

- [54] **VIDEO BANDWIDTH REDUCTION SYSTEM EMPLOYING INTERFRAME BLOCK DIFFERENCING AND TRANSFORM DOMAIN CODING**
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- [51] Int. Cl.<sup>4</sup> ..... **H04N 7/12**
- [52] U.S. Cl. .... **358/133; 358/135**
- [58] Field of Search ..... **358/133, 135, 136, 138, 358/13; 382/43; 364/725, 726, 727, 826, 827**

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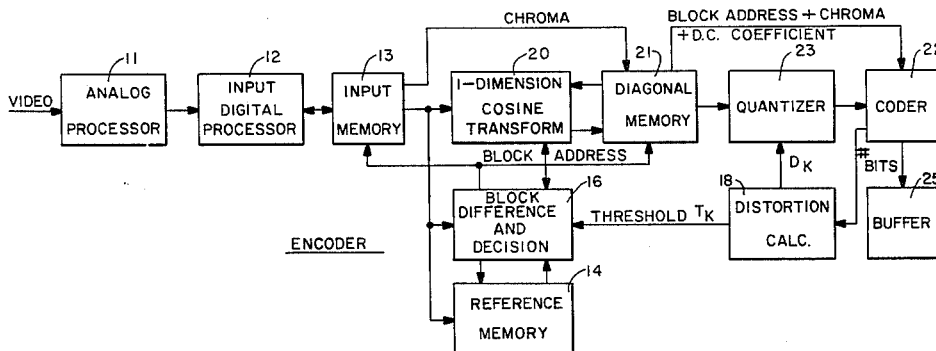
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[57] **ABSTRACT**

Video type information signals are compressed for transmission and reproduction by comparing corresponding blocks of time domain information signals from successive fields, converting a block of the time domain information signals to a transform domain signal represented by discrete cosine transform coefficients when the difference between the corresponding blocks exceeds a block difference threshold, and encoding the transform domain coefficients for transmission to a decoding site. Corresponding blocks of time domain information signals from successive fields are compared by storing the successive fields in memory on a pixel by pixel basis, retrieving each block on a pixel by pixel basis, forming the difference between corresponding pixels from the successive blocks, squaring the resulting difference signal, summing the squares and dividing by the number of pixels per block. Successive fields are merged by weighted summing of corresponding pixels.

