DOCUMENT 452-86

OPTICAL SYSTEMS GROUP

VIDEO STANDARDS AND FORMATS

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KWAJALEIN MISSILE RANGE
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DUGWAY PROVING GROUND
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VIDEO STANDARDS AND FORMATS

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Range Commanders Council

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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

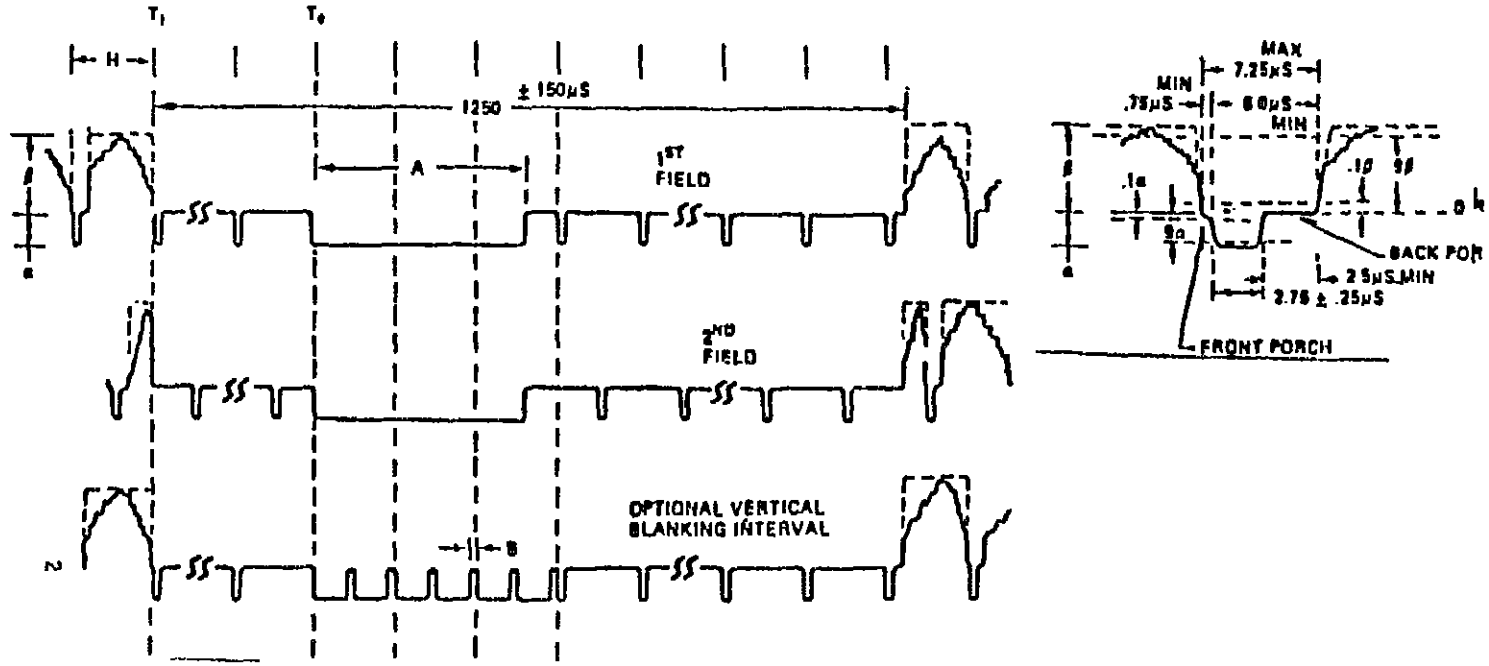
1.1 General

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

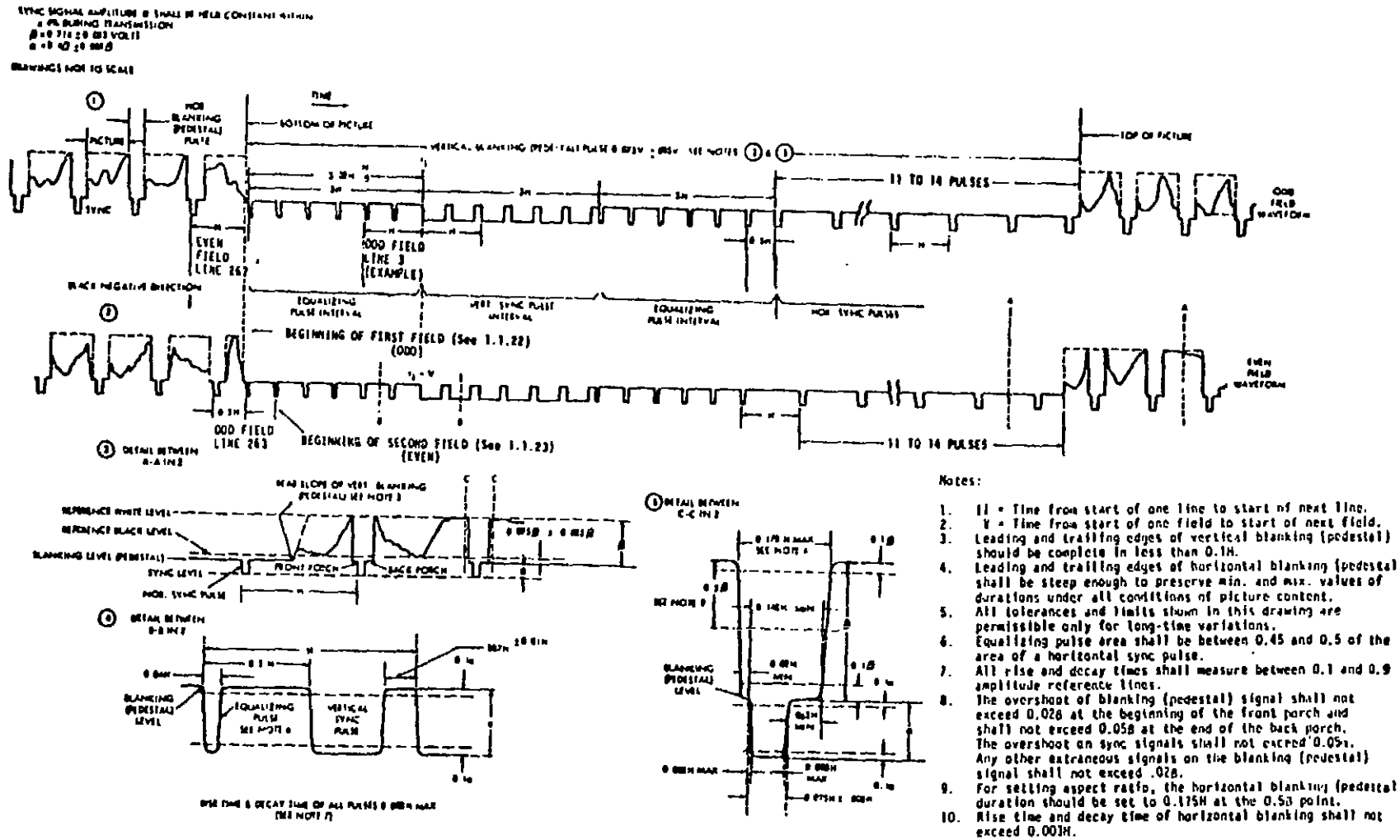
The purpose of this document is to provide users of standard and high resolution monochrome and standard color closed circuit television equipment with the criteria essential for interchange and compatibility of equipment, tape recordings and live signals. These criteria are intended to apply not only 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 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. β = 0.714±0.1 volts (100 IRE Units).
2. α = 0.286 (40 IRE Units) nominal.
3. Sync to total signal ratio $\frac{\alpha}{\beta + \alpha}$ = 28.6±5%.
4. Blanking = 7.5±5 IRE Units (2.5% to 12.5% of β).
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 β at beginning of front porch and 0.05 β at end of back porch.
7. Overshoot on sync signal shall not exceed 0.05 β.
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.
12. Rise and fall times of vertical blanking and vertical sync pulse, measured from 10% to 90% amplitudes, shall be less than 5 µ/s.
13. Tilt on vertical sync pulse shall be less than 0.1α.
14. 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.
15. B - vertical serration = 2±.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.
16. If equalizing pulses are used in the vertical blanking interval waveforms 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.
17. 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.

