
200	1 1 0 0 1 0 0 0	0 0 0 0	1 1 1 1
201	1 1 0 0 1 0 0 1	0 0 1 1	1 1 0 0
202	1 1 0 0 1 0 1 0	0 1 0 1	1 0 1 0
203	1 1 0 0 1 0 1 1	0 1 1 0	1 0 0 1
204	1 1 0 0 1 1 0 0	0 1 1 0	1 0 0 1
205	1 1 0 0 1 1 0 1	0 1 0 1	1 0 1 0
206	1 1 0 0 1 1 1 0	0 0 1 1	1 1 0 0
207	1 1 0 0 1 1 1 1	0 0 0 0	1 1 1 1
208	1 1 0 1 0 0 0 0	1 1 1 0	0 0 0 1
209	1 1 0 1 0 0 0 1	1 1 0 1	0 0 1 0
210	1 1 0 1 0 0 1 0	1 0 1 1	0 1 0 0
211	1 1 0 1 0 0 1 1	1 0 0 0	0 1 1 1
212	1 1 0 1 0 1 0 0	1 0 0 0	0 1 1 1
213	1 1 0 1 0 1 0 1	1 0 1 1	0 1 0 0
214	1 1 0 1 0 1 1 0	1 1 0 1	0 0 1 0
215	1 1 0 1 0 1 1 1	1 1 1 0	0 0 0 1
216	1 1 0 1 1 0 0 0	1 0 0 1	0 1 1 0
217	1 1 0 1 1 0 0 1	1 0 1 0	0 1 0 1
218	1 1 0 1 1 0 1 0	1 1 0 0	0 1 1 1
219	1 1 0 1 1 0 1 1	1 1 1 1	0 0 0 0
220	1 1 0 1 1 1 0 0	1 1 1 1	0 0 0 0
221	1 1 0 1 1 1 0 1	1 1 0 0	0 0 1 1
222	1 1 0 1 1 1 1 0	1 0 1 0	0 1 0 1
223	1 1 0 1 1 1 1 1	1 0 0 1	0 1 1 0
224	1 1 1 0 0 0 0 0	1 1 0 1	0 0 1 0
225	1 1 1 0 0 0 0 1	1 1 1 0	0 0 0 1
226	1 1 1 0 0 0 1 0	1 0 0 0	0 1 1 1
227	1 1 1 0 0 0 1 1	1 0 1 1	0 1 0 0
228	1 1 1 0 0 1 0 0	1 0 1 1	0 1 0 0
229	1 1 1 0 0 1 0 1	1 0 0 0	0 1 1 1
230	1 1 1 0 0 1 1 0	1 1 1 0	0 0 0 1
231	1 1 1 0 0 1 1 1	1 1 0 1	0 0 1 0
232	1 1 1 0 1 0 0 0	1 0 1 0	0 1 0 1
233	1 1 1 0 1 0 0 1	1 0 0 1	0 1 1 0
234	1 1 1 0 1 0 1 0	1 1 1 1	0 0 0 0

235	1 1 1 0 1 0 1 1	1 1 0 0	0 0 1 1
236	1 1 1 0 1 1 0 0	1 1 0 0	0 0 1 1
237	1 1 1 0 1 1 0 1	1 1 1 1	0 0 0 0
238	1 1 1 0 1 1 1 0	1 0 0 1	0 1 1 0
239	1 1 1 0 1 1 1 1	1 0 1 0	0 1 0 1
240	1 1 1 1 0 0 0 0	0 1 0 0	1 0 1 1
241	1 1 1 1 0 0 0 1	0 1 1 1	1 0 0 0
242	1 1 1 1 0 0 1 0	0 0 0 1	1 1 1 0
243	1 1 1 1 0 0 1 1	0 0 1 0	1 1 0 1
244	1 1 1 1 0 1 0 0	0 0 1 0	1 1 0 1
245	1 1 1 1 0 1 0 1	0 0 0 1	1 1 1 0
246	1 1 1 1 0 1 1 0	0 1 1 1	1 0 0 0
247	1 1 1 1 0 1 1 1	0 1 0 0	1 0 1 1
248	1 1 1 1 1 0 0 0	0 0 1 1	1 1 0 0
249	1 1 1 1 1 0 0 1	0 0 0 0	1 1 1 1
250	1 1 1 1 1 0 1 0	0 1 1 0	1 0 0 1
251	1 1 1 1 1 0 1 1	0 1 0 1	1 0 1 0
252	1 1 1 1 1 1 0 0	0 1 0 1	1 0 1 0
253	1 1 1 1 1 1 0 1	0 1 1 0	1 0 0 1
254	1 1 1 1 1 1 1 0	0 0 0 0	1 1 1 1
255	1 1 1 1 1 1 1 1	0 0 1 1	1 1 0 0

TABLE 8-2
HAMMING DECODE TABLE

ADD DATA		(Hexadecimal notation is used)													
IN	OUT														
000	00	001	00	002	00	003	01	004	00	005	02	006	04	007	08
008	00	009	10	00A	20	00B	40	00C	80	00D	02	00E	04	00F	14
010	00	011	01	012	01	013	01	014	09	015	05	016	03	017	01
018	41	019	21	01A	11	01B	01	01C	15	01D	05	01E	03	01F	81
020	00	021	02	022	0A	023	06	024	02	025	02	026	03	027	02