**35 Claims, 8 Drawing Figures**



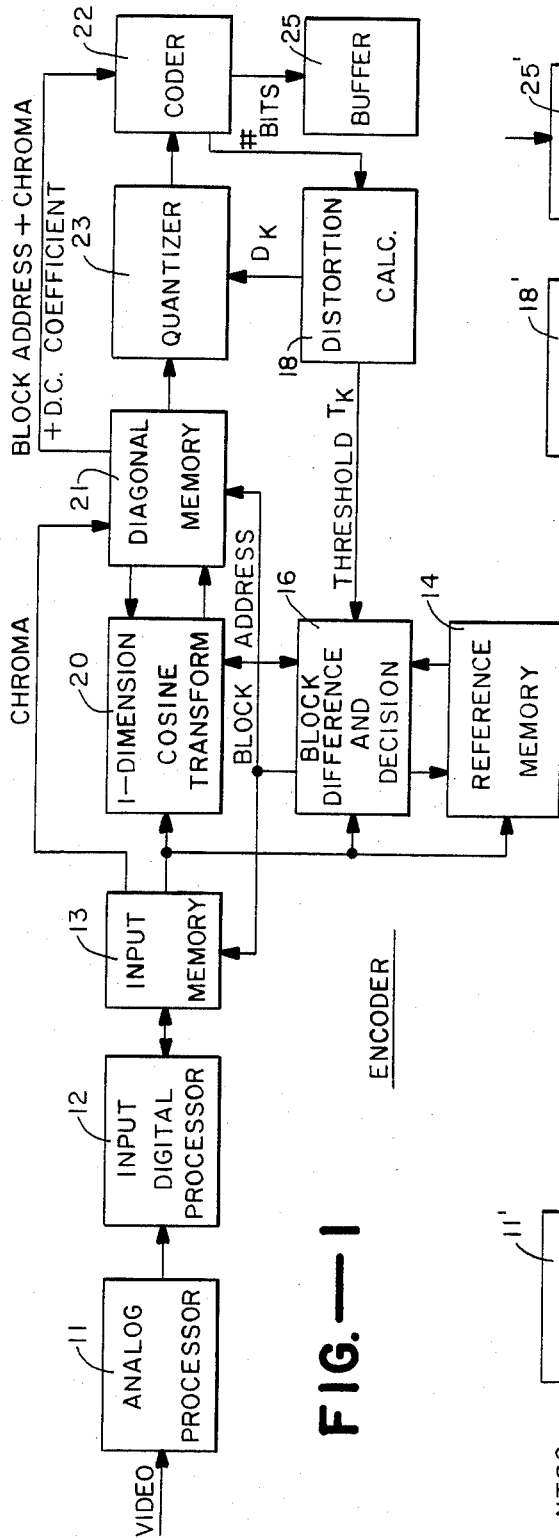


FIG.—1

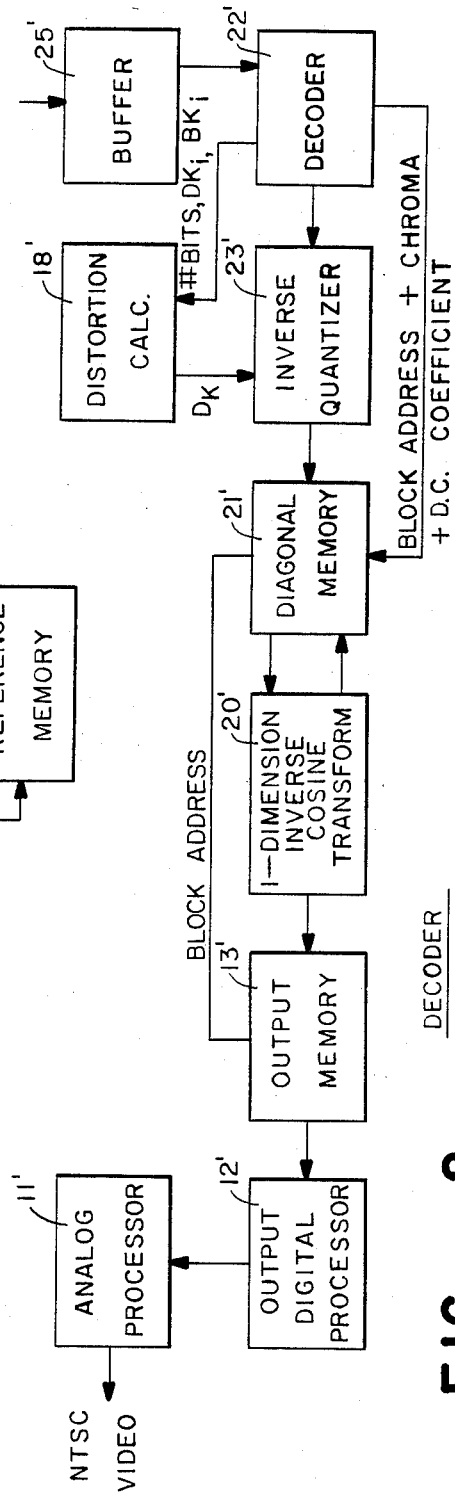


FIG.—2

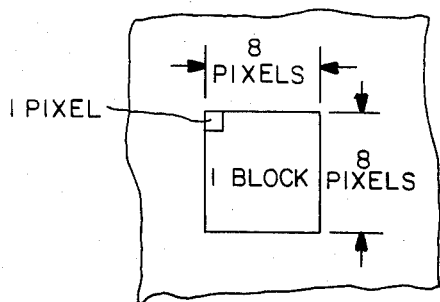


FIG.—3

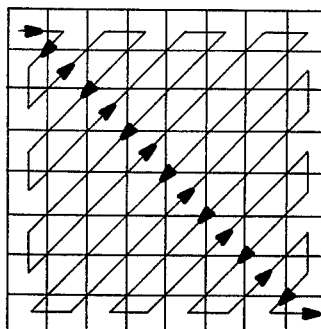


FIG.—5

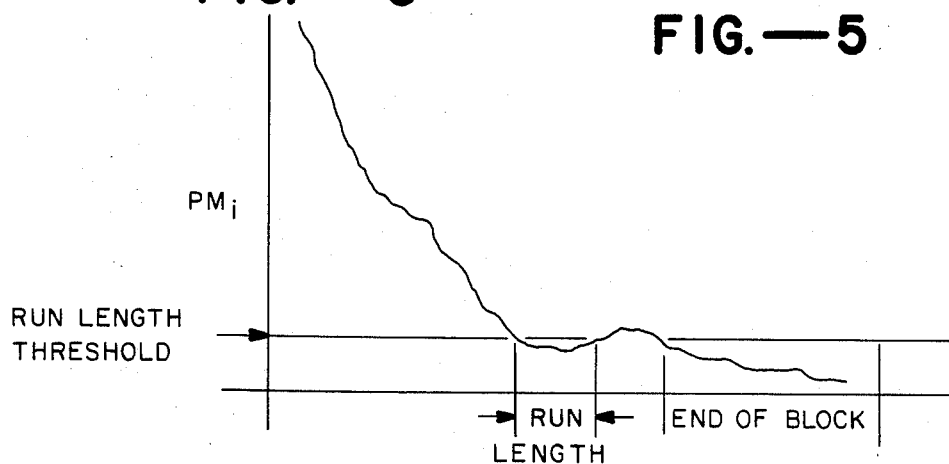


FIG.—7

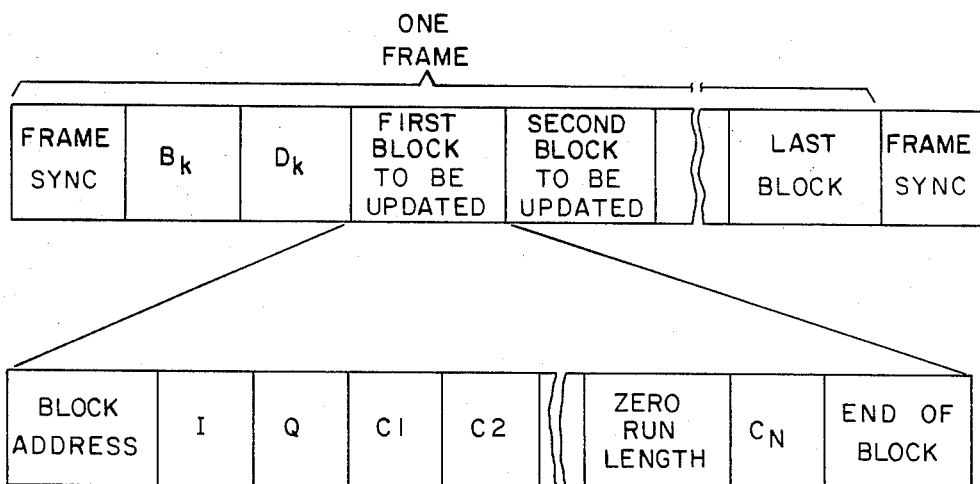


FIG.—8

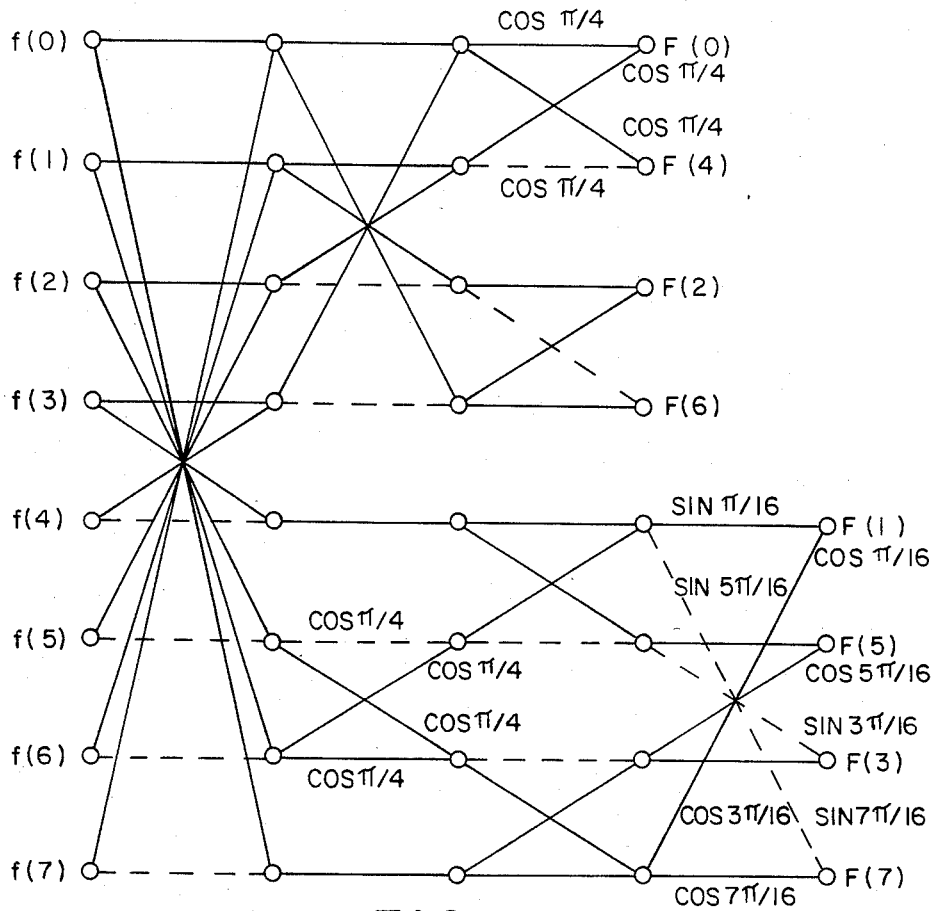


FIG.— 4

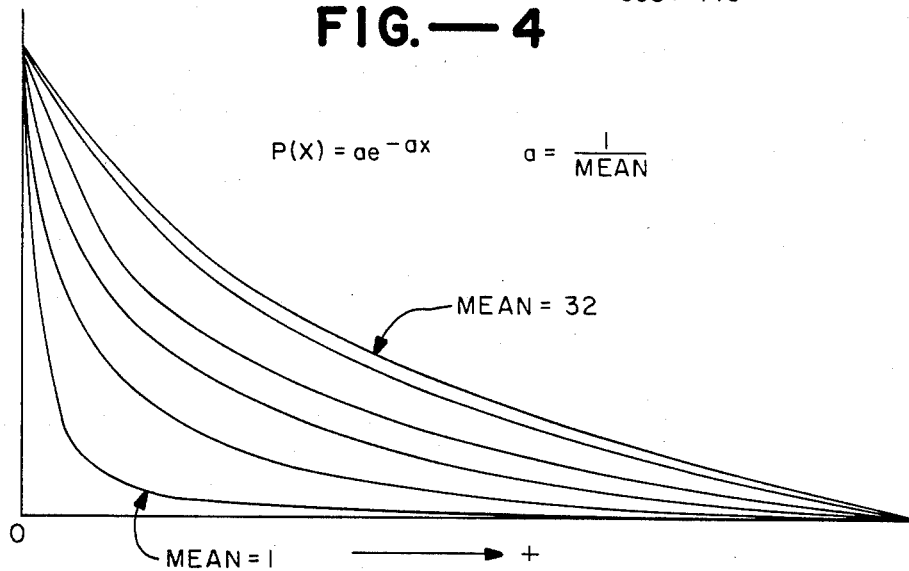


FIG.— 6

**VIDEO BANDWIDTH REDUCTION SYSTEM  
EMPLOYING INTERFRAME BLOCK  
DIFFERENCING AND TRANSFORM DOMAIN  
CODING**

**BACKGROUND OF THE INVENTION**

This invention relates to information signal processing in general, and in particular to the field of processing time sequential information signals (such as video signals) for the purpose of compressing the amount of information to be transferred from an encoding site to a decoding site.

In recent years, increasing efforts have been directed toward providing more efficient information signal encoding techniques used to process time sequential information signals prior to their transmission from a transmitting station to a receiving station. The requirement for more efficient encoding techniques has been prompted by two major factors: firstly, a substantial increase in the quantity of information required to be transferred via communication links and, secondly, maximum occupancy of the communication frequency bands available for voice and data transmission. An early technique employed to reduce the amount of information required to be transferred without substantial degradation is the signal processing technique known as conditional replenishment, described in U.S. Patent No. 3,984,626 to Mounts et al., the disclosure of which is hereby incorporated by reference. Briefly, in the conditional replenishment signal processing technique, individual line element sample signals from a successive field of information are compared with the corresponding line elements in the previous field; and the difference therebetween is tested against a fixed threshold. If the difference exceeds the threshold value, the new value is encoded and transmitted to a receiving station, along with an appropriate address code specifying the line location of the sample to be updated in the field memory of the receiving station. Thus, rather than transmitting each and every line sample for every field, only those samples which differ by a significant threshold amount are transmitted, which substantially reduces the number of samples in the communication channel pipeline. Although this saving in the amount of actual data flowing through the communication pipeline is somewhat offset by the necessity of simultaneously transmitting the address information, this disadvantage is more than overcome by the substantial reduction in the total number of samples which must be transmitted in order to maintain the information current at the decoding site. When used to process video type information signals, an even greater reduction in the required number of transmitted samples is achieved due to the inherent nature of video signals, which possess intrinsic interfield correlation (e.g. abrupt interfield changes for background portions of video images occur relatively infrequently).

Another compression technique known in the art is the use of transform domain encoding, in which each field of information signals is divided into a number of rectangular or square arrays of individual picture elements (for example a 16 pixel by 16 pixel array) termed blocks, and each block is converted to the transform domain. For each converted block, the individual transform coefficients are then encoded and transmitted along with appropriate address codes, as well as additional overhead information (e.g. field start signals,

frame start signals and the like). One such transform domain processing system is disclosed in U.S. Pat. No. 4,189,748 to Reis, the disclosure of which is hereby incorporated by reference.

Although many types of mathematical transform functions have been proposed for implementation in a transform domain signal processing system, in reality most transform functions are inappropriate for implementation due to the complexity of the required logic circuitry. This disadvantage is exacerbated in applications requiring real time signal processing by virtue of the minimum time period required to perform the signal processing necessary to generate the values of the transform coefficients. For a general discussion of the advantages and disadvantages of the different types of transform functions, reference should be had to the collection of technical publications entitled "Image Transmission Techniques, Advances in Electronics and Electron Physics, Supplement 12", Pratt, Academic Press, 1979, particularly the section entitled "Transform Image Coding".

**SUMMARY OF THE INVENTION**

The invention comprises a method and system for processing time domain information signals which combines the advantages of conditional replenishment and transform domain coding in such a manner that information signal compression of a magnitude substantially greater than that available in known systems is achieved while affording real time information signal processing.

In its broadest aspect, the invention provides a method of processing time domain information signals having a successive field format to effect substantial compression of the signals, the method including the steps of comparing corresponding blocks of time domain information signals from successive fields, converting a block of the time domain information signals to a transform domain signal represented by discrete cosine transform coefficients when the difference between the corresponding blocks exceeds a first variable parametric value, and encoding the transform domain coefficients for subsequent utilization, e.g. transmission from a transmitting station to a receiving station, recording on video tape or other magnetic media, etc. The corresponding blocks of time domain information signals from successive fields are compared by storing the successive fields in memory on a pixel by pixel basis, retrieving the corresponding blocks from memory also on a pixel by pixel basis, forming the difference between corresponding pixels from the successive blocks, squaring the resulting difference signal, summing the squares of the resulting difference signals, and dividing the resulting sum by the number of pixels per block. In the preferred embodiment, the method is optimized by employing a total of 64 pixels per block arranged in an 8 by 8 array and by merging successive fields on a pixel by pixel basis, the merging being performed by summing corresponding pixels from successive fields in accordance with a predetermined weighting factor of  $\frac{3}{4}$  for the earlier appearing (previously merged) field and  $\frac{1}{4}$  for the later appearing field.

The conversion of a block of the time domain information signals to the transform domain is accomplished by first transforming the individual block samples along a first direction, which is the horizontal line direction in the preferred embodiment, and subsequently transforming the same block samples along the orthogonal direc-

tion, which is the vertical direction in the preferred embodiment. For each transformed block, the individual block samples corresponding to the previous field are replaced with the updated block information, and the transformed coefficients for the converted block are stored in diagonal format in a diagonal memory unit. In addition, an address code indicating the field address of a transformed block is also stored in the diagonal memory for subsequent encoding.

The transform coefficients for each converted block stored in the diagonal memory are encoded using a plurality of different code tables, one of the tables being dedicated to the first coefficient in each diagonal group, corresponding to the DC term and representing the average signal intensity of the converted block, and the remaining tables being selected on a coefficient by coefficient basis. Specifically, each transform coefficient (other than the first or DC coefficient) is first quantized by digitally dividing the coefficient by a variable parametric value  $D_K$ , after which the predictive mean value of each quantized coefficient is calculated by summing a weighted portion of the actual value of that quantized coefficient with the predictive mean value of the previous quantized coefficient weighted by a different factor, and the newly calculated predictive mean value is used to select that one of the several available individual code tables capable of encoding the quantized coefficient value with a minimum number of binary bits. In addition to the tables noted above, separate tables are provided for encoding the block address of the encoded transform coefficients, for directly encoding the D.C. coefficient, and for run length coding certain coefficient values. In the case of time domain information signals comprising color video signals with quadrature components two preselected quantized coefficient code tables are used to represent the average value of each color quadrature component of the corresponding converted block.

To further compress the amount of information encoded prior to utilization, those successive transform coefficients with zero value whose predictive mean lies below the value of a preselected fixed threshold are transmitted as a run length code. In addition, when the predictive values for successive remaining cosine coefficients in the converted block lie below the preselected fixed threshold, a single end-of-block code is generated.