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



Notes:

1. 1H = Time from start of one line to start of next line.
2. V = Time from start of one field to start of next field.
3. Leading and trailing edges of vertical blanking (pedestal) should be complete in less than 0.1H.
4. Leading and trailing edges of horizontal blanking (pedestal) shall be steep enough to preserve min. and max. values of durations under all conditions of picture content.
5. All tolerances and limits shown in this drawing are permissible only for long-time variations.
6. Equalizing pulse area shall be between 0.45 and 0.5 of the area of a horizontal sync pulse.
7. All rise and decay times shall measure between 0.1 and 0.9 amplitude reference lines.
8. The overshoot of blanking (pedestal) signal shall not exceed 0.02δ at the beginning of the front porch and shall not exceed 0.05δ at the end of the back porch. The overshoot on sync signals shall not exceed 0.05δ. Any other extraneous signals on the blanking (pedestal) signal shall not exceed .02δ.
9. For setting aspect ratio, the horizontal blanking (pedestal) duration should be set to 0.175H at the 0.5δ point.
10. Rise time and decay time of horizontal blanking shall not exceed 0.001H.

Figure 1-2. Standard Monochrome Video Signal Characteristics.

TABLE 1-1

HIGH RESOLUTION TV SYSTEM PARAMETERS

Lines/ Frame	(1) Active Lines	(2) Ver. Res Rv	(3) f_h KHz	(4) t_h µsecs	(5) t_{h_a} µsecs	Fundamental Generated Frequency (MHz)(8)							
						R_hMHz(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 µsecs nominal.

Horizontal Blanking = 7 µsecs 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 µsecs).
(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 quate 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.

l. **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 $\pm$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$\pm$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 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 ± 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 Circle)	Nominal Reflectance Relative to MgO (Percent)	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 ambiquity, 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 appproach 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

instrumention 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 standardizaion 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