028	00	029	82	02A	16	02B	06	02C	12	02D	02	02E	42	02F	22
030	07	031	0B	032	33	033	01	034	03	035	02	036	03	037	03
038	07	039	17	03A	83	03B	01	03C	23	03D	43	03E	03	03F	13
040	00	041	0C	042	04	043	06	044	04	045	05	046	04	047	04
048	00	049	10	04A	84	04B	06	04C	24	04D	44	04E	04	04F	14
050	07	051	05	052	0D	053	01	054	05	055	05	056	04	057	05
058	07	059	85	05A	11	05B	01	05C	15	05D	05	05E	45	05F	25
060	07	061	06	062	06	063	06	064	0E	065	02	066	04	067	06
068	46	069	26	06A	16	06B	06	06C	12	06D	02	06E	04	06F	86
070	07	071	07	072	07	073	06	074	07	075	05	076	03	077	0F
078	07	079	17	07A	27	07B	47	07C	87	07D	05	07E	03	07F	13
080	00	081	0C	082	0A	083	08	084	09	085	08	086	08	087	08
088	1C	089	0C	08A	0A	08B	88	08C	48	08D	28	08E	18	08F	08
090	09	091	0B	092	0D	093	01	094	09	095	09	096	09	097	08
098	89	099	0B	09A	0D	09B	1D	09C	09	09D	19	09E	29	09F	49
0A0	0A	0A1	0B	0A2	0A	0A3	0A	0A4	0E	0A5	02	0A6	0A	0A7	08
0A8	2A	0A9	4A	0AA	0A	0AB	1A	0AC	0E	0AD	1E	0AE	8A	0AF	08
0B0	0B	0B1	0B	0B2	CA	0B3	0B	0B4	09	0B5	0B	0B6	03	0B7	0F
0B8	1B	0B9	0B	0BA	4B	0BB	2B	0BC	09	0BD	8B	0BE	1F	0BF	0F
0C0	0C	0C1	0C	0C2	0D	0C3	0C	0C4	0E	0C5	0C	0C6	04	0C7	08
0C8	1C	0C9	0C	0CA	4C	0CB	2C	0CC	0E	0CD	8C	0CE	18	0CF	08
0D0	0D	0D1	0C	0D2	0D	0D3	0D	0D4	09	0D5	05	0D6	0D	0D7	0F
0D8	2D	0D9	4D	0DA	0D	0DB	1D	0DC	09	0DD	19	0DE	8D	0DF	0F
0E0	0E	0E1	0C	0E2	0A	0E3	06	0E4	0E	0E5	0E	0E6	0E	0E7	0F
0E8	8E	0E9	0C	0EA	0A	0EB	1A	0EC	0E	0ED	1E	0EE	2E	0EF	4E
0F0	07	0F1	0B	0F2	0D	0F3	0F	0F4	0E	0F5	0F	0F6	0F	0F7	0F
0F8	1B	0F9	0B	0FA	0D	0FB	8F	0FC	4F	0FD	2F	0FE	1F	0FF	0F
100	00	101	10	102	10	103	30	104	12	105	90	106	04	107	14
108	10	109	10	10A	11	10B	10	10C	12	10D	10	10E	18	10F	14
110	31	111	51	112	11	113	01	114	15	115	05	116	91	117	13
118	11	119	10	11A	11	11B	11	11C	15	11D	19	11E	11	11F	13
120	92	121	10	122	16	123	06	124	12	125	02	126	32	127	52
128	12	129	10	12A	16	12B	1A	12C	12	12D	12	12E	12	12F	13
130	07	131	17	132	11	133	93	134	53	135	33	136	03	137	13
138	1B	139	17	13A	11	13B	13	13C	12	13D	13	13E	13	13F	13
140	00	141	10	142	16	143	94	144	54	145	34	146	04	147	14
148	1C	149	10	14A	16	14B	14	14C	15	14D	14	14E	14	14F	14
150	95	151	17	152	11	153	01	154	15	155	05	156	35	157	55
158	15	159	17	15A	11	15B	1D	15C	15	15D	15	15E	15	15F	14
160	36	161	56	162	16	163	06	164	12	165	02	166	96	167	14
168	16	169	17	16A	16	16B	16	16C	12	16D	1E	16E	16	16F	14
170	07	171	17	172	57	173	37	174	15	175	97	176	03	177	13
178	17	179	17	17A	16	17B	17	17C	15	17D	17	17E	1F	17F	13
180	1C	181	0C	182	98	183	1A	184	38	185	58	186	18	187	08