The codes corresponding to a given converted block are transferred at a available rate to a rate buffer in the order of generation prior to utilization, and the number of binary bits transferred to the buffer is monitored in order to gauge the buffer fullness. The dynamic occupancy of the buffer is used to control the value of the variable parametric value  $D_K$  in order to minimize the possibility of buffer overflow, utilizing a special algorithm. The buffer fullness state is also used to control the first variable parametric value—termed the block difference threshold  $T_K$ —also by employing a special algorithm. Thus, as the rate buffer approaches the completely filled state, the magnitude of  $D_K$  is increased, which increases the minimum quantizing interval employed in sampling the transform coefficients during the encoding process. In addition, the block difference threshold  $T_K$  is similarly increased to reduce the number of blocks selected for conversion to the transform domain and subsequent encoding. Similarly, as the state of the buffer fullness decreases, both  $D_K$  and  $T_K$  are lowered in value in accordance with the special algorithms employed in order to increase the number of

blocks selected for conversion to the transform domain and to decrease the minimum quantization interval used in the encoding process.

The codes representing the converted blocks are formatted in the rate buffer in the following fashion. The start of each frame is denoted by a frame sync code signal, which is followed by a first control code signal representative of the buffer fullness at the beginning of the frame and a second control code signal representative of the quantizing interval  $D_K$  value at the beginning of the same frame. The control code signals are followed by individual block replenishment code symbols which include a block address code specifying the field address of the corresponding block, the DC code term representative of the average intensity of the corresponding block, and the plurality of coefficient code terms representative of the predictive mean value of the transform coefficients for the corresponding block. For color video signal processing, the quadrature component code terms are included between the block address code and the DC code term. The termination of the last block is signified by the subsequent appearance of the frame sync code signal for the next succeeding frame.

The decoding process is essentially the inverse of the encoding process. For each frame of encoded information, the first and second control code signals are used to establish the initial minimum quantization interval to be employed for inverse quantizing the block replenishment code symbols. The received replenishment code symbols are decoded using a parallel set of inverse code tables, which are selected using the same predictive mean algorithm as that employed in the encoding process. The block address, quadrature chrominance and D.C. term codes are coupled directly to a diagonal memory unit, while the coefficient code terms are inverse quantized by multiplying each code term by  $D_k$ , using the transmitted initial value of  $D_K$  for the first block of data, and the resulting coefficients are stored in the diagonal memory unit. After the first block has been decoded, the distortion constant  $D_k$  is recalculated and the newly calculated value of  $D_k$  is used to inverse quantize the next block of data.

The coefficients stored in the diagonal memory unit are then transformed to time domain digital samples using an inverse discrete cosine transform, and the resulting samples are stored in an output memory unit, replacing previous samples representing the same block. The merged field samples stored in the output memory unit, which replicate the merged field samples stored in a corresponding reference memory unit at the encoder side, are finally processed to provide video output signals.

Further compression is achieved according to the invention by special initial processing of the luminance and chrominance samples. The luminance signals are sub-sampled at less than the standard rate (which is 512 lines/frame and 512 samples/line for NTSC video), the preferred embodiment employing 256 lines/frame and 256 samples/line. Each quadrature chrominance component is sub-sampled at less than the standard rate and averaged over a given block. In the preferred embodiment, each quadrature component is sub-sampled at one-half the standard rate for each block line and the sub-samples for each block line are averaged, after which each block line average is combined to obtain a block average. Prior to averaging, each chrominance component sample is further modified by discarding the two least significant bits of the sample. After trans-

mission from an encoding site to a decoding site, the full range of luminance and chrominance samples is recovered by individual interpolative processing of the received luminance and chrominance samples.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram illustrating an encoder incorporating the invention;

FIG. 2 is a block diagram illustrating a decoder incorporating the invention;

FIG. 3 is a schematic view of a portion of a display screen illustrating the replenishment block size;

FIG. 4 is a trellis diagram illustrating the cosine transform algorithm employed in the preferred embodiment;

FIG. 5 is a schematic diagram illustrating the manner in which transform coefficients are stored in a diagonal memory unit;

FIG. 6 is set of probability distribution curves illustrating the manner in which the quantized coefficient encoding tables are constructed;

FIG. 7 is a schematic diagram illustrating typical predictive mean values for a single block; and

FIG. 8 is a schematic diagram illustrating the code formatting for one frame of replenishment information.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

Turning now to the drawings, FIG. 1 is a block diagram illustrating a preferred embodiment of the encoded portion of the invention. As seen in this FIG., analog video signals are coupled to the input of an analog processor unit 11 in which composite video input signals are separated into the standard luminance and quadrature chrominance components and converted to multi-bit digital samples at a predetermined sampling rate. In the preferred embodiment eight bit digital samples are taken at a 10.7 MHz sampling rate. The equivalent digital samples produced in analog processor unit 11 are coupled to the input of an input digital processor 12 in which incoming field samples are merged with the corresponding samples from the previous field in the manner described below. The resulting individual merged field samples from input digital processor 12 are stored in an input memory unit 13 having a sufficient capacity to contain one field of digital information. An additional memory unit 14, termed a reference memory, is coupled to the data output of input memory unit 13. Reference memory unit 14 stores a reference field of information for comparison with a newly merged field stored in input memory unit 13, and has the same capacity as input memory unit 13.

In operation, the individual digital samples from an incoming field supplied to input digital processor 12 are added to the corresponding digital samples of the previously merged field stored in input memory unit 13 on a weighted basis, and the resulting weighted sums are stored in input memory unit 13, replacing the previously stored samples on a pixel by pixel basis. In the preferred embodiment, the samples are weighted by a factor of 3 to 1 between the older samples stored in the input memory unit 13 and the incoming field samples, i.e. the earlier samples are multiplied by a factor of  $\frac{3}{4}$ , the later samples are multiplied by the factor of  $\frac{1}{4}$  and the resulting weighted samples are added together. The weighting multiplication and the addition are accomplished with conventional digital multipliers and ad-

ders, in combination with appropriate conventional addressing logic.

Each newly merged field stored in input memory unit 13 is compared on a block by block basis with the reference field stored in reference memory unit 14 by means of a block difference and decision unit 16. As illustrated in FIG. 3, each block element consists of a rectangular array of 8 pixels by 8 pixels, and the difference between each block is obtained by digitally subtracting corresponding pixel samples read from input memory unit 13 and reference memory unit 14 in block difference and decision unit 16, squaring the resulting difference signals, summing the squares of the resulting difference signals, and dividing the resulting sum by the number of pixels per block (64). Each block difference value so obtained is tested against a threshold  $T_K$  supplied from a distortion calculation unit 18. If the block difference exceeds the threshold, the corresponding block in input memory unit 13 is converted to a set of transform coefficients by means of a one dimension cosine transform unit 20, and the transform coefficients are stored in a diagonal memory unit 21 along with a corresponding block address code specifying the field block to which the transform coefficients correspond. In addition, whenever a block is selected for conversion to the transform domain, the reference memory unit 14 is updated by replacing the corresponding block in reference memory unit 14 with the newly selected block.

The conversion of each selected block to the transform domain is done by a one dimensional cosine transform unit 20 in two steps: a first transformation along the horizontal direction, followed by a second transformation along the vertical direction. The cosine transform unit 20 implements the well known discrete cosine transform function:

$$F(R) = \frac{2C(k)}{N} \sum_{j=0}^{N-1} f(j) \cos \left[ \frac{(2j+1)k\pi}{2N} \right]$$

where

$$C(k) = \frac{1}{\sqrt{2}}$$

at zero, 1 for  $k(1, N-1)$  and zero elsewhere and comprises a plurality of conventional digital multiplying accumulators configured to implement the 8 point cosine transform algorithm shown in the trellis diagram of FIG. 4. During the transformation along the horizontal direction, developing coefficients are stored in diagonal memory unit 21, and are subsequently recalled during the transformation in the vertical direction. After the selected block has been completely converted to the transform domain, the resulting series of coefficients is stored in diagonal memory unit 21 along with a multi-bit digital word specifying the block address of the block corresponding to the series of coefficients and two multi-bit digital words specifying the average value of the chrominance quadrature components for the corresponding block, the coefficients being arranged in the diagonal form illustrated schematically in FIG. 5.

The transform coefficients and corresponding block address and chrominance quadrature digital characters are next encoded for subsequent transmission in the following manner. The block address digital character corresponding to a series of transform coefficients is

coupled directly to a coder unit 22 which contains in the preferred embodiment nine separate code tables, eight tables containing a set of code characters arranged according to the Huffman code technique, in which the number of bits per specific character depends upon the probability of occurrence of that character, and one table containing a set of code characters arranged according to a special variable length coding technique specified below. The special variable length code table is dedicated for use with the block address code, and the application of a new block address code to the dedicated code table results in the generation of a block address transmission code. The block address is actually encoded by forming the numerical difference between the current block address and the address of the most recent previously encoded block address, and generating a code in accordance with the following algorithm:

If  $\Delta_k=1$ , code 1 bit ( $\Delta_k$ )

If  $\Delta_k < 32$ , code 1 bit zero + 5 bits ( $\Delta_k$ )

If  $\Delta_k \geq 32$ , code 6 bits zero + 10 bits ( $\Delta_k$ )

where

$\Delta_k = A_k - A_{k-1}$

$A_k$  = numerical address of current block

$A_{k-1}$  = numerical address of most recently encoded block.

The color quadrature components are encoded using dedicated Huffman code tables in coder unit 22. The tables listed as table number 2 and table number 3 in appendix A are used for the Q and I component values, respectively. After the block address and the color quadrature components have been encoded in the manner noted above, the first coefficient in diagonal memory unit 21 corresponding to the block, and which represents the average luminance of the block, is encoded using dedicated Huffman code table number 7 shown in appendix A. Thereafter, the cosine coefficients are processed for encoding by passing each cosine coefficient through a quantizer unit 23 in which the individual coefficients are divided by a distortion constant  $D_k$  supplied by distortion calculator unit 18. More particularly, each coefficient is multiplied by the quantity  $1/D_k$  using a digital multiplier, and the resulting rounded product, designated as a quantized cosine coefficient, is coupled to coder unit 22. In the preferred embodiment, each quantized cosine coefficient comprises a 12 bit digital character having 1 sign bit and 11 bits of magnitude. For each quantized cosine coefficient received in coder unit 22, the predictive mean value is calculated using the following relationship:

$$PM_K = \frac{1}{4}C_K + \frac{3}{4}PM_{K-1}$$

where  $PM_K$  is the predictive mean value of the  $K^{th}$  quantized coefficient,  $C_K$  is the value of the  $K^{th}$  quantized coefficient and  $PM_{K-1}$  is the predictive mean value of the  $(K-1)^{th}$  quantized coefficient. The predictive mean value  $PM_K$  is used to select one of six of the Huffman code tables 1-6 listed in Appendix A to be used to encode the next appearing quantized coefficient, in the manner described below. Thus,  $PM_K$  is used to select the Huffman code table for quantized coefficient  $K+1$ ,  $PM_{K+1}$  is used for quantized coefficient  $K+2$ , etc.