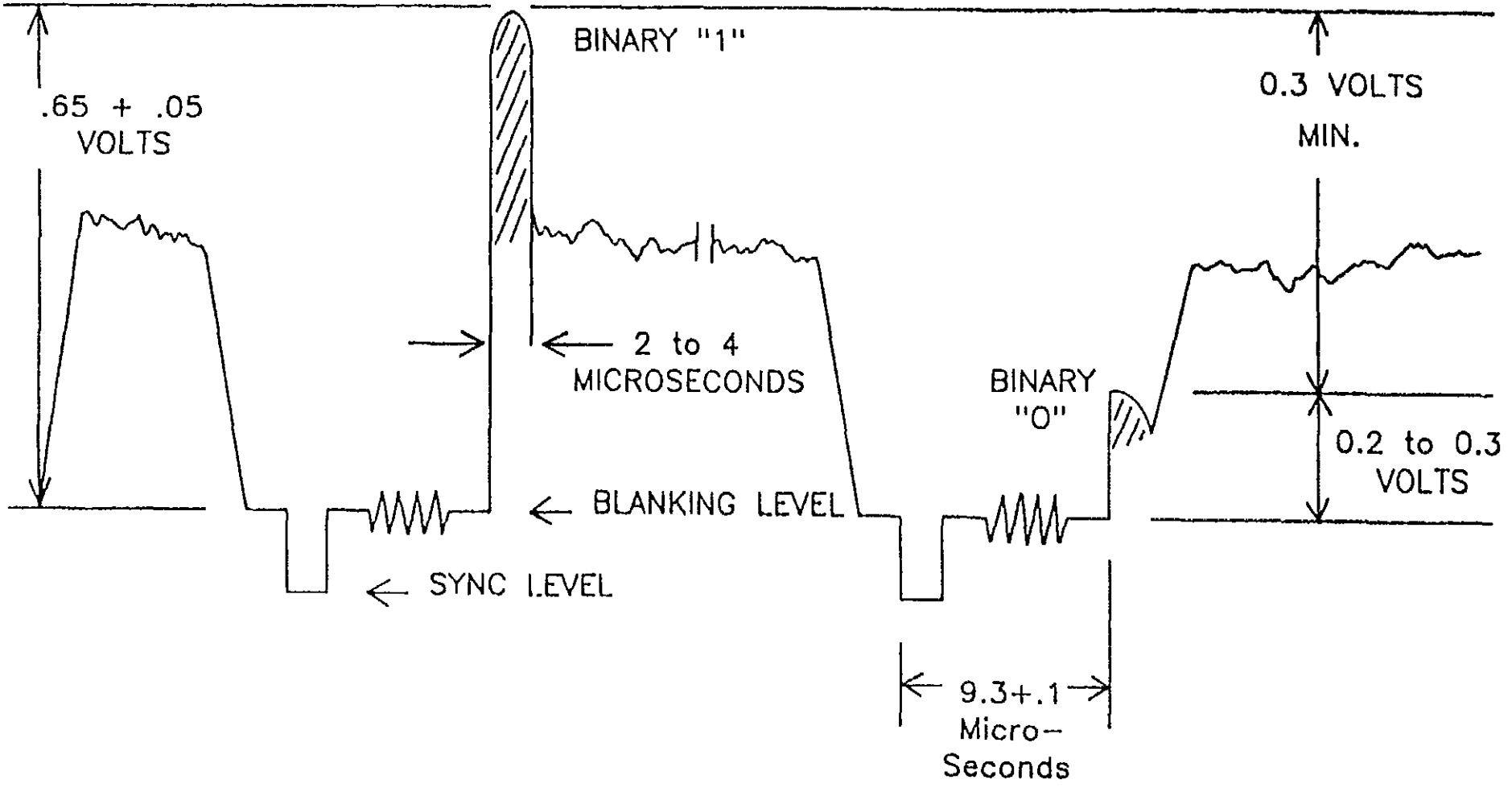


Figure 7-1. Video Signal Plus Binary Data.

FORMAT FOR EACH 12-BIT GROUP IN THE DATA BLOCK

$D_7\ D_6\ D_5\ D_4\ D_3\ D_2\ D_1\ D_0\ H_3\ H_2\ H_1\ H_0$

WHERE: D_7 is encoded first in time, then D_6, D_5, etc.

D = Data Bit

H = Normal Polarity Hamming Bit (See Polarity, figure 7-1.)

H_0 = D_0 ⊕* D_1 ⊕ D_3 ⊕ D_4 ⊕ D_6

H_1 = D_0 ⊕ D_2 ⊕ D_3 ⊕ D_5 ⊕ D_6

H_2 = D_1 ⊕ D_2 ⊕ D_3 ⊕ D_7

H_3 = D_4 ⊕ D_5 ⊕ D_6 ⊕ D_7

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 = Data Bit n Interpreted (Corrected if Necessary)

d_n = Data Bit n Transmitted (Raw)

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

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

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

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

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 millseconds. 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.

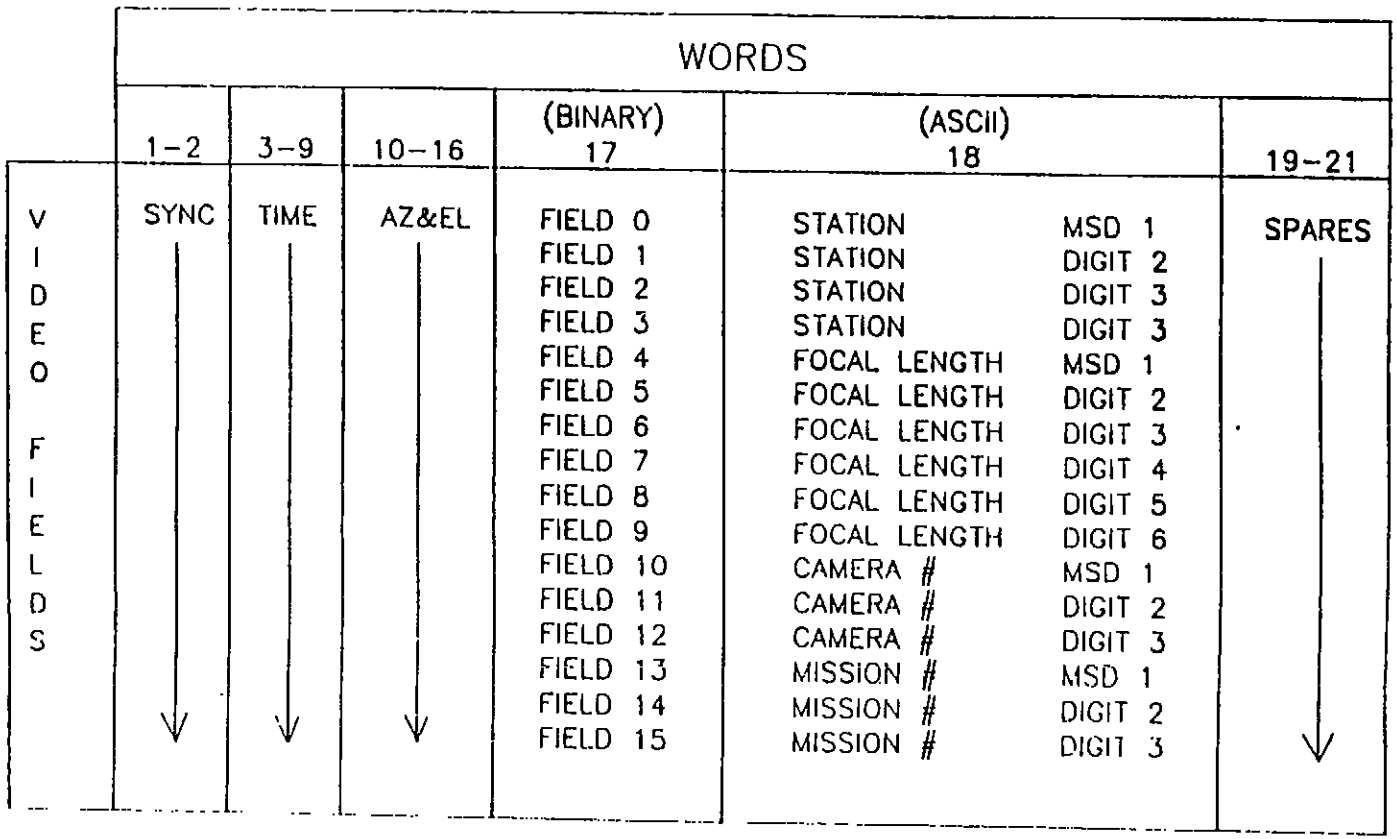


Figure 7-4. WSMR Capacity Usage.