188	1C	189	10	18A	18	18B	1A	18C	18	18D	19	18E	18	18F	18
190	1B	191	99	192	0D	193	1D	194	09	195	19	196	59	197	39
198	1B	199	19	19A	11	19B	1D	19C	19	19D	19	19E	18	19F	19

1A0 5A	1A1 3A	1A2 0A	1A3 1A	1A4 0E	1A5 1E	1A6 18	1A7 9A
1A8 1B	1A9 1A	1AA 1A	1AB 1A	1AC 12	1AD 1E	1AE 18	1AF 1A
1B0 1B	1B1 0B	1B2 3B	1B3 5B	1B4 9B	1B5 19	1B6 1F	1B7 CF
1B8 1B	1B9 1B	1BA 1B	1BB 1A	1BC 1B	1BD 19	1BE 1F	1BF 13
1C0 1C	1C1 0C	1C2 3C	1C3 5C	1C4 9C	1C5 1E	1C6 18	1C7 06
1C8 1C	1C9 1C	1CA 1C	1CB 1D	1CC 1C	1CD 1E	1CE 18	1CF 14
1D0 5D	1D1 3D	1D2 0D	1D3 1D	1D4 09	1D5 19	1D6 1F	1D7 9D
1D8 1C	1D9 1D	1DA 1D	1DB 1D	1DC 15	1DD 19	1DE 1F	1DF 1D
1E0 1C	1E1 9E	1E2 0A	1E3 1A	1E4 CE	1E5 1E	1E6 5E	1E7 3E
1E8 1C	1E9 1E	1EA 16	1EB 1A	1EC 1E	1ED 1E	1EE 1F	1EF 1C
1F0 1B	1F1 0B	1F2 9F	1F3 1D	1F4 3F	1F5 5F	1F6 1F	1F7 CF
1F8 1B	1F9 17	1FA 1F	1FB 1D	1FC 1F	1FD 1E	1FE 1F	1FF 1F
200 00	201 60	202 20	203 30	204 24	205 34	206 A0	207 22
208 20	209 21	20A 20	20B 20	20C 24	20D 28	20E 20	20F 22
210 31	211 21	212 61	213 01	214 23	215 A1	216 35	217 25
218 21	219 21	21A 20	21B 21	21C 23	21D 21	21E 29	21F 23
220 36	221 26	222 20	223 A2	224 62	225 02	226 32	227 22
228 2A	229 26	22A 20	22B 22	22C 23	22D 22	22E 22	22F 22
230 A3	231 21	232 27	233 37	234 23	235 33	236 03	237 63
238 23	239 21	23A 27	23B 2B	23C 23	23D 23	23E 23	23F 22
240 A4	241 26	242 20	243 30	244 24	245 34	246 04	247 64
248 24	249 26	24A 20	24B 2C	24C 24	24D 24	24E 24	24F 25
250 31	251 21	252 27	253 A5	254 65	255 05	256 35	257 25
258 2D	259 21	25A 27	25B 25	25C 24	25D 25	25E 25	25F 25
260 36	261 26	262 66	263 06	264 24	265 A6	266 32	267 22
268 26	269 26	26A 27	26B 26	26C 24	26D 26	26E 2E	26F 22
270 07	271 67	272 27	273 37	274 23	275 33	276 A7	277 25
278 27	279 26	27A 27	27B 27	27C 23	27D 2F	27E 27	27F 25
280 2A	281 A8	282 3C	283 2C	284 38	285 28	286 68	287 08
288 2A	289 28	28A 20	28B 2C	28C 28	28D 28	28E 29	28F 28
290 2D	291 3D	292 A9	293 2B	294 09	295 69	296 29	297 39
298 2D	299 21	29A 29	29B 2B	29C 29	29D 28	29E 29	29F 29
2A0 2A	2A1 3A	2A2 0A	2A3 6A	2A4 AA	2A5 28	2A6 2E	2A7 3E
2A8 2A	2A9 2A	2AA 2A	2AB 2B	2AC 2A	2AD 28	2AE 2E	2AF 22
2B0 6B	2B1 0B	2B2 3B	2B3 2B	2B4 3F	2B5 2F	2B6 29	2B7 AB
2B8 2A	2B9 2B	2BA 2B	2BB 2B	2BC 23	2BD 2F	2BE 29	2BF 2B
2C0 6C	2C1 0C	2C2 3C	2C3 2C	2C4 38	2C5 28	2C6 2E	2C7 AC
2C8 2D	2C9 2C	2CA 2C	2CB 2C	2CC 24	2CD 28	2CE 2E	2CF 2C
2D0 2D	2D1 3D	2D2 0D	2D3 6D	2D4 AD	2D5 2F	2D6 29	2D7 39
2D8 2D	2D9 2D	2DA 2D	2DB 2C	2DC 2D	2DD 2F	2DE 29	2DF 25