The four most significant magnitude bits of each quantized coefficient are next examined in coder unit 22 using conventional logic circuitry and, if the most significant four bits are zero, the quantized coefficient is Huffman coded using one of tables 1-6 listed in appen-

dx A. Each table 1-6 is constructed using a different one of six probability distribution curves illustrated in FIG. 6. Each curve comprises an exponential function, with different curves having different mean values ranging from 1 to 32. The calculated predictive mean value  $PM_K$  measures the steepness of the probability curve for a given quantized coefficient, and thus each Huffman code table is selected for a particular quantized coefficient by converting the value of  $PM_K$  to the log (base 2) equivalent value, and using the converted value to specify the appropriate table. The table selected is ideally that table capable of encoding the quantized coefficient with the least number of bits.

When the four most significant bits of a quantized coefficient are non-zero, a Huffman coded special escape symbol from the appropriate table and the actual twelve-bit quantized coefficient are transmitted. The escape symbol is the last symbol found in the Appendix A tables.

Coding of the transform coefficients proceeds as described until the predictive mean falls below a preselected fixed threshold, termed the run length threshold. When this occurs, a run length code corresponding to the number of successive quantized coefficients having value zero is generated by coder unit 22 using table number 8 from appendix A. If the zero run extends to the end of the block, a special end of block code is generated by coder unit 22 from table number 8. The above described encoding process is graphically illustrated in FIG. 7 in which the trend of the predictive mean values is illustrated by the solid curve labelled  $PM_k$ . The run length threshold is designated by the horizontal broken line, and the run length and end of block segments are designated with the legends RL and EOB, respectively. In the preferred embodiment, the numerical value of the run length threshold is one.

The code characters generated in coder unit 22 are stored in their order of generation in a rate buffer unit 25 having a predetermined maximum capacity N. Rate buffer 25 is a conventional unit capable of accepting binary input bits at a variable rate and generating bits at the output thereof at a constant rate of  $2.39 \times 10^5$  bits/sec. in the preferred embodiment. Since the rate at which coder unit 22 supplies binary bits to the input of rate buffer 25 can vary widely, while the buffer output bit rate is constant, a rate feedback technique is incorporated into the encoder of FIG. 1 to minimize the probability of buffer overflow. For this purpose, a signal representative of the number of bits actually transferred from coder unit 22 to buffer unit 25 is coupled to distortion calculator unit 18 for each replenishment block K, and the value of the distortion constant  $D_k$ , which establishes the magnitude of the minimum quantization interval for quantizer unit 23, is recalculated. The calculation is performed in accordance with the following relationship:

#### DISTORTION CALCULATION

$$D = D'_K + K_D \cdot \text{BFN}(B_K - N/2)$$

where:

$$\text{BFN}(X) = (X/N - |X|)$$

$D_K$  = Distortion parameter for block K

$D'_K$  = Filtered distortion parameter

$$D'_K = T \cdot D'_{K-1} + (1-T)D_{K-1}$$

where

$T$ =a constant (close to 1)  
 $K_D$ =a constant  
 $B_K$ =# of bits in buffer for block  $K$   
 $N$ =Max. number of bits

In addition, the distortion calculator 18 updates the value of the block difference threshold  $T_k$  for each encoded replenishment block in accordance with the following relationship:

#### REPLENISHMENT CALCULATION

$$T_K = T_{INIT}$$

for  $B_{LOW} \leq B_K \leq B_{HIGH}$

$$T_K = T_{INIT} + K_R \cdot BFN(B_{LOW} - B_K)$$

for  $B_K < B_{LOW}$

$$T_L = T_{INIT} + K_R \cdot BFN(B_K - B_{HIGH})$$

for  $B_K > B_{HIGH}$   
 where

$T_K$ =replenishment threshold for block  $K$   
 $T_{INIT}$ =initial threshold (about 5 for 8-bit input data)  
 $K_R$ =multiplier constant (about 25-75)  
 $B_{LOW}$ =low cutoff (about 0.1 of buffer)  
 $B_{HIGH}$ =high cutoff (about 0.75 of buffer)

Thus, as the buffer unit 25 fullness increases, the quantizer unit 23 provides coarser quantization intervals for the encoding of the transform coefficients, which tends to reduce the number of bits per symbol generated by coder unit 22, and thus tends to reduce the buffer fullness. In addition, the block difference threshold  $T_k$  is raised, which tends to reduce the number of blocks selected for replenishment transformation, which also tends to reduce the buffer fullness. Similarly, when the buffer fullness decreases, the distortion constant  $D_k$  provides finer quantization intervals for processing the transform coefficients, which tends to increase the number of bits per symbol generated by coder unit 22; and the block difference threshold  $T_k$  is lowered, tending to select more blocks for replenishment processing, both of which tend to increase the buffer fullness.

The manner in which the serially generated code symbols representing the block replenishment information are arranged for transmission from buffer unit 25 to a decoder site is shown in FIG. 8, which illustrates one entire frame of information. As seen in this FIG., a frame of information commences with a frame sync code signal indicating the beginning of the frame, followed by a first control code signal  $B_K$  which specifies the state of buffer fullness at the beginning of the frame. This control code signal is followed by the second control code signal  $D_k$ , which is the actual value of the distortion constant at the beginning of the frame. Following this header information, which is used to reset the decoder shown in FIG. 2 at the beginning of each frame, are groups of block symbols containing the block replenishment information. After the last such group, a new frame sync code signal indicates the beginning of the succeeding frame of information.

Each group of block replenishment code symbols commences with the block address code, is followed by the two color quadrature component code symbols and continues with the coefficient code symbols, as indicated in FIG. 8. The arrangement of the coefficient codes indicated in FIG. 8 for the first block to be up-

dated corresponds to the representative plot shown in FIG. 7.

The block replenishment symbols encoded in the manner described above are transmitted over a suitable communication link to the decoder system shown in FIG. 2, which provides inverse processing for the received information code symbols. Thus, after receipt of a frame sync code signal, the initial value of the distortion constant  $D_k$  is coupled to an inverse quantizer unit 23' and the first block of replenishment information is initially decoded in decoder unit 22'. Decoder unit 22' contains the inverse code tables illustrated in appendix B which generate digital values from the received code symbols applied to the input thereof. The tables are arranged in a manner similar to that employed in coder unit 22, so that the block address codes, the color quadrature component codes and the DC coefficient code are all applied to their respective dedicated tables, while the cosine coefficient codes are applied on an individual basis to a selected one of six tables, depending on the value of the predictive mean calculated for each received quantized coefficient code. The emerging twelve-bit digital characters representing the quantized coefficients are inverse quantized in unit 23' by simply digitally multiplying each twelve-bit character with the value of  $D_k$ , and the resulting inversely quantized cosine coefficients are stored in diagonal memory unit 21', along with the corresponding block address digital character, the digital character representing the DC term and the quadrature chrominance characters. The coefficients are transformed to the time domain by subjecting the coefficients to a two-step inverse cosine transformation in unit 20', with the intermediate resulting values being stored back in diagonal memory unit 21'. After the inverse cosine transformation process has been completed, the resulting pixel samples are stored in output memory unit 13, replacing the former eight by eight block of pixel information. It should be noted that the field of information stored in output memory unit 13' comprises a replica of the field of information stored in reference memory unit 14 of the FIG. 1 encoder.

The replenished field information contained in output memory unit 13' is coupled to an output digital processor unit 12', and thence to analog processor unit 11' which converts the digital video data to analog form. The emerging analog video signals are coupled to a suitable utilization device, such as a raster scan monitor.

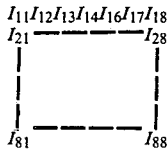
As binary bits are transferred from buffer unit 25' to decoder unit 22', a signal representing the number of bits transferred is coupled to distortion calculator unit 18', which updates the value of the distortion constant  $D_k$  for each block of replenishment information. The distortion calculator 18' employs the same algorithm as that noted above for distortion calculator 18.

Further compression of the input video is obtained by two additional signal processing techniques. Firstly, the luminance portion of a field of input video is subsampled to provide 256 lines/frame and 256 samples/line (65,536 pixels/frame), as opposed to the normal standard of 512 lines/frame and 512 samples/line (262,144 pixels/frame). After decoding, the full luminance field is recovered in output digital processor 12' by interpolative processing of the actual luminance samples transmitted through the system. Deleted luminance samples are reconstructed by summing adjacent samples and dividing the result by two. Thus, if A and B are adjacent luminance samples in a line, the intermediate sample is

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reconstructed by forming the sum  $A/2 + B/2$ , and inserting this result between sample A and sample B.

The quadrature chrominance components for each  $8 \times 8$  block of input video are compressed by first discarding the 2 least significant bits of each 8-bit digital chrominance quadrature component sample to form 6-bit digital characters. For each  $8 \times 8$  block, the separate quadrature component samples are averaged over the block by summing every other component sample in a given line, dividing the result by four, storing the result obtained for each line, summing the result for the eight lines in a block and dividing the result by eight. Specifically, for the I quadrature component for block K, the initial sample array is:



The first row average is:

$$I_{AV1} = (I_{11} + I_{13} + I_{15} + I_{17})/4$$

The last row average is:

$$I_{AV8} = (I_{81} + I_{83} + I_{85} + I_{87})/4$$

The block average is:

$$I_{AV \text{ BLOCK } K} = (I_{AV1} + I_{AV2} + \dots + I_{AV8})/8$$

For the Q quadrature component, the first row average is:

$$Q_{AV1} = (Q_{12} + Q_{14} + Q_{16} + Q_{18})/4$$

The last row average is:

$$Q_{AV8} = (Q_{82} + Q_{84} + Q_{86} + Q_{88})/4$$

The block average is:

$$Q_{AV \text{ BLOCK } K} = (Q_{AV1} + Q_{AV2} + \dots + Q_{AV8})/8$$

The resulting block average for each component is stored as a 6-bit character in input memory 13. The full chrominance field is recovered in output digital processor 12' by inverse interpolative processing of the average chrominance samples transmitted through the system.

While suitable for many applications requiring information signal compression, the invention is especially adapted for use in a video teleconferencing system in which the prime criterion is bandwidth reduction with minimum degradation in the subjective quality of the video images. At a typical sampling rate of 10.7 MHz for digital video transmission using eight-bits per digital sample character, the required bit rate to reliably transmit video information without compression is  $8.56 \times 10^7$  bits per second. By processing video signals according to the invention, using the same sample rate and the same size digital characters (i.e. eight-bits) in the analog to digital converter section of the encoder, and the digital to analog section of the decoder, compressed digital video can be transmitted from the encoder buffer unit 25 to the decoder buffer unit 25' at a rate of  $2.39 \times 10^5$  bits per second, which is 0.25 percent of the

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standard uncompressed digital bit rate. As will be appreciated by those skilled in the art, such a substantial reduction in the bit rate enables video information of good picture quality to be transmitted over a communication link having a substantially narrower bandwidth, for example four conventional digital voice channels, with the result that substantially more information traffic can be routed over available communication links.