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.

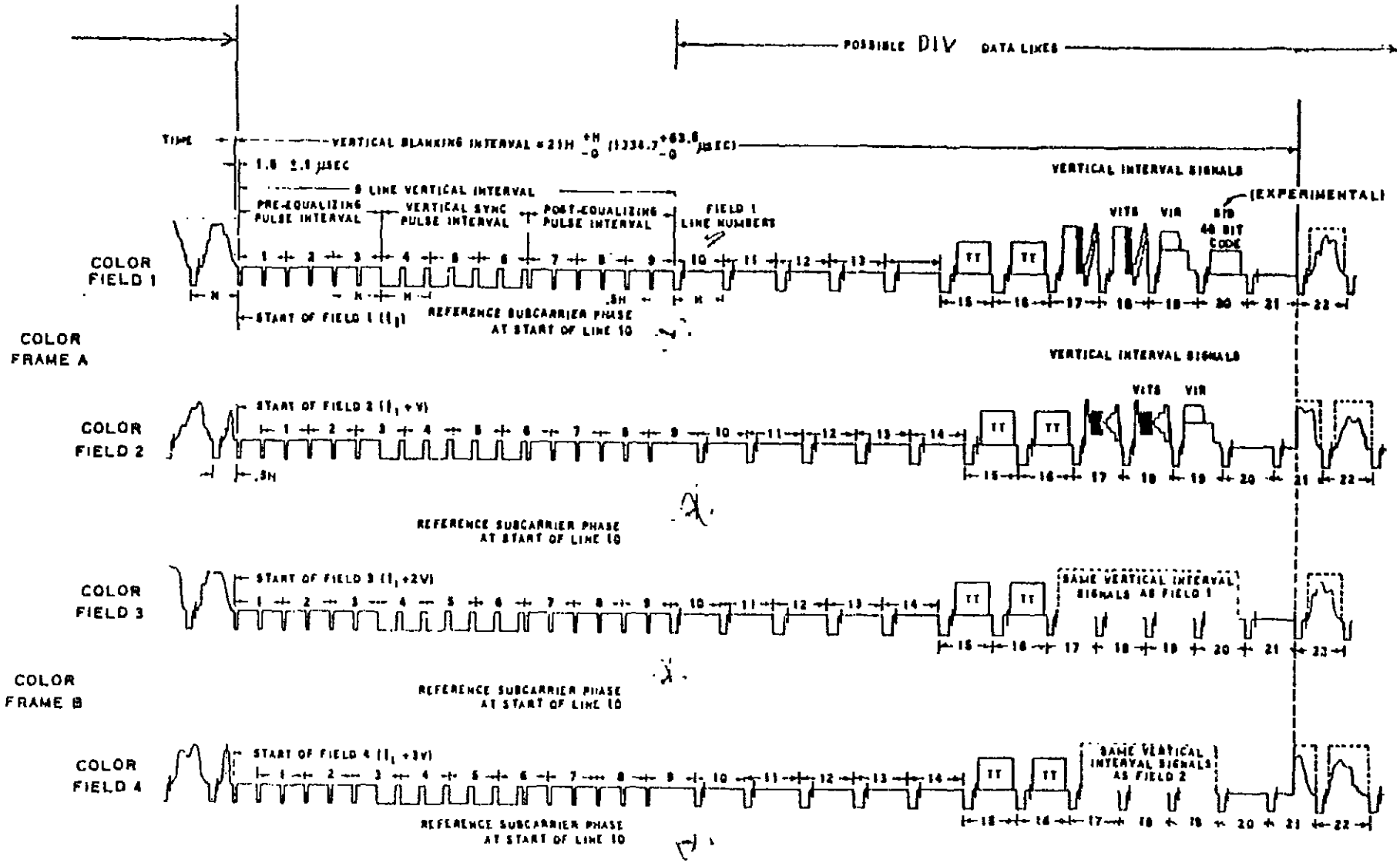


Figure 8-1. Composite Video Signal.