2E0 2A	2E1 3A	2E2 AE	2E3 2C	2E4 0E	2E5 6E	2E6 2E	2E7 3E
2E8 2A	2E9 26	2EA 2E	2EB 2C	2EC 2E	2ED 2F	2EE 2E	2EF 2E
2F0 2D	2F1 AF	2F2 3B	2F3 2B	2F4 3F	2F5 2F	2F6 6F	2F7 0F
2F8 2D	2F9 2F	2FA 27	2FB 2B	2FC 2F	2FD 2F	2FE 2E	2FF 2F
300 31	301 30	302 30	303 30	304 38	305 34	306 32	307 30
308 70	309 10	30A 20	30B 30	30C 24	30D 34	30E 32	30F 60
310 31	311 31	312 31	313 30	314 31	315 33	316 35	317 39
318 31	319 21	31A 11	31B 71	31C B1	31D 33	31E 35	31F 25
320 36	321 3A	322 32	323 30	324 32	325 33	326 32	327 32
328 36	329 26	32A B2	32B 30	32C 12	32D 72	32E 32	32F 22
330 31	331 33	332 3B	333 37	334 33	335 32	336 32	337 33
338 31	339 B3	33A 27	33B 37	33C 23	33D 33	33E 73	33F 13
340 36	341 34	342 3C	343 30	344 34	345 34	346 35	347 34
348 36	349 B4	34A 20	34B 30	34C 24	34D 34	34E 74	34F 14
350 31	351 3D	352 35	353 37	354 35	355 34	356 35	357 35
358 31	359 21	35A B5	35B 37	35C 15	35D 75	35E 35	35F 25
360 36	361 36	362 36	363 37	364 36	365 34	366 32	367 3E
368 36	369 26	36A 16	36B 76	36C B6	36D 34	36E 32	36F 22
370 36	371 37	372 37	373 37	374 3F	375 33	376 35	377 27
378 77	379 17	37A 27	37B 37	37C 23	37D 33	37E 35	37F 27

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420 46	421 56	422 C2	423 40	424 62	425 02	426 42	427 52
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430 41	431 C3	432 57	433 47	434 53	435 43	436 03	437 63
438 41	439 43	43A 4B	43B 47	43C 43	43D 43	43E 42	43F 43
440 46	441 C4	442 50	443 40	444 54	445 44	446 04	447 64
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450 41	451 51	452 C5	453 47	454 65	455 05	456 45	457 55
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460 46	461 56	462 66	463 06	464 C6	465 44	466 42	467 52
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628 E2	629 60	62A 66	62B 76	62C 62	62D 72	62E 42	62F 22
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A18 A3	A19 21	A1A B5	A1B A5	A1C B1	A1D A1	A1E E1	A1F 81
A20 A3	A21 A2	A22 A2	A23 A2	A24 AA	A25 A6	A26 A0	A27 A2
A28 E2	A29 82	A2A B2	A2B A2	A2C B6	A2D A6	A2E A0	A2F 22
A30 A3	A31 A3	A32 A3	A33 A2	A34 A3	A35 A1	A36 A7	A37 A3
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A60 A4	A61 A6	A62 AE	A63 A2	A64 A6	A65 A6	A66 A7	A67 A6
A68 A4	A69 26	A6A B2	A6B A2	A6C B6	A6D A6	A6E E6	A6F 66
A70 A3	A71 AF	A72 A7	A73 A5	A74 A7	A75 A6	A76 A7	A77 A7
A78 A3	A79 B3	A7A 27	A7B A5	A7C 87	A7D E7	A7E A7	A7F B7
A80 A8	A81 A8	A82 A9	A83 A8	A84 AA	A85 A8	A86 A0	A87 AC
A88 B8	A89 A8	A8A E8	A8B 88	A8C AA	A8D 28	A8E BC	A8F AC