While the above provides a full and complete disclosure of the preferred embodiments of the invention, various modifications, alternate constructions and equivalents may be employed without departing from the true spirit and scope of the invention. For example, while eight by eight pixel blocks are employed in the preferred embodiment of the invention, blocks of other sizes may be employed, if desired. The relevant criteria for selecting appropriate block sizes are the processing time required by the block difference and decision unit 16, the cosine transform unit 20, the quantizer unit 23, the coder unit 22 and the distortion calculator 18. In general, larger blocks require more processing time, and the speed of currently available digital circuitry provides a practical limitation of about 32 pixels by 32 pixels on the maximum block size. In addition, for applications in which the amount of interframe image motion is excessive (i.e. greater than that normally present in video conferencing applications), a smaller block size may be necessary in order to provide decoded video signals of good subjective quality. Selection of smaller block sizes, however, increases the required minimum bit rate for the buffer units 25, 25'. In addition, different weighting factors may be employed for field merging, if desired; however, in the development of the preferred embodiment it has been discovered that a ratio of seven to one results in decoded video signals which are quite blurry, while a ratio approaching one to one results in a substantially increased number of blocks selected for replenishment, requiring a higher minimum bit rate for reliable transmission and decoding. The above description and illustrations, therefore, should not be construed as limiting the scope of the invention, which is defined by the appended claims.

APPENDIX A

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T A B L E I

Entry	* Occurrences	* Length	* Huffman Code
0	56718.	1	0000
1	63441.	2	0003
2	7747.	3	0005
3	2258.	4	0008
4	894.	6	0027
5	446.	6	0024
6	276.	7	0048
7	167.	8	009A
8	115.	8	0095
9	94.	9	0137
10	61.	9	0131
11	55.	9	0129
12	51.	9	0128
13	38.	10	0265
14	25.	11	040B
15	14.	11	04C2
16	23.	11	0409
17	19.	11	04CC
18	12.	12	09B5
19	9.	12	0993
20	18.	11	04C8
21	10.	12	09B1
22	3.	13	130C
23	5.	13	1369
24	9.	12	0992



67	0.	16
68	2.	14
69	0.	16
70	0.	16
71	2.	14
72	0.	16
73	0.	16
74	0.	16
75	0.	16
76	0.	16
77	0.	16
78	0.	16
79	0.	16
80	0.	16
81	0.	16
82	0.	16
83	0.	16
84	0.	16
85	0.	16
86	0.	16
87	0.	16
88	0.	16
89	0.	16
90	0.	16
91	0.	16
92	0.	16
93	0.	16
94	0.	16
95	0.	16
96	0.	16
97	0.	16
98	0.	16
99	0.	16
100	0.	16
101	0.	16
102	0.	16
103	0.	16
104	0.	16
105	0.	16
106	0.	16
107	0.	16
108	0.	16
109	0.	16
110	0.	16
111	0.	16
112	0.	16
113	0.	16
114	0.	16
115	0.	16
116	0.	16
117	0.	16
118	0.	16
119	0.	16
120	0.	16
121	0.	16
122	0.	16
123	0.	16
124	0.	16
125	0.	16
126	0.	16
127	0.	16
128	0.	16

9AC5	5
26B7	
9AC4	
9AC3	
26B6	
9AC2	
9AC1	
9AC0	
9A7F	
9A7E	
9A7D	
9A7C	
9A7B	10
9A7A	
9A79	
9A78	
9A77	
9A76	
9A75	
9A74	15
9A73	
9A72	
9A71	
9A70	
9A6F	
9A6E	
9A6D	20
9A6C	
9A6B	
9A6A	
9A69	
9A68	
9A67	
9A66	25
9A65	
9A64	
9A63	
9A62	
9A61	
9A60	
9A1F	30
9A1E	
9A1D	
9A1C	
9A1B	
9A1A	
9A19	
9A18	35
9A17	
9A16	
9A15	
9A14	
9A13	
9A12	
9A11	40
9A10	
92E7	
92E6	
92E5	
92E4	
92E3	
92E2	45

16	
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9	002A
9	00AA
9	0020
9	0025
10	0170
10	0050
10	0053
11	02E2
10	0057
11	02E7
11	02E4
11	02AE
11	00A5
11	02E3
11	0090
11	00AC
11	0093
12	015B
13	0AB3
12	0148
12	0147
12	055A
12	010F
12	010E
12	0146
13	0B96
13	0B95
12	015A
13	0AB2
12	0145
13	0AB1
13	0B94
13	024B
12	010D
12	0144
13	0AB0
13	024A
14	0423
12	010C
16	1495
14	157D
14	0422
13	0249
14	157C
14	0421
13	0248
14	0420
13	0247
13	0246
14	157B
14	157A
13	0245
15	2E6F
14	1579
15	2E6E
15	2E6D
14	1578
13	0293
13	0ABF
15	2E6C
13	0244
12	010B
15	2E6B
16	1494
15	2E6A
15	2E69
15	2E68
15	2E67
15	2E66
16	1493
15	2E65
13	0215
16	1492
15	2E64
15	2E63
15	2E62
14	156F
15	2E61
16	1491
14	156E
15	2E60
16	1490
16	10A7
16	10A6
16	10A5
15	2E5F
16	10A4
15	2E5E
14	156D
15	2E5D
16	10A3
16	10A2
16	10A1
16	10A0

Total Symbols = 42954.  
 Symbol Entropy = 2.048  
 Bits per Symbol = 2.074

\*\*\*\*\*  
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 T A B L E 3

Entry \* Occurrences \* Length \* Huffman Code \*\*\*

0	16170.	2	0003	
1	14815.	2	0002	
2	6726.	3	0003	
3	3891.	3	0001	
4	2383.	4	0004	
5	1615.	4	0000	60
6	1161.	5	0003	
7	722.	6	0016	
8	545.	6	0014	
9	414.	7	002F	
10	350.	7	002B	
11	259.	7	000B	65
12	194.	8	005D	
13	141.	8	0054	
14	115.	8	0013	
15	101.	8	0011	

110	Ø.	16	1Ø9F
111	Ø.	16	1Ø9E
112	Ø.	16	1Ø9D
113	1.	15	2E5C
114	2.	14	156C
115	Ø.	16	1Ø9C
116	Ø.	16	1Ø9B
117	Ø.	16	1Ø9A
118	Ø.	16	1Ø99
119	Ø.	16	1Ø98
120	Ø.	16	1Ø97
121	Ø.	16	1Ø96
122	Ø.	16	1Ø95
123	Ø.	16	1Ø94
124	Ø.	16	1Ø93
125	1.	15	ØA4B
126	Ø.	16	1Ø92
127	Ø.	16	1Ø91
120	Ø.	16	1Ø9Ø

5	60	4.	13	199F
	61	7.	12	Ø8C3
	62	3.	13	115B
	63	4.	13	199E
	64	7.	12	Ø8C2
	65	4.	13	199D
	66	7.	12	Ø8C1
	67	5.	13	1ØD7
	68	2.	14	378A
	69	3.	13	115A
	70	7.	12	Ø8CØ
	71	8.	12	Ø8C7
10	72	4.	13	199C
	73	3.	13	1159
	74	7.	12	Ø8AF
	75	5.	13	1ØD6
	76	6.	12	Ø8A5
	77	2.	14	3789
	78	2.	14	3788
15	79	1.	14	Ø87A
	80	3.	13	1158
	81	6.	12	Ø8A4
	82	2.	14	33ØF
	83	7.	12	Ø8AE
	84	2.	14	33BE
	85	2.	14	33BD
20	86	4.	13	11BF
	87	2.	14	33BC
	88	3.	13	114F
	89	2.	14	33BD
	90	Ø.	16	CEC1
	91	2.	14	33BA
	92	3.	13	114E
	93	3.	13	Ø43F
	94	2.	14	33B9
	95	1.	14	Ø879
	96	1.	14	Ø878
	97	1.	15	6F7F
	98	Ø.	16	CECØ
	99	Ø.	16	21F7
	100	1.	15	6F7E
30	101	1.	15	6F7D
	102	2.	14	33B8
	103	Ø.	16	21F6
	104	2.	14	33B3
	105	1.	15	6F7C
	106	4.	13	11BE
	107	1.	15	6F7B
35	108	Ø.	16	21F5
	109	Ø.	16	21F4
	110	Ø.	16	21F3
	111	1.	15	6F7A
	112	Ø.	16	21F2
	113	Ø.	16	21F1
40	114	2.	14	33B2
	115	1.	15	6F79
	116	1.	15	6F78
	117	Ø.	16	21FØ
	118	Ø.	16	21EF
	119	Ø.	16	21EE
	120	1.	15	6F77
45	121	Ø.	16	21ED
	122	Ø.	16	21EC
	123	2.	14	33B1
	124	1.	15	6F76
	125	1.	15	6F75
	126	1.	15	6F74
	127	1.	15	6761
50	128	28.	1Ø	Ø22C

Total Symbols = 5Ø336.  
 Symbol Entropy = 2.774  
 Bits Per Symbol = 2.834

\*\*\*\*\*  
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 TABLE 4

Entry	* Occurrences	* Length	* Huffman Code	***
Ø	5652.	3	ØØØ7	25
1	6448.	2	ØØØ1	
2	3916.	3	ØØØ5	
3	2656.	3	ØØØØ	
4	2Ø19.	4	ØØØ9	
5	1581.	4	ØØØ3	
6	1229.	5	ØØ1A	30
7	979.	5	ØØ18	
8	811.	5	ØØØ5	
9	618.	6	ØØ36	
10	518.	6	ØØ32	
11	417.	6	ØØ21	
12	4Ø4.	6	ØØ2Ø	
13	321.	7	ØØ6E	35
14	256.	7	ØØ47	
15	211.	7	ØØ44	
16	181.	7	ØØ11	
17	177.	8	ØØDF	
18	156.	8	ØØCF	
19	14Ø.	8	ØØCD	
20	1Ø3.	8	ØØ27	40
21	93.	8	ØØ24	
22	98.	8	ØØ26	
23	88.	8	ØØ2Ø	
24	71.	9	Ø19C	
25	68.	9	Ø198	
26	63.	9	Ø119	
27	59.	9	Ø117	45
28	5Ø.	9	ØØ4B	
29	44.	9	ØØ42	
30	39.	10	Ø379	
31	35.	10	Ø33A	
32	32.	10	Ø235	
33	31.	10	Ø234	
34	33.	10	Ø236	50
35	27.	10	Ø22A	
36	24.	10	ØØ95	
37	22.	10	ØØ86	
38	28.	10	Ø22D	
39	21.	11	Ø6F6	
40	23.	10	ØØ94	
41	19.	11	Ø6FØ	55
42	17.	11	Ø666	
43	17.	11	Ø665	
44	9.	12	ØCED	
45	17.	11	Ø664	
46	15.	11	Ø462	
47	1Ø.	12	ØDEA	
48	8.	12	Ø8DE	60
49	12.	11	Ø451	
50	16.	11	Ø46E	
51	1Ø.	12	ØDE9	
52	1Ø.	12	ØDE8	
53	11.	11	Ø1ØE	
54	12.	11	Ø45Ø	
55	7.	12	Ø8C6	65
56	1Ø.	12	ØDE3	
57	6.	12	Ø8A6	
58	2.	14	378B	
59	5.	13	1ØDC	

\* Total Symbols = 3Ø144.  
 \* Symbol Entropy = 3.793  
 \* Bits Per Symbol = 3.835