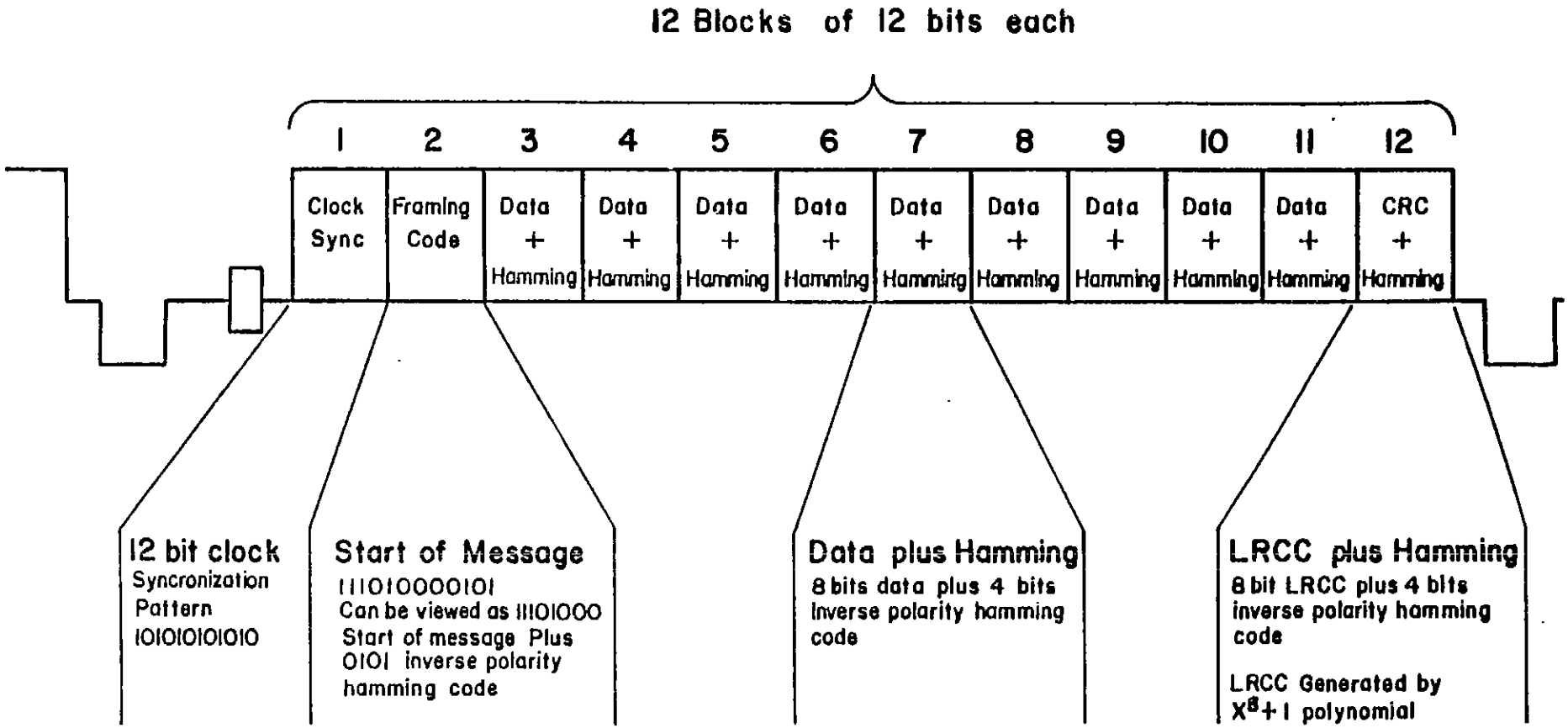


Figure 8-2. Encoded Line Format.

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 $\pm$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 $\pm$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.

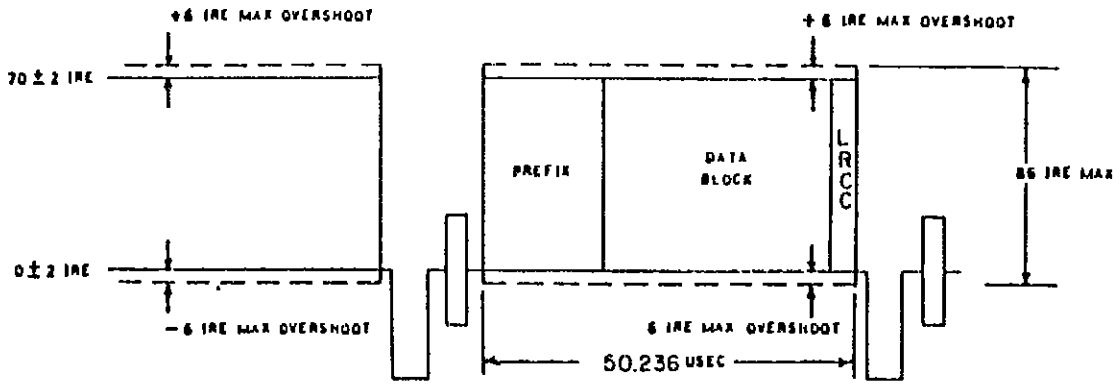
8.10 A Hamming error correction code is used in each data group and in the error detection (LRCC) group (see figure 8-2). Details of the Hamming code generation and format are shown in figure 7-2A and table 8-1. Details of the Hamming code interpretation upon decoding in the presence of noise are shown 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 ± 2 IRE units)

A data "0" is recorded as a low (0 ± 2 IRE units)