A90 A9	A91 A8	A92 A9	A93 A9	A94 AD	A95 A1	A96 A9	A97 AB
A98 89	A99 E9	A9A A9	A9B B9	A9C AD	A9D BD	A9E 29	A9F AB
AA0 AA	AA1 A8	AA2 AE	AA3 A2	AA4 AA	AA5 AA	AA6 AA	AA7 AB
AA8 2A	AA9 A8	AAA AE	AAB BE	AAC AA	AAD BA	AAE 8A	AAF 8A
AB0 A3	AB1 AF	AB2 A9	AB3 AB	AB4 AA	AB5 AB	AB6 AB	AB7 AB
AB8 BF	AB9 AF	ABA A9	ABB 2B	ABC EB	ABD 8B	ABE BB	ABF AB
AC0 A4	AC1 A8	AC2 AE	AC3 AC	AC4 AD	AC5 AC	AC6 AC	AC7 AC
AC8 B8	AC9 A8	ACA AE	ACB 2C	ACC EC	ACD 8C	ACE BC	ACF AC
AD0 AD	AD1 AF	AD2 A9	AD3 A5	AD4 AD	AD5 AD	AD6 AD	AD7 AC
AD8 2D	AD9 AF	ADA A9	ADB B9	ADC AD	ADD BD	ADE 8D	ADF ED
AE0 AE	AE1 AF	AE2 AE	AE3 AE	AE4 AA	AE5 A6	AE6 AE	AE7 AC
AE8 8E	AE9 EE	AEA AE	AEB BE	AEC AA	AED BA	AEE 2E	AEF AC
AF0 AF	AF1 AF	AF2 AE	AF3 AF	AF4 AD	AF5 AF	AF6 A7	AF7 AB
AF8 BF	AF9 AF	AFA EF	AFB 8F	AFC AD	AFD 2F	AFE BB	AFF AB

B00 A4	B01 B4	B02 B2	B03 30	B04 FC	B05 90	B06 A0	B07 B0
B08 B8	B09 B4	B0A B2	B0B B0	B0C B1	B0D B0	B0E B0	B0F B0
B10 31	B11 B3	B12 B5	B13 A5	B14 B1	B15 A1	B16 91	B17 F1
B18 B1	B19 B3	B1A B5	B1B B9	B1C B1	B1D B1	B1E B1	B1F B0
B20 92	B21 F2	B22 B2	B23 A2	B24 B6	B25 A6	B26 32	B27 B0
B28 B2	B29 B3	B2A B2	B2B B2	B2C B6	B2D BA	B2E B2	B2F B0
B30 A3	B31 B3	B32 F3	B33 93	B34 B1	B35 33	B36 A7	B37 B7
B38 B3	B39 B3	B3A B2	B3B B3	B3C B1	B3D B3	B3E BB	B3F B7
B40 A4	B41 B4	B42 F4	B43 94	B44 B6	B45 34	B46 A0	B47 B0
B48 B4	B49 B4	B4A B5	B4B B4	B4C B6	B4D B4	B4E BC	B4F B0
B50 95	B51 F5	B52 B5	B53 A5	B54 B1	B55 A1	B56 35	B57 B7
B58 B5	B59 B4	B5A B5	B5B B5	B5C B1	B5D BD	B5E B5	B5F B7
B60 36	B61 B4	B62 B2	B63 A2	B64 B6	B65 A6	B66 96	B67 F6
B68 B6	B69 B4	B6A B2	B6B BE	B6C B6	B6D B6	B6E B6	B6F B7
B70 A3	B71 B3	B72 B5	B73 37	B74 F7	B75 97	B76 A7	B77 B7
B78 BF	B79 B3	B7A B5	B7B B7	B7C B6	B7D B7	B7E B7	B7F B7
B80 B8	B81 A2	B82 98	B83 F8	B84 38	B85 BA	B86 BC	B87 AC
B88 B8	B89 B8	B8A B8	B8B B9	B8C B8	B8D BA	B8E BC	B8F B0
B90 F9	B91 99	B92 A9	B93 B9	B94 AD	B95 BD	B96 BB	B97 39
B98 B8	B99 B9	B9A B9	B9B B9	B9C B1	B9D BD	B9E BB	B9F B9
BA0 B8	BA1 3A	BA2 AE	BA3 BE	BA4 AA	BA5 BA	BA6 FA	BA7 9A
BA8 B8	BA9 3A	BAA B2	BAB BE	BAC BA	BAD BA	BAE BB	BAF BA
BB0 BF	BB1 AF	BB2 3B	BB3 B9	BB4 9B	BB5 FB	BB6 BB	BB7 AB
BB8 BF	BB9 B3	BBA BB	BBB B9	BBC BB	BBD BA	BBE BB	BBF BB
BC0 B8	BC1 A8	BC2 3C	BC3 BE	BC4 9C	BC5 FC	BC6 BC	BC7 AC
BC8 B8	BC9 B4	BCA BC	BCB BE	BCC BC	BCD BD	BCE BC	BCF BC
BD0 BF	BD1 3D	BD2 A9	BD3 B9	BD4 AD	BD5 BD	BD6 FD	BD7 9D
BD8 BF	BD9 BD	BDA B5	BDB B9	BDC BD	BDD BD	BDE BC	BDF BD
BE0 FE	BE1 9E	BE2 AE	BE3 BE	BE4 AA	BE5 BA	BE6 BC	BE7 3E