\*\*\*\*\*  
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 TABLE 5

Entry	* Occurrences	* Length	* Huffman Code	***
Ø	166Ø.	3	ØØØ4	
1	18Ø4.	3	ØØØ5	
2	1425.	3	ØØØ2	
3	978.	4	ØØØD	
4	822.	4	ØØØ7	
5	637.	4	ØØØØ	
6	595.	4	ØØØØ	
7	522.	5	ØØ1E	
8	411.	5	ØØ18	
9	393.	5	ØØØC	

10	372.	5	0007
11	300.	5	0002
12	270.	6	003E
13	248.	6	003A
14	234.	6	0033
15	236.	6	0038
16	161.	6	000C
17	143.	7	007E
18	123.	7	0073
19	131.	7	0077
20	94.	7	001B
21	102.	7	0036
22	96.	7	0034
23	76.	7	000D
24	61.	8	00E5
25	76.	7	000C
26	53.	8	006F
27	56.	8	00CA
28	57.	8	00CB
29	40.	8	001E
30	31.	9	01DA
31	43.	8	0034
32	28.	9	0193
33	31.	9	0109
34	39.	8	001C
35	25.	9	00DC
36	37.	9	01FE
37	27.	9	0192
38	19.	9	003A
39	17.	10	03F9
40	29.	9	01C8
41	23.	9	00D4
42	11.	10	00D7
43	20.	9	003B
44	16.	10	03B6
45	13.	10	0320
46	18.	10	03FB
47	27.	9	0191
48	16.	10	0393
49	6.	11	035E
50	12.	10	01AC
51	11.	10	00D6
52	11.	10	00D5
53	5.	11	01A8
54	12.	10	01AB
55	9.	11	07FE
56	6.	11	035D
57	9.	11	07FD
58	12.	10	01AA
59	4.	12	0FE8
60	6.	11	035C
61	5.	11	00FF
62	7.	11	0725
63	17.	10	03F8
64	7.	11	0724
65	10.	10	007D
66	5.	11	00FE
67	4.	12	0EDF
68	5.	11	00FD
69	5.	11	00FC
70	1.	13	06A5
71	2.	13	1FF2
72	3.	12	0C84
73	4.	12	0E0E
74	6.	11	035B
75	3.	12	06EF
76	7.	11	0643
77	3.	12	06EE
78	4.	12	0E0D
79	5.	11	00F9
80	3.	12	06ED
81	0.	17	6429
82	1.	13	06A4
83	3.	12	06EC
84	6.	11	035A
85	3.	12	06EB
86	3.	12	06EA
87	2.	13	1FF1
88	3.	12	06E9
89	1.	13	03E3
90	1.	13	03E2
91	0.	15	6428
92	0.	16	C05F
93	2.	13	1FF0
94	2.	13	1FD7
95	0.	16	C05E
96	1.	13	03E1
97	0.	16	C05D
98	1.	13	03E0
99	2.	13	1FD6
00	2.	13	1FD5
01	2.	13	1FD4
02	3.	12	06E8
03	0.	16	C05C
04	0.	16	C05B

05	1.	14	3FFF
06	1.	14	3FFE
07	2.	13	1FD3
08	4.	12	0EDC
09	2.	13	1FD2
10	1.	14	3FFD
11	0.	16	C85A
12	3.	12	06BF
13	1.	14	3FFC
14	1.	14	3FFB
15	1.	14	3FFA
16	1.	14	3FF9
17	0.	16	C859
18	3.	12	06BE
19	0.	16	C858
20	1.	14	3FF8
21	0.	16	C057
22	1.	14	3FE7
23	0.	16	C856
24	0.	16	C855
25	1.	14	3FE6
26	3.	12	0353
27	0.	16	C854
28	31.	9	01D8

Total Symbols = 12959.  
 Symbol Entropy = 4.557  
 Bits Per Symbol = 4.578

\*\*\*\*\*  
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 T A B L E 6  
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Entry	* Occurrences	* Length	* Huffman Code
30	0	496.	3 0005
	1	366.	3 0001
	2	294.	4 000E
	3	232.	4 0008
	4	213.	4 0005
	5	157.	5 001F
	6	142.	5 001B
	7	134.	5 0019
35	8	118.	5 0012
	9	104.	5 0009
	10	88.	5 0001
	11	96.	5 0003
	12	67.	6 0031
	13	71.	6 0035
	14	54.	6 001A
40	15	57.	6 001E
	16	60.	6 001F
	17	55.	6 001C
	18	66.	6 0027
	19	45.	6 0004
	20	44.	6 0001
45	21	54.	6 0019
	22	39.	7 007A
	23	27.	7 0037
	24	35.	7 0068
	25	31.	7 004D
	26	27.	7 0036
	27	36.	7 0078
	28	26.	7 0023
50	29	25.	7 0022
	30	21.	8 00F7
	31	24.	7 000B
	32	28.	7 003B
	33	22.	7 0001
	34	25.	7 0021
55	35	19.	8 00F3
	36	16.	8 00C0
	37	13.	8 0063
	38	14.	8 0098
	39	13.	8 0062
	40	14.	8 0075
	41	13.	8 0061
60	42	11.	8 0015
	43	13.	8 0060
	44	9.	9 0014
	45	11.	8 0014
	46	10.	9 01E0
	47	10.	9 01EC
	48	8.	9 0133
65	49	11.	8 0001
	50	6.	9 0083
	51	9.	9 01A7
	52	5.	9 0000
	53	5.	10 03CB
	54	4.	10 0309

55	4.	10	0308	
56	4.	10	0307	
57	4.	10	0306	
58	2.	11	0695	
59	1.	11	0005	
60	4.	10	0305	5
61	7.	9	00E9	
62	3.	10	01D1	
63	4.	10	0304	
64	4.	10	0265	
65	2.	11	0694	
66	2.	11	0693	
67	2.	11	0692	10
68	2.	11	0691	
69	2.	11	0690	
70	6.	9	0062	
71	0.	14	2645	
72	2.	11	061F	
73	1.	11	0004	
74	2.	11	061E	15
75	2.	11	061D	
76	2.	11	061C	
77	1.	12	0F2B	
78	2.	11	061B	
79	3.	10	01D0	
80	0.	14	2644	
81	0.	14	2643	20
82	2.	11	061A	
83	0.	14	2642	
84	0.	14	2641	
85	1.	12	0F2A	
86	0.	14	2640	
87	0.	15	4C9F	
88	1.	12	0F29	25
89	1.	12	0F28	
90	2.	11	0619	
91	0.	15	4C9E	
92	2.	11	0618	
93	1.	12	0D37	
94	0.	15	4C9D	
95	2.	11	0617	30
96	3.	10	0003	
97	1.	12	0D36	
98	1.	12	0D35	
99	1.	12	0D34	
100	1.	12	0D33	
101	0.	15	4C9C	
102	0.	15	4C9B	35
103	0.	15	4C9A	
104	0.	15	4C99	
105	1.	12	0D32	
106	0.	15	4C98	
107	0.	15	4C97	
108	0.	15	4C96	
109	0.	15	4C95	40
110	1.	12	0D31	
111	1.	12	0D30	
112	0.	15	4C94	
113	2.	11	0616	
114	0.	15	4C93	
115	0.	15	4C92	45
116	1.	12	0D F	
117	1.	12	0D E	
118	0.	15	4C91	
119	1.	12	0D2D	
120	0.	15	4C90	
121	0.	15	4C8F	
122	1.	12	0D2C	50
123	0.	15	4C8E	
124	0.	15	4C8D	
125	2.	11	0615	
126	0.	15	4C8C	
127	2.	11	0614	
128	12.	8	0040	

5	632.	5	001F
6	611.	5	001D
7	546.	5	0018
8	489.	5	0014
9	500.	5	0015
10	503.	5	0016
11	423.	5	000C
12	317.	6	003D
13	353.	5	0005
14	344.	5	0004
15	381.	5	0007
16	241.	6	0026
17	197.	6	0012
18	266.	6	002F
19	233.	6	0021
20	220.	6	001C
21	170.	6	0007
22	149.	7	0067
23	213.	6	001A
24	243.	6	0027
25	206.	6	0015
26	216.	6	001B
27	162.	6	0002
28	230.	6	0020
29	200.	6	0013
30	193.	6	0011
31	181.	6	000C
32	160.	6	0001
33	278.	6	0032
34	209.	6	0016
35	191.	6	0010
36	154.	7	007B
37	168.	6	0005
38	109.	7	003A
39	170.	6	0006
40	159.	6	0000
41	101.	7	0029
42	100.	7	0028
43	105.	7	002E
44	77.	8	00F2
45	56.	8	0076
46	62.	8	0077
47	79.	8	00F3
48	81.	7	0008
49	94.	7	0018
50	89.	7	001A
51	125.	7	005C
52	165.	6	0003
53	149.	7	0066
54	55.	8	005F
55	22.	9	0026
56	21.	9	0025
57	28.	9	0174
58	23.	9	0027
59	17.	10	02EB
60	17.	10	02EA
61	13.	10	017A
62	13.	10	0179
63	14.	10	017B
64	1.	13	0BC4
65	0.	15	2F14
66	1.	13	0BC3
67	0.	15	091B
68	0.	15	091A
69	1.	13	0BC2
70	0.	15	0919
71	0.	15	0918
72	1.	13	0BC1
73	0.	15	0917
74	0.	15	0916
75	0.	15	0915
76	1.	13	0BC0
77	1.	13	024F
78	0.	15	0914
79	0.	15	0913
80	1.	13	024E
81	0.	15	0912
82	0.	15	0911
83	0.	15	0910
84	0.	15	090F
85	0.	15	090E
86	2.	12	0124
87	0.	15	090D
88	1.	13	024D
89	0.	15	090C
90	1.	13	024C
91	0.	15	090B
92	0.	15	090A
93	0.	15	0909
94	0.	15	0908
95	0.	15	0907
96	1.	13	024B
97	0.	15	0906
98	0.	15	0905
99	0.	15	0904

Total Symbols = 3705.  
 Symbol Entropy = 5.023  
 Bits Per Symbol = 5.047

\*\*\*\*\*  
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 TABLE 7

Entry	* Occurrences	* Length	* Huffman Code	*
0	1134.	4	000D	65
1	476.	5	0011	
2	463.	5	000F	
3	482.	5	0012	
4	607.	5	001C	