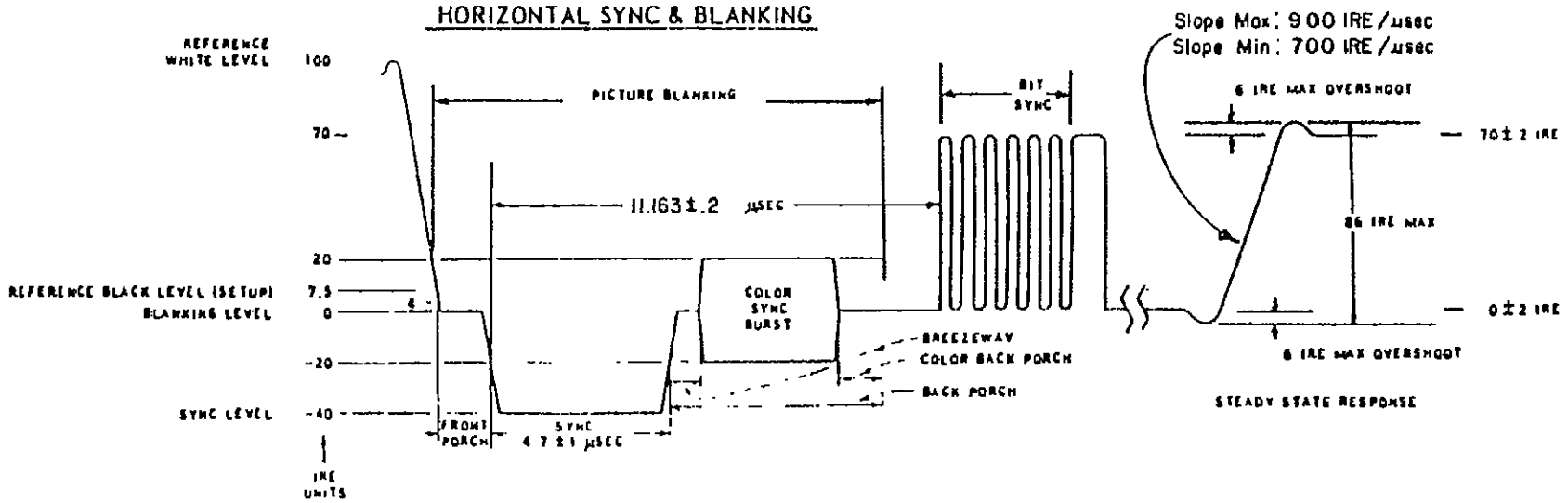
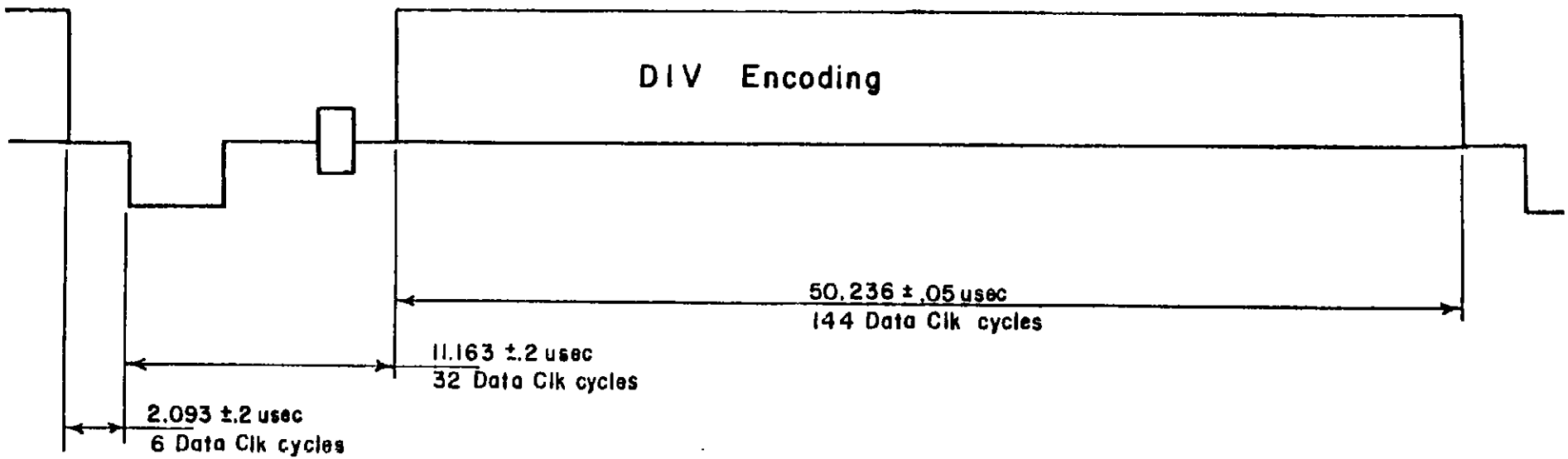


Figure 8-3. Amplitude and Slopes.



Bit Rate (Data Clk) = 182 x the video horizontal line rate = 2.8665 MHz for monochrome.

For color, either 182 x 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 H 3	H 2	H 1	H 0	INVERSE CODE 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 0 1 1	0	1	1	0	1	0	0	1
4	0 0 0 0 0 1 0 0	0	1	1	0	1	0	0	1
5	0 0 0 0 0 1 0 1	0	1	0	1	1	0	1	0
6	0 0 0 0 0 1 1 0	0	0	1	1	1	1	0	0
7	0 0 0 0 0 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 0 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	0	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	0	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	0	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 0 0	1	0	0	0	0	1	1	1
29	0 0 0 1 1 1 0 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	0	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 0 0	1	0	1	1	0	1	0	0
45	0 0 1 0 1 1 0 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	1	0	1	0	0	1
53	0 0 1 1 0 1 0 1	0	1	0	0	1	0	1	1
54	0 0 1 1 0 1 1 0	0	0	1	1	1	1	0	0

55	0	0	1	1	0	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	0	0	0	0
58	0	0	1	1	1	0	1	0	0	0	1	1	1	1	0	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	0	1	0	0	1	1	1	0	0	0
83	0	1	0	1	0	0	0	1	1	0	1	0	1	0	1	1
84	0	1	0	1	0	0	1	0	0	0	1	0	0	1	1	1
85	0	1	0	1	0	0	1	0	1	0	1	1	1	0	0	0
86	0	1	0	1	0	0	1	1	0	0	0	0	1	1	1	0
87	0	1	0	1	0	0	1	1	1	0	0	1	0	1	1	1
88	0	1	0	1	1	0	0	0	0	0	1	0	1	1	0	1
89	0	1	0	1	1	0	0	0	1	0	1	1	0	1	0	1
90	0	1	0	1	1	0	0	1	0	0	0	0	0	1	1	1
91	0	1	0	1	1	0	0	1	1	0	0	1	1	1	0	0
92	0	1	0	1	1	1	0	0	0	0	0	1	1	1	0	0
93	0	1	0	1	1	1	0	0	1	0	0	0	0	1	1	1
94	0	1	0	1	1	1	0	1	0	0	1	1	0	1	0	1
95	0	1	0	1	1	1	0	1	1	0	1	0	1	1	1	0
96	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	0
97	0	1	1	0	0	0	0	0	1	0	0	1	0	1	1	1
98	0	1	1	0	0	0	0	1	0	0	1	0	0	1	1	0
99	0	1	1	0	0	0	0	1	1	0	1	1	1	1	0	0
100	0	1	1	0	0	0	1	0	0	0	1	1	1	1	0	0
101	0	1	1	0	0	0	1	0	1	0	1	0	0	1	1	1
102	0	1	1	0	0	0	1	1	0	0	0	1	0	1	1	1
103	0	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0
104	0	1	1	0	1	0	0	0	0	0	1	1	0	1	0	1
105	0	1	1	0	1	0	0	0	1	0	1	0	1	1	0	0
106	0	1	1	0	1	0	0	1	0	0	0	1	1	1	0	0
107	0	1	1	0	1	0	0	1	1	0	0	0	0	1	1	1
108	0	1	1	0	1	1	0	0	0	0	0	0	0	1	1	1
109	0	1	1	0	1	1	0	0	1	0	0	0	1	1	0	0
110	0	1	1	0	1	1	0	1	0	0	1	0	1	1	0	0
111	0	1	1	0	1	1	1	0	1	0	1	1	0	1	0	1
112	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	1
113	0	1	1	1	0	0	0	0	1	1	0	1	1	0	0	0
114	0	1	1	1	0	0	0	1	0	1	1	0	1	0	0	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	0	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
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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	0	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 IN / DATA OUT (Hexadecimal notation is used)