BE8 BF	BE9 BE	BEA BE	BEB BE	BEC B6	BED BA	BEE BC	BEF BE
BF0 BF	BF1 AF	BF2 9F	BF3 FF	BF4 3F	BF5 BD	BF6 BB	BF7 AB
BF8 BF	BF9 BF	BFA BF	BFB BE	BFC BF	BFD BU	BFE BB	BF7 E7
C00 C8	C01 C4	C02 C2	C03 C0	C04 C1	C05 C0	C06 C0	C07 C0
C08 D4	C09 C4	C0A C2	C0B 40	C0C 80	C0D E0	C0E D0	C0F C0
C10 C1	C11 C3	C12 C5	C13 C9	C14 C1	C15 C1	C16 C1	C17 C0
C18 41	C19 C3	C1A C5	C1B D5	C1C C1	C1D D1	C1E E1	C1F 81
C20 C2	C21 C3	C22 C2	C23 C2	C24 C6	C25 CA	C26 C2	C27 C0
C28 E2	C29 82	C2A C2	C2B D2	C2C C6	C2D D6	C2E 42	C2F C0
C30 C3	C31 C3	C32 C2	C33 C3	C34 C1	C35 C3	C36 CB	C37 C7
C38 D3	C39 C3	C3A 83	C3B E3	C3C C1	C3D 43	C3E D7	C3F C7
C40 C4	C41 C4	C42 C5	C43 C4	C44 C6	C45 C4	C46 CC	C47 C0
C48 D4	C49 C4	C4A 84	C4B E4	C4C C6	C4D 44	C4E D0	C4F C0
C50 C5	C51 C4	C52 C5	C53 C5	C54 C1	C55 CD	C56 C5	C57 C7
C58 E5	C59 85	C5A C5	C5B D5	C5C C1	C5D D1	C5E 45	C5F C7
C60 C6	C61 C4	C62 C2	C63 CE	C64 C6	C65 C6	C66 C6	C67 C7
C68 46	C69 C4	C6A C2	C6B D2	C6C C6	C6D D6	C6E E6	C6F 86
C70 CF	C71 C3	C72 C5	C73 C7	C74 C6	C75 C7	C76 C7	C77 C7
C78 D3	C79 C3	C7A C5	C7B 47	C7C 87	C7D E7	C7E D7	C7F C7
C80 C8	C81 C8	C82 C8	C83 C9	C84 C8	C85 CA	C86 CC	C87 C0
C88 C8	C89 D8	C8A E8	C8B 88	C8C 48	C8D CA	C8E CC	C8F BC
C90 C8	C91 C9	C92 C9	C93 C9	C94 C1	C95 CD	C96 CB	C97 C9
C98 89	C99 E9	C9A D9	C9B C9	C9C DD	C9D CD	C9E CB	C9F 49
CA0 C8	CA1 CA	CA2 C2	CA3 CE	CA4 CA	CA5 CA	CA6 CB	CA7 CA
CA8 C8	CA9 4A	CAA DE	CAB CE	CAC DA	CAD CA	CAE 8A	CAF CA
CB0 CF	CB1 C3	CB2 CB	CB3 C9	CB4 CB	CB5 CA	CB6 CB	CB7 C3
CB8 CF	CB9 DF	CBA 4B	CBB C9	CBC EB	CBD 3B	CBE CB	CBF D3
CC0 C8	CC1 C4	CC2 CC	CC3 CE	CC4 CC	CC5 CD	CC6 CC	CC7 CC
CC8 C8	CC9 D8	CCA 4C	CCB CE	CCC EC	CCD 8C	CCE CC	CCF DC
CD0 CF	CD1 CD	CD2 C5	CD3 C9	CD4 CD	CD5 CD	CD6 CC	CD7 CD
CD6 CF	CD9 4D	CDA D9	CDB C9	CDC DD	CDD CD	CDE 8D	CDF DD

CE0 CF	CE1 CE	CE2 CE	CE3 CE	CE4 C6	CE5 CA	CE6 CC	CE7 CE
CE8 8E	CE9 EE	CEA DE	CEB CE	CEC DA	CED CA	CEE CC	CEF 4E
CF0 CF	CF1 CF	CF2 CF	CF3 CE	CF4 CF	CF5 CD	CF6 CB	CF7 C7
CF8 CF	CF9 DF	CFA EF	CFB 8F	CFC 4F	CFD CD	CFE CB	CFF DB
D00 D4	D01 C4	D02 50	D03 D2	D04 F0	D05 90	D06 D0	D07 C0
D08 D4	D09 D8	D0A D0	D0B D2	D0C D0	D0D D1	D0E D0	D0F D0
D10 D3	D11 51	D12 C5	D13 D5	D14 C1	D15 D1	D16 91	D17 F1
D18 D3	D19 D1	D1A D9	D1B D5	D1C D1	D1D D1	D1E D0	D1F D1
D20 92	D21 F2	D22 C2	D23 D2	D24 C6	D25 D6	D26 D0	D27 52
D28 D3	D29 D2	D2A D2	D2B D2	D2C DA	D2D D6	D2E D0	D2F D2
D30 D3	D31 C3	D32 F3	D33 93	D34 53	D35 D1	D36 D7	D37 C7
D38 D3	D39 D3	D3A D3	D3B D2	D3C D3	D3D D1	D3E D7	D3F DB