## APPENDIX B

\*\*\*\*\*  
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## T A B L E 1

Entry \* Father \* Bit \* Value or Sons \* ROM Data: EOB,Z,E,T,D6-D0 \*\*\*

0	none	0	0	2 8 0
1	none	1	0000001x	0 0 1
2	1	0	0000010x	0 0 2
3	1	1	1	0 8 1
4	2	0	0000011x	0 0 3
5	2	1	2	0 8 2
6	4	0	3	0 8 3
7	4	1	0000100x	0 0 4
8	7	0	0000110x	0 0 6
9	7	1	0000101x	0 0 5
10	9	0	0001000x	0 0 8
11	9	1	4	0 8 4
12	8	0	5	0 8 5
13	8	1	0000111x	0 0 7
14	13	0	0001010x	0 0 A
15	13	1	6	0 8 6
16	10	0	0001100x	0 0 C
17	10	1	0001001x	0 0 9
18	17	0	7	0 8 7
19	17	1	0001011x	0 0 B
20	14	0	0001110x	0 0 E
21	14	1	8	0 8 8
22	19	0	0010001x	0 1 1
23	19	1	9	0 8 9
24	16	0	0001101x	0 0 D
25	16	1	0001111x	0 0 F
26	24	0	0010011x	0 1 3
27	24	1	10	0 8 A
28	20	0	12	0 8 C
29	20	1	11	0 8 B
30	25	0	0010000x	0 1 0
31	25	1	0010110x	0 1 6
32	30	0	0011001x	0 1 9
33	30	1	13	0 8 D
34	22	0	0010101x	0 1 5
35	22	1	0010010x	0 1 2
36	35	0	0011000x	0 1 8
37	35	1	14	0 8 E
38	26	0	0100000x	0 2 0
39	26	1	0010100x	0 1 4
40	39	0	15	0 8 F
41	39	1	0011100x	0 1 C
42	34	0	0011011x	0 1 B
43	34	1	16	0 9 0
44	31	0	0010111x	0 1 7
45	31	1	0100010x	0 2 2
46	44	0	17	0 9 1
47	44	1	1100001x	0 6 1
48	36	0	0011110x	0 1 E
49	36	1	18	0 9 2
50	32	0	20	0 9 4
51	32	1	0011010x	0 1 A
52	51	0	24	0 9 8
53	51	1	19	0 9 3
54	42	0	25	0 9 9
55	42	1	21	0 9 5
56	41	0	0011101x	0 1 D
57	41	1	0011111x	0 1 F
58	56	0	22	0 9 6
59	56	1	37	0 A 5
60	48	0	29	0 9 D
61	48	1	23	0 9 7
62	57	0	32	0 A 0
63	57	1	26	0 9 A
64	38	0	0101000x	0 2 8
65	38	1	0100001x	0 2 1

66	65	0	28	0 9 C
67	65	1	27	0 9 B
68	45	0	1000010x	0 4 2
69	45	1	0100011x	0 2 3
70	69	0	0110011x	0 3 3
71	69	1	0100100x	0 2 4
72	71	0	0101100x	0 2 C
73	71	1	0100101x	0 2 5
74	73	0	33	0 A 1
75	73	1	0100110x	0 2 6
76	75	0	0100111x	0 2 7
77	75	1	48	0 B 0
78	76	0	35	0 A 3
79	76	1	30	0 9 E
80	64	0	0101001x	0 2 9
81	64	1	31	0 9 F
82	80	0	0101011x	0 2 B
83	80	1	0101010x	0 2 A
84	83	0	36	0 A 4
85	83	1	34	0 A 2
86	82	0	41	0 A 9
87	82	1	38	0 A 6
88	72	0	0110000x	0 3 0
89	72	1	0101101x	0 2 D
90	89	0	0101111x	0 2 F
91	89	1	0101110x	0 2 E
92	91	0	40	0 A 8
93	91	1	39	0 A 7
94	90	0	43	0 A 8
95	90	1	42	0 A A
96	88	0	0110010x	0 3 2
97	88	1	0110001x	0 3 1
98	97	0	45	0 A D
99	97	1	44	0 A C
100	96	0	47	0 A F
101	96	1	46	0 A E
102	70	0	0111011x	0 3 B
103	70	1	0110100x	0 3 4
104	103	0	0111000x	0 3 8
105	103	1	0110101x	0 3 5
106	105	0	0110111x	0 3 7
107	105	1	0110110x	0 3 6
108	107	0	50	0 B 2
109	107	1	49	0 B 1
110	106	0	52	0 B 4
111	106	1	51	0 B 3
112	104	0	0111010x	0 3 A
113	104	1	0111001x	0 3 9
114	113	0	54	0 B 6
115	113	1	53	0 B 5
116	112	0	56	0 B 8
117	112	1	55	0 B 7
118	102	0	0111111x	0 3 F
119	102	1	0111100x	0 3 C
120	119	0	0111110x	0 3 E
121	119	1	0111101x	0 3 D
122	121	0	58	0 B A
123	121	1	57	0 B 9
124	120	0	60	0 B C
125	120	1	59	0 B B
126	118	0	1000001x	0 4 1
127	118	1	1000000x	0 4 0
128	127	0	62	0 B E
129	127	1	61	0 B D
130	126	0	64	0 C 0
131	126	1	63	0 B F
132	68	0	1010010x	0 5 2
133	68	1	1000011x	0 4 3
134	133	0	1001011x	0 4 B
135	133	1	1000100x	0 4 4
136	135	0	1001000x	0 4 8
137	135	1	1000101x	0 4 5
138	137	0	1000111x	0 4 7
139	137	1	1000110x	0 4 6

140	139	0	66	0	C	2
141	139	1	65	0	C	1
142	138	0	68	0	C	4
143	138	1	67	0	C	3
144	136	0	1001010x	0	4	A
145	136	1	1001001x	0	4	9
146	145	0	70	0	C	6
147	145	1	69	0	C	5
148	144	0	72	0	C	8
149	144	1	71	0	C	7
150	134	0	1001111x	0	4	F
151	134	1	1001100x	0	4	C
152	151	0	1001110x	0	4	E
153	151	1	1001101x	0	4	D
154	153	0	74	0	C	A
155	153	1	73	0	C	9
156	152	0	76	0	C	C
157	152	1	75	0	C	B
158	150	0	1010001x	0	5	1
159	150	1	1010000x	0	5	0
160	159	0	78	0	C	E
161	159	1	77	0	C	D
162	158	0	80	0	D	0
163	158	1	79	0	C	F
164	132	0	1011010x	0	5	A
165	132	1	1010011x	0	5	3
166	165	0	1010111x	0	5	7
167	165	1	1010100x	0	5	4
168	167	0	1010110x	0	5	6
169	167	1	1010101x	0	5	5
170	169	0	82	0	D	2
171	169	1	81	0	D	1
172	168	0	84	0	D	4
173	168	1	83	0	D	3
174	166	0	1011001x	0	5	9
175	166	1	1011000x	0	5	8
176	175	0	86	0	D	6
177	175	1	85	0	D	5
178	174	0	88	0	D	8
179	174	1	87	0	D	7
180	164	0	1011110x	0	5	E
181	164	1	1011011x	0	5	B
182	181	0	1011101x	0	5	D
183	181	1	1011100x	0	5	C
184	183	0	90	0	D	A
185	183	1	89	0	D	9
186	182	0	92	0	D	C
187	182	1	91	0	D	B
188	180	0	1100000x	0	6	0
189	180	1	1011111x	0	5	F
190	189	0	94	0	D	E
191	189	1	93	0	D	D
192	188	0	96	0	E	0
193	188	1	95	0	D	F
194	47	0	1110001x	0	7	1
195	47	1	1100010x	0	6	2
196	195	0	1101010x	0	6	A
197	195	1	1100011x	0	6	3
198	197	0	1100111x	0	6	7
199	197	1	1100100x	0	6	4
200	199	0	1100110x	0	6	6
201	199	1	1100101x	0	6	5
202	201	0	98	0	E	2
203	201	1	97	0	E	1
204	200	0	100	0	E	4
205	200	1	99	0	E	3
206	198	0	1101001x	0	6	9
207	198	1	1101000x	0	6	8
208	207	0	102	0	E	6
209	207	1	101	0	E	5
210	206	0	104	0	E	8
211	206	1	103	0	E	7
212	196	0	1101110x	0	6	E
213	196	1	1101011x	0	6	B
214	213	0	1101101x	0	6	D

215	213	1	1101100x	0 6 C
216	215	0	106	0 E A
217	215	1	105	0 E 9
218	214	0	108	0 E C
219	214	1	107	0 E B
220	212	0	1110000x	0 7 0
221	212	1	1101111x	0 6 F
222	221	0	110	0 E E
223	221	1	109	0 E D
224	220	0	112	0 F 0
225	220	1	111	0 E F
226	194	0	1111001x	0 7 9
227	194	1	1110010x	0 7 2
228	227	0	1110110x	0 7 6
229	227	1	1110011x	0 7 3
230	229	0	1110101x	0 7 5
231	229	1	1110100x	0 7 4
232	231	0	114	0 F 2
233	231	1	113	0 F 1
234	230	0	116	0 F 4
235	230	1	115	0 F 3
236	228	0	1111000x	0 7 8
237	228	1	1110111x	0 7 7
238	237	0	118	0 F 6
239	237	1	117	0 F 5
240	236	0	120	0 F 8
241	236	1	119	0 F 7
242	226	0	1111101x	0 7 D
243	226	1	1111010x	0 7 A
244	243	0	1111100x	0 7 C
245	243	1	1111011x	0 7 B
246	245	0	122	0 F A
247	245	1	121	0 F 9
248	244	0	124	0 F C
249	244	1	123	0 F B
250	242	0	1111111x	0 7 F
251	242	1	1111110x	0 7 E
252	251	0	126	0 F E
253	251	1	125	0 F D
254	250	0	128	1 8 0
255	250	1	127	0 F F

\*\*\*\*\*  
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 TABLE 2

\*\*\* Entry \* Father \* Bit \* Value or Sons \* ROM Data: EOB,Z,E,T,D6-D0 \*\*\*

0	none	0	0	2 8 0
1	none	1	0000001x	0 0 1
2	1	0	0000010x	0 0 2
3	1	1	1	0 8 1
4	2	0	0000011x	0 0 3
5	2	1	2	0 8 2
6	4	0	3	0 8 3
7	4	1	0000100x	0 0 4
8	7	0	0000110x	0 0 6
9	7	1	0000101x	0 0 5
10	9	0	0000111x	0 0 7
11	9	1	4	0 8 4
12	8	0	0001000x	0 0 8
13	8	1	5	0 8 5
14	10	0	6	0 8 6
15	10	1	0001010x	0 0 A
16	12	0	7	0 8 7
17	12	1	0001001x	0 0 9
18	17	0	0001111x	0 0 F
19	17	1	8	0 8 8
20	15	0	0001101x	0 0 D
21	15	1	0001011x	0 0 B
22	21	0	9	0 8 9