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 03	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 0A	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 50	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
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230 A3	231 21	232 27	233 37	234 23	235 33	236 03	237 63
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240 A4	241 26	242 20	243 30	244 24	245 34	246 04	247 64
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440 46	441 C4	442 50	443 40	444 54	445 44	446 04	447 64
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860 92	861 82	862 84	863 06	864 C6	865 A6	866 96	867 86
868 8E	869 82	86A 84	86B 86	86C 87	86D 86	86E 86	86F 86
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880 C8	881 A8	882 98	883 88	884 9C	885 8C	886 8A	887 08
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8C0 8C	8C1 0C	8C2 98	8C3 88	8C4 9C	8C5 8C	8C6 CC	8C7 AC
8C8 8E	8C9 8C	8CA 84	8CB 88	8CC 8C	8CD 8C	8CE 8D	8CF 8C
8D0 89	8D1 99	8D2 0D	8D3 8F	8D4 AD	8D5 CD	8D6 8D	8D7 9D
8D8 89	8D9 85	8DA 8D	8DB 8F	8DC 8D	8DD 8C	8DE 8D	8DF 8D
8E0 8E	8E1 9E	8E2 AE	8E3 CE	8E4 0E	8E5 8C	8E6 8A	8E7 9A
8E8 8E	8E9 8E	8EA 8E	8EB 8F	8EC 8E	8ED 8C	8EE 8A	8EF 86
8F0 CF	8F1 AF	8F2 9F	8F3 8F	8F4 9B	8F5 8B	8F6 8D	8F7 0F
8F8 8E	8F9 8F	8FA 8F	8FB 8F	8FC 87	8FD 8B	8FE 8D	8FF 8F
900 92	901 90	902 98	903 94	904 90	905 90	906 91	907 90
908 92	909 10	90A 84	90B 94	90C 80	90D 90	90E D0	90F B0
910 95	911 99	912 91	913 93	914 91	915 90	916 91	917 91
918 95	919 85	91A 11	91B 93	91C B1	91D D1	91E 91	91F 81

920 92	921 92	922 92	923 93	924 92	925 90	926 96	927 9A
928 92	929 82	92A B2	92B D2	92C 12	92D 90	92E 96	92F 86
930 92	931 93	932 93	933 93	934 9B	935 97	936 91	937 93
938 D3	939 B3	93A 83	93B 93	93C 87	93D 97	93E 91	93F 13
940 95	941 94	942 94	943 94	944 9C	945 90	946 96	947 9[illegible]
948 D4	949 B4	94A 84	94B 94	94C 80	94D 90	94E 96	94F 1[illegible]
950 95	951 95	952 95	953 94	954 95	955 97	956 91	957 9D
958 95	959 85	95A B5	95B D5	95C 15	95D 97	95E 91	95F 81
960 92	961 9E	962 96	963 94	964 96	965 97	966 96	967 96
968 92	969 82	96A 16	96B 94	96C B6	96D D6	96E 96	96F 86
970 95	971 97	972 9F	973 93	974 97	975 97	976 96	977 97
978 95	979 17	97A 83	97B 93	97C 87	97D 97	97E D7	97F 87
980 98	981 99	982 98	983 98	984 9C	985 90	986 98	987 9A
988 B8	989 D8	98A 98	98B 88	98C 9C	98D 8C	98E 18	98F 9A
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998 89	999 99	99A D9	99B B9	99C 9B	99D 19	99E 8D	99F 9D
9A0 92	9A1 9E	9A2 98	9A3 9A	9A4 9B	9A5 9A	9A6 9A	9A7 9A
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9B0 9B	9B1 99	9B2 9F	9B3 93	9B4 9B	9B5 9B	9B6 9B	9B7 9A
9B8 1B	9B9 99	9BA 9F	9BB 8F	9BC 9B	9BD 8B	9BE BB	9BF DB
9C0 9C	9C1 9E	9C2 98	9C3 94	9C4 9C	9C5 9C	9C6 9C	9C7 9D
9C8 1C	9C9 9E	9CA 98	9CB 88	9CC 9C	9CD 8C	9CE BC	9CF DC
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9D8 89	9D9 99	9DA 9F	9DB 1D	9DC DD	9DD BD	9DE 8D	9DF 9D
9E0 9E	9E1 9E	9E2 9F	9E3 9E	9E4 9C	9E5 9E	9E6 96	9E7 9A
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9F8 BF	9F9 DF	9FA 9F	9FB 8F	9FC 9B	9FD 8B	9FE 1F	9FF 9D
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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 AB
A38 A3	A39 B3	A3A 83	A3B E3	A3C 23	A3D A1	A3E A7	A3F B7
A40 A4	A41 A4	A42 A4	A43 A5	A44 A4	A45 A6	A46 A0	A47 AC
A48 A4	A49 B4	A4A 84	A4B E4	A4C 24	A4D A6	A4E A0	A4F BC
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A58 E5	A59 85	A5A B5	A5B A5	A5C B1	A5D A1	A5E A7	A5F 25
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 97
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
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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 A3
AA8 2A	AA9 A8	AAA AE	AAB BE	AAC AA	AAD BA	AAE BA	AAF 2A
AB0 A3	AB1 AF	AB2 A9	AB3 A8	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