D40 D4	D41 C4	D42 F4	D43 94	D44 54	D45 D6	D46 D0	D47 CC
D48 D4	D49 D4	D4A D4	D4B D5	D4C D4	D4D D6	D4E D0	D4F DC
D50 95	D51 F5	D52 C5	D53 D5	D54 C1	D55 D1	D56 D7	D57 55
D58 D4	D59 D5	D5A D5	D5B D5	D5C DD	D5D D1	D5E D7	D5F D5
D60 D4	D61 56	D62 C2	D63 D2	D64 C6	D65 D6	D66 96	D67 F6
D68 D4	D69 D6	D6A DE	D6B D2	D6C D6	D6D D6	D6E D7	D6F D6
D70 D3	D71 C3	D72 57	D73 D5	D74 F7	D75 97	D76 D7	D77 C7
D78 D3	D79 DF	D7A D7	D7B D5	D7C D7	D7D D6	D7E D7	D7F D7
D80 C8	D81 D8	D82 98	D83 F8	D84 DA	D85 58	D86 CC	D87 DC
D88 D8	D89 D8	D8A D9	D8B D8	D8C DA	D8D D8	D8E D0	D8F DC
D90 F9	D91 99	D92 D9	D93 C9	D94 DD	D95 CD	D96 59	D97 DB
D98 D9	D99 D8	D9A D9	D9B D9	D9C DD	D9D D1	D9E D9	D9F DB
DA0 5A	DA1 D8	DA2 DE	DA3 CE	DA4 DA	DA5 CA	DA6 FA	DA7 9A
DA8 DA	DA9 D8	DAA DE	DAB D2	DAC DA	DAD DA	DAE DA	DAF DB
DB0 CF	DB1 DF	DB2 D9	DB3 5B	DB4 9B	DB5 FB	DB6 CB	DB7 DB
DB8 D3	DB9 DF	DBA D9	DBB DB	DBC DA	DBD DB	DBE DB	DBF DB
DC0 C8	DC1 D8	DC2 DE	DC3 5C	DC4 9C	DC5 FC	DC6 CC	DC7 DC
DC8 D4	DC9 D8	DCA DE	DCB DC	DCC DD	DCD DC	DCE DC	DCF DC
DD0 5D	DD1 DF	DD2 D9	DD3 C9	DD4 DD	DD5 CD	DD6 FD	DD7 9D
DD8 DD	DD9 DF	DDA D9	ddb D5	DDC DD	DDD DD	DDE DD	DDF DC
DE0 FE	DE1 9E	DE2 DE	DE3 CE	DE4 DA	DE5 CA	DE6 5E	DE7 DC
DE8 DE	DE9 DF	DEA DE	DEB DE	DEC DA	DED D6	DEE DE	DEF DC
DF0 CF	DF1 DF	DF2 9F	DF3 FF	DF4 DD	DF5 5F	DF6 CB	DF7 DB
DF8 DF	DF9 DF	DFA DE	DFB DF	DFC DD	DFD DF	DFF D7	DFE DB
E00 E2	E01 60	E02 F4	E03 E4	E04 F0	E05 E0	E06 A0	E07 C0
E08 E2	E09 E0	E0A E8	E0B E4	E0C E0	E0D E0	E0E E1	E0F E0
E10 E5	E11 F5	E12 61	E13 E3	E14 C1	E15 A1	E1C E1	E17 F1
E18 E5	E19 E9	E1A E1	E1B E3	E1C E1	E1D E0	E1E E1	E1F E1
E20 E2	E21 F2	E22 C2	E23 A2	E24 62	E25 E0	E26 E6	E27 F6
E28 E2	E29 E2	E2A E2	E2B E3	E2C E2	E2D E0	E2E E6	E2F EA
E30 A3	E31 C3	E32 F3	E33 E3	E34 F7	E35 E7	E36 E1	E37 63
E38 E2	E39 E3	E3A E3	E3B E3	E3C EB	E3D E7	E3E E1	E3F E3
E40 A4	E41 C4	E42 F4	E43 E4	E44 F0	E45 E0	E46 E6	E47 64
E48 E5	E49 E4	E4A E4	E4B E4	E4C EC	E4D E0	E4E E6	E4F E4
E50 E5	E51 F5	E52 C5	E53 A5	E54 65	E55 E7	E56 E1	E57 F1
E58 E5	E59 E5	E5A E5	E5B E4	E5C E5	E5D E7	E5E E1	E5F ED
E60 E2	E61 F2	E62 66	E63 E4	E64 C6	E65 A6	E66 E6	E67 F6
E68 E2	E69 EE	E6A E6	E6B E4	E6C E6	E6D E7	E6E E6	E6F E6
E70 E5	E71 67	E72 F3	E73 E3	E74 F7	E75 E7	E76 A7	E77 C7
E78 E5	E79 E7	E7A EF	E7B E3	E7C E7	E7D E7	E7E E6	E7F E7
E80 C8	E81 A8	E82 E8	E83 F8	E84 EC	E85 FC	E86 68	E87 EA
E88 E8	E89 E9	E8A E8	E8B E8	E8C EC	E8D E0	E8E E8	E8F EA
E90 F9	E91 E9	E92 A9	E93 C9	E94 EB	E95 69	E96 FD	E97 ED