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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 A8   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 BD   BFE BB   BFF B7
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 DC
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 CB
CB8 CF   CB9 DF   CBA 4B   CBB C9   CBC EB   CBD 8B   CBE CB   CBF DB
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
CD8 CF   CD9 4D   CDA D9   CDB C9   CDC DD   CDD CD   CDE 8D   CDF DD
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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	C0
D48	D4	D49	D4	D4A	D4	D4B	D5	D4C	D4	D4D	D6	D4E	D0	D4F	DC
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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
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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
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DC8	D4	DC9	D8	DCA	DE	DCB	DC	DCC	DD	DCD	DC	DCE	DC	DCF	DC
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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	DFE	D7	DFF	DB
E00	E2	E01	60	E02	F4	E03	E4	E04	F0	E05	E0	E06	A0	E07	C0
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E10	E5	E11	F5	E12	61	E13	E3	E14	C1	E15	A1	E16	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	52	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	C4	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
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E88	E8	E89	E9	E8A	E8	E8B	E8	E8C	EC	E8D	E0	E8E	E8	E8F	CA
E90	F9	E91	E9	E92	A9	E93	C9	E94	EB	E95	69	E96	FD	E97	ED
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EB0	6B	EB1	E9	EB2	EF	EB3	FF	EB4	EB	EB5	FB	EB6	CB	EB7	AB
EB8	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 DD
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 ED
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 E0	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 E[illegible]	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
FD0 F9	FD1 F5	FD2 FD	FD3 FF	FD4 FD	FD5 FC	FD6 FD	FD7 FD
FD8 F9	FD9 E9	FDA 7D	FDB FF	FDC DD	FDD BD	FDE FD	FDF ED
FE0 FE	FE1 FE	FE2 FE	FE3 FF	FE4 FE	FE5 FC	FE6 FA	FE7 F6
FE8 FE	FE9 EE	FEA DE	FEB BE	FEC 7E	FED FC	FEE FA	FEF EA
FF0 FE	FF1 FF	FF2 FF	FF3 FF	FF4 F7	FF5 FB	FF6 FD	FF7 FF
FF8 BF	FF9 DF	FFA EF	FFB FF	FFC EB	FFD FB	FFE FD	FFF 7F

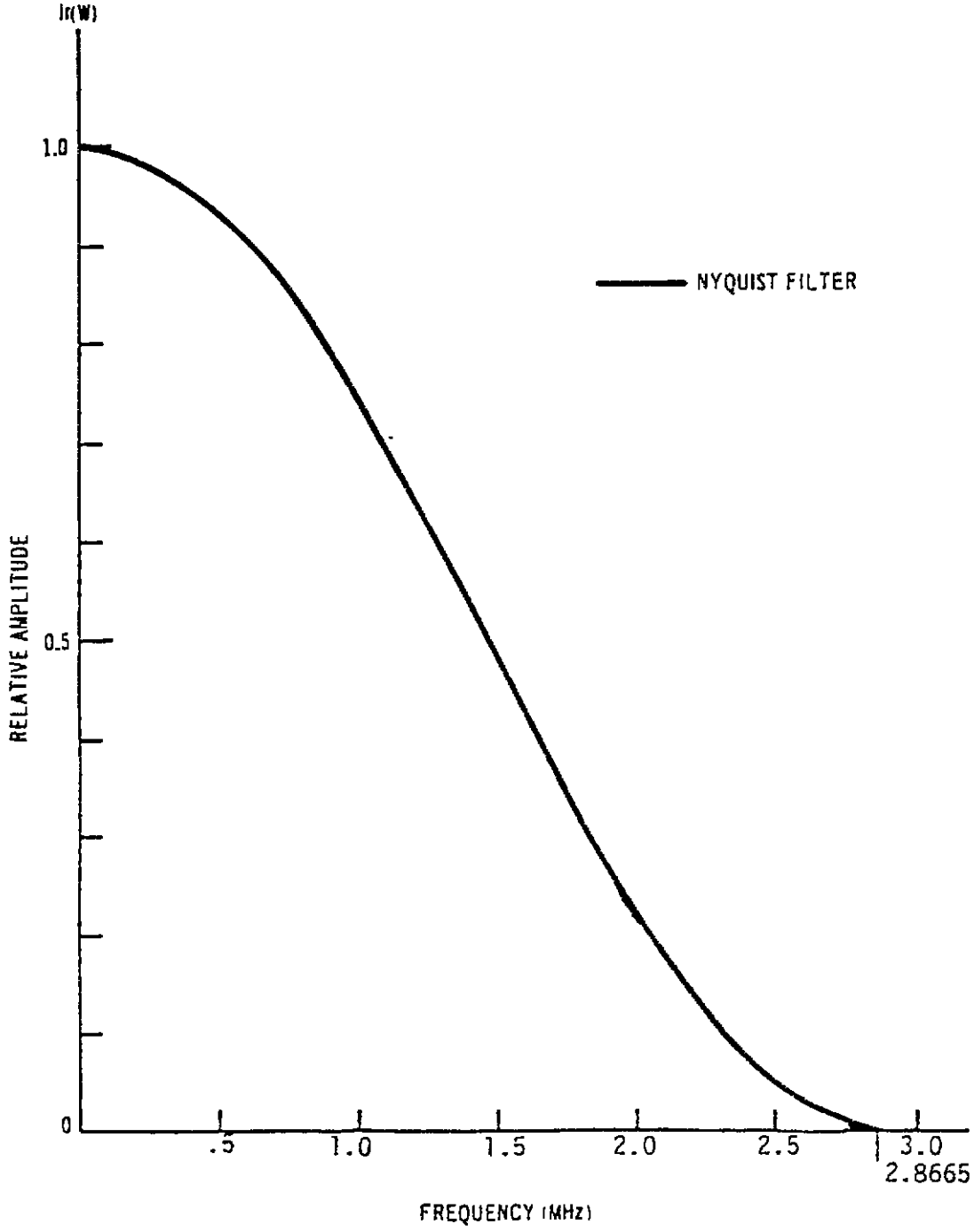

Figure 8-5. Data Spectrum After 100% Roll-Off Nyquist Filter.