E98 E9	E99 E9	E9A E8	E9B E9	E9C EB	E9D E9	E9E E1	E9F ED
EA0 FE	EA1 EE	EA2 E8	EA3 6A	EA4 AA	EA5 CA	EA6 FA	EA7 EA
EA8 E2	EA9 EE	EAA E8	EAB EA	EAC EB	EAD EA	EAE EA	EAF EA
EB0 6B	EB1 E9	EB2 EF	EB3 FF	EB4 EB	EB5 FB	EB6 CB	EB7 AB
EB6 EB	EB9 E9	EBA EF	EBB E3	EBC EB	EBD EB	EBE EB	EBF EA

EC0 6C	EC1 EE	EC2 E8	EC3 F8	EC4 EC	EC5 FC	EC6 CC	EC7 AC
EC8 EC	EC9 EE	ECA E8	ECB E4	ECC EC	ECD EC	ECE EC	ECF ED
ED0 F9	ED1 E9	ED2 EF	ED3 6D	ED4 AD	ED5 CD	ED6 FD	ED7 ED
ED8 E5	ED9 E9	EDA EF	EDB ED	EDC EC	EDD ED	EDE ED	EDF ED
EE0 FE	EE1 EE	EE2 AE	EE3 CE	EE4 EC	EE5 6E	EE6 FA	EE7 EA
EE8 EE	EE9 EE	EEA EF	EEB EE	EEC EC	EED EE	EEE E6	EEF EA
EF0 CF	EF1 AF	EF2 EF	EF3 FF	EF4 EB	EF5 FB	EF6 6F	EF7 EC
EF8 EF	EF9 EE	EFA EF	EFB EF	EFC EB	EFD E7	EFE EF	EFF ED
F00 F0	F01 F2	F02 F4	F03 F8	F04 F0	F05 F0	F06 F0	F07 F1
F08 70	F09 F2	F0A F4	F0B E4	F0C F0	F0D E0	F0E D0	F0F B0
F10 F9	F11 F5	F12 F3	F13 F1	F14 F0	F15 F1	F16 F1	F17 F1
F18 E5	F19 F5	F1A F3	F1B 71	F1C B1	F1D D1	F1E E1	F1F F1
F20 F2	F21 F2	F22 F3	F23 F2	F24 F0	F25 F2	F26 FA	F27 F6
F28 E2	F29 F2	F2A B2	F2B D2	F2C F0	F2D 72	F2E E6	F2F F6
F30 F3	F31 F2	F32 F3	F33 F3	F34 F7	F35 FB	F36 F3	F37 F1
F38 D3	F39 B3	F3A F3	F3B E3	F3C F7	F3D E7	F3E 73	F3F F1
F40 F4	F41 F5	F42 F4	F43 F4	F44 F0	F45 FC	F46 F4	F47 F6
F48 D4	F49 B4	F4A F4	F4B E4	F4C F0	F4D EC	F4E 74	F4F F6
F50 F5	F51 F5	F52 F4	F53 F5	F54 F7	F55 F5	F56 FD	F57 F1
F58 E5	F59 F5	F5A B5	F5B D5	F5C F7	F5D 75	F5E E1	F5F F1
F60 FE	F61 F2	F62 F4	F63 F6	F64 F7	F65 F6	F66 F6	F67 F6
F68 E2	F69 F2	F6A F4	F6B 76	F6C B6	F6D D6	F6E E7	F6F F6
F70 F7	F71 F5	F72 F3	F73 FF	F74 F7	F75 F7	F76 F7	F77 F6
F78 77	F79 F5	F7A F3	F7B E3	F7C F7	F7D E7	F7E D7	F7F B7
F80 F9	F81 F8	F82 F8	F83 F8	F84 F0	F85 FC	F86 FA	F87 F8
F88 B8	F89 D8	F8A E8	F8B F8	F8C EC	F8D FC	F8E FA	F8F 78
F90 F9	F91 F9	F92 F9	F93 F8	F94 F9	F95 FB	F96 FD	F97 F1
F98 F9	F99 E9	F9A D9	F9B B9	F9C 79	F9D FB	F9E FD	F9F ED
FA0 FE	FA1 F2	FA2 FA	FA3 F8	FA4 FA	FA5 FB	FA6 FA	FA7 FA
FA8 FE	FA9 EE	FAA 7A	FAB F8	FAC DA	FAD BA	FAE FA	FAF EA
FB0 F9	FB1 FB	FB2 F3	FB3 FF	FB4 FB	FB5 FB	FB6 FA	FB7 FB
FB8 F9	FB9 7B	FBA EF	FBB FF	FBC EB	FBD FB	FBE BB	FBF DB
FC0 FE	FC1 FC	FC2 F4	FC3 F8	FC4 FC	FC5 FC	FC6 FD	FC7 FC
FC8 FE	FC9 7C	FCA E8	FCB F8	FCC EC	FCD FC	FCE BC	FCF DC
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FD8 F9	FD9 E9	FDA 7D	FDB FF	FDC DD	FDD BD	FDE FD	PDF ED
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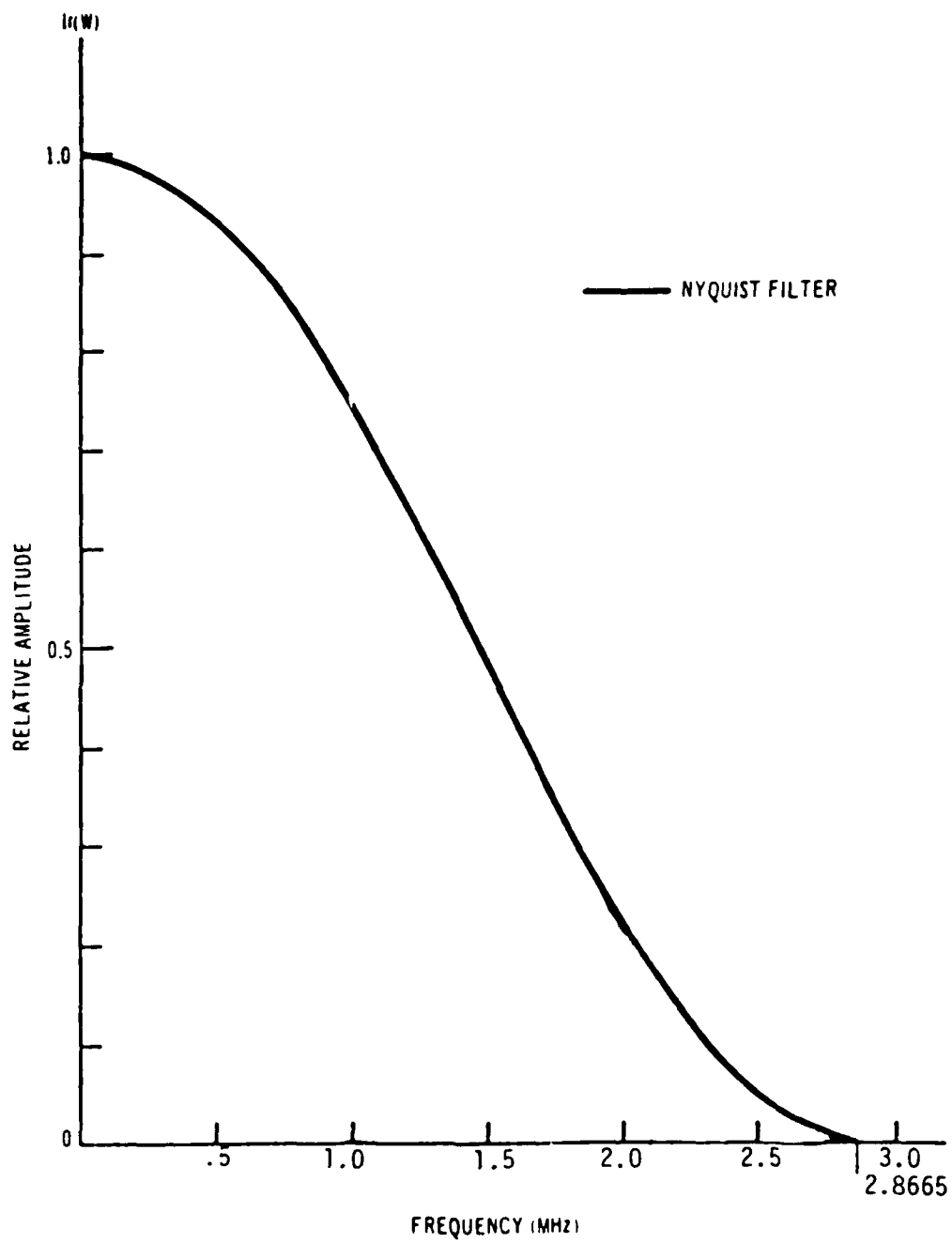


Figure 8-5. Data Spectrum After 100% Roll-Off Nyquist Filter.