23	21	1	0001100x	0 0 C
24	23	0	0010101x	0 1 5
25	23	1	10	0 8 A
26	20	0	0010010x	0 1 2
27	20	1	0001110x	0 0 E
28	27	0	11	0 8 B
29	27	1	0100000x	0 2 0
30	18	0	0010000x	0 1 0
31	18	1	0010001x	0 1 1
32	30	0	0010111x	0 1 7
33	30	1	12	0 8 C
34	31	0	13	0 8 D
35	31	1	0011101x	0 1 D
36	26	0	0010100x	0 1 4
37	26	1	0010011x	0 1 3
38	37	0	14	0 8 E
39	37	1	1001110x	0 4 E
40	36	0	0010110x	0 1 6
41	36	1	15	0 8 F
42	24	0	16	0 9 0
43	24	1	0011000x	0 1 8
44	40	0	17	0 9 1
45	40	1	1101101x	0 6 D
46	32	0	19	0 9 3
47	32	1	18	0 9 2
48	43	0	0011010x	0 1 A
49	43	1	0011001x	0 1 9
50	49	0	28	0 9 C
51	49	1	20	0 9 4
52	48	0	0110010x	0 3 2
53	48	1	0011011x	0 1 B
54	53	0	0110001x	0 3 1
55	53	1	0011100x	0 1 C
56	55	0	33	0 A 1
57	55	1	21	0 9 5
58	35	0	0100110x	0 2 6
59	35	1	0011110x	0 1 E
60	59	0	0101000x	0 2 8
61	59	1	0011111x	0 1 F
62	61	0	24	0 9 8
63	61	1	22	0 9 6
64	29	0	0101100x	0 2 C
65	29	1	0100001x	0 2 1
66	65	0	0100100x	0 2 4
67	65	1	0100010x	0 2 2
68	67	0	0100011x	0 2 3
69	67	1	0111000x	0 3 8
70	68	0	23	0 9 7
71	68	1	1000101x	0 4 5
72	66	0	0111010x	0 3 A
73	66	1	0100101x	0 2 5
74	73	0	44	0 A C
75	73	1	25	0 9 9
76	58	0	0101011x	0 2 B
77	58	1	0100111x	0 2 7
78	77	0	29	0 9 D
79	77	1	26	0 9 A
80	60	0	0101001x	0 2 9
81	60	1	30	0 9 E
82	80	0	0101010x	0 2 A
83	80	1	1111100x	0 7 C
84	82	0	27	0 9 B
85	82	1	1111111x	0 7 F
86	76	0	32	0 A 0
87	76	1	31	0 9 F
88	64	0	0111101x	0 3 D
89	64	1	0101101x	0 2 D
90	89	0	0101110x	0 2 E
91	89	1	1001010x	0 4 A
92	90	0	0110101x	0 3 5
93	90	1	0101111x	0 2 F
94	93	0	0110100x	0 3 4
95	93	1	0110000x	0 3 0
96	95	0	37	0 A 5

97	95	1	34	0 A 2
98	54	0	36	0 A 4
99	54	1	35	0 A 3
100	52	0	0110111x	0 3 7
101	52	1	0110011x	0 3 3
102	101	0	43	0 A B
103	101	1	38	0 A 6
104	94	0	40	0 A 8
105	94	1	39	0 A 7
106	92	0	0111100x	0 3 C
107	92	1	0110110x	0 3 6
108	107	0	42	0 A A
109	107	1	41	0 A 9
110	100	0	46	0 A E
111	100	1	45	0 A D
112	69	0	0111011x	0 3 B
113	69	1	0111001x	0 3 9
114	113	0	49	0 B 1
115	113	1	47	0 A F
116	72	0	51	0 B 3
117	72	1	48	0 B 0
118	112	0	57	0 B 9
119	112	1	50	0 B 2
120	106	0	53	0 B 5
121	106	1	52	0 B 4
122	88	0	1000110x	0 4 6
123	88	1	0111110x	0 3 E
124	123	0	1000010x	0 4 2
125	123	1	0111111x	0 3 F
126	125	0	1000001x	0 4 1
127	125	1	1000000x	0 4 0
128	127	0	55	0 B 7
129	127	1	54	0 B 6
130	126	0	58	0 B A
131	126	1	56	0 B 8
132	124	0	1000100x	0 4 4
133	124	1	1000011x	0 4 3
134	133	0	60	0 B C
135	133	1	59	0 B B
136	132	0	62	0 B E
137	132	1	61	0 B D
138	71	0	65	0 C 1
139	71	1	63	0 B F
140	122	0	1001011x	0 4 B
141	122	1	1000111x	0 4 7
142	141	0	1001001x	0 4 9
143	141	1	1001000x	0 4 8
144	143	0	66	0 C 2
145	143	1	64	0 C 0
146	142	0	69	0 C 5
147	142	1	67	0 C 3
148	91	0	71	0 C 7
149	91	1	68	0 C 4
150	140	0	1001101x	0 4 D
151	140	1	1001100x	0 4 C
152	151	0	72	0 C 8
153	151	1	70	0 C 6
154	150	0	74	0 C A
155	150	1	73	0 C 9
156	39	0	1011110x	0 5 E
157	39	1	1001111x	0 4 F
158	157	0	1010111x	0 5 7
159	157	1	1010000x	0 5 0
160	159	0	1010100x	0 5 4
161	159	1	1010001x	0 5 1
162	161	0	1010011x	0 5 3
163	161	1	1010010x	0 5 2
164	163	0	76	0 C C
165	163	1	75	0 C B
166	162	0	78	0 C E
167	162	1	77	0 C D
168	160	0	1010110x	0 5 6
169	160	1	1010101x	0 5 5
170	169	0	80	0 D 0

171	169	1	79
172	168	0	82
173	168	1	81
174	158	0	1011011x
175	158	1	1011000x
176	175	0	1011010x
177	175	1	1011001x
178	177	0	84
179	177	1	83
180	176	0	86
181	176	1	85
182	174	0	1011101x
183	174	1	1011100x
184	183	0	88
185	183	1	87
186	182	0	90
187	182	1	89
188	156	0	1100110x
189	156	1	1011111x
190	189	0	1100011x
191	189	1	1100000x
192	191	0	1100010x
193	191	1	1100001x
194	193	0	92
195	193	1	91
196	192	0	94
197	192	1	93
198	190	0	1100101x
199	190	1	1100100x
200	199	0	96
201	199	1	95
202	198	0	98
203	198	1	97
204	188	0	1101010x
205	188	1	1100111x
206	205	0	1101001x
207	205	1	1101000x
208	207	0	100
209	207	1	99
210	206	0	102
211	206	1	101
212	204	0	1101100x
213	204	1	1101011x
214	213	0	104
215	213	1	103
216	212	0	106
217	212	1	105
218	45	0	1110101x
219	45	1	1101110x
220	219	0	1110010x
221	219	1	1101111x
222	221	0	1110001x
223	221	1	1110000x
224	223	0	108
225	223	1	107
226	222	0	110
227	222	1	109
228	220	0	1110100x
229	220	1	1110011x
230	229	0	112
231	229	1	111
232	228	0	114
233	228	1	113
234	218	0	1111001x
235	218	1	1110110x
236	235	0	1111000x
237	235	1	1110111x
238	237	0	116
239	237	1	115
240	236	0	118
241	236	1	117
242	234	0	1111011x
243	234	1	1111010x
244	243	0	120

0	C	F
0	D	2
0	D	1
0	5	B
0	5	8
0	5	A
0	5	9
0	D	4
0	D	3
0	D	6
0	D	5
0	5	D
0	5	C
0	D	8
0	D	7
0	D	A
0	D	9
0	6	6
0	5	F
0	6	3
0	6	0
0	6	2
0	6	1
0	D	C
0	D	B
0	D	E
0	D	D
0	6	5
0	6	4
0	E	0
0	D	F
0	E	2
0	E	1
0	6	A
0	6	7
0	6	9
0	6	8
0	E	4
0	E	3
0	E	6
0	E	5
0	6	C
0	6	B
0	E	8
0	E	7
0	E	A
0	E	9
0	7	5
0	6	E
0	7	2
0	6	F
0	7	1
0	7	0
0	E	C
0	E	B
0	E	E
0	E	D
0	7	4
0	7	3
0	F	0
0	E	F
0	F	2
0	F	1
0	7	9
0	7	6
0	7	8
0	7	7
0	F	4
0	F	3
0	F	6
0	F	5
0	7	B
0	7	A
0	F	8

245	243	1	119	0 F 7
246	242	0	122	0 F A
247	242	1	121	0 F 9
248	83	0	1111110x	0 7 E
249	83	1	1111101x	0 7 D
250	249	0	124	0 F C
251	249	1	123	0 F B
252	248	0	126	0 F E
253	248	1	125	0 F D
254	85	0	128	1 8 0
255	85	1	127	0 F F

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T A B L E 3

Entry \* Father \* Bit \* Value or Sons \* ROM Data: EOB,Z,E,T,D6-D0 \*\*\*

0	none	0	0000010x	0 0 2
1	none	1	0000001x	0 0 1
2	1	0	1	0 8 1
3	1	1	0	2 8 0
4	0	0	0000100x	0 0 4
5	0	1	0000011x	0 0 3
6	5	0	0000101x	0 0 5
7	5	1	2	0 8 2
8	4	0	0000110x	0 0 6
9	4	1	3	0 8 3
10	6	0	4	0 8 4
11	6	1	0001000x	0 0 8
12	8	0	5	0 8 5
13	8	1	0000111x	0 0 7
14	13	0	0001101x	0 0 D
15	13	1	6	0 8 6
16	11	0	0001010x	0 0 A
17	11	1	0001001x	0 0 9
18	17	0	7	0 8 7
19	17	1	0001011x	0 0 B
20	16	0	8	0 8 8
21	16	1	0001100x	0 0 C
22	19	0	0001111x	0 0 F
23	19	1	9	0 8 9
24	21	0	0010000x	0 1 0
25	21	1	10	0 8 A
26	14	0	0010001x	0 1 1
27	14	1	0001110x	0 0 E
28	27	0	0010100x	0 1 4
29	27	1	11	0 8 B
30	22	0	0011001x	0 1 9
31	22	1	12	0 8 C
32	24	0	13	0 8 D
33	24	1	0010110x	0 1 6
34	26	0	0010011x	0 1 3
35	26	1	0010010x	0 1 2
36	35	0	0011000x	0 1 8
37	35	1	14	0 8 E
38	34	0	0010111x	0 1 7
39	34	1	15	0 8 F
40	28	0	0011011x	0 1 B
41	28	1	0010101x	0 1 5
42	41	0	16	0 9 0
43	41	1	0011111x	0 1 F
44	33	0	17	0 9 1
45	33	1	0100011x	0 2 3
46	38	0	18	0 9 2
47	38	1	0110010x	0 3 2
48	36	0	0100110x	0 2 6
49	36	1	19	0 9 3
50	30	0	0011010x	0 1 A
51	30	1	0100000x	0 2 0
52	50	0	20	0 9 4
53	50	1	0011110x	0 1 E

54	40	0	0011100x	0 1 C
55	40	1	0011101x	0 1 D
56	54	0	21	0 9 5
57	54	1	0101111x	0 2 F
58	55	0	0100101x	0 2 5
59	55	1	22	0 9 6
60	53	0	23	0 9 7
61	53	1	29	0 9 D
62	43	0	0101000x	0 2 8
63	43	1	24	0 9 8
64	51	0	0100010x	0 2 2
65	51	1	0100001x	0 2 1
66	65	0	1001111x	0 4 F
67	65	1	25	0 9 9
68	64	0	26	0 9 A
69	64	1	0110101x	0 3 5
70	45	0	0101011x	0 2 B
71	45	1	0100100x	0 2 4
72	71	0	27	0 9 B
73	71	1	1000101x	0 4 5
74	58	0	0101110x	0 2 E
75	58	1	28	0 9 C
76	48	0	0100111x	0 2 7
77	48	1	0101001x	0 2 9
78	76	0	30	0 9 E
79	76	1	1001010x	0 4 A
80	62	0	31	0 9 F
81	62	1	0101010x	0 2 A
82	77	0	0111010x	0 3 A
83	77	1	32	0 A 0
84	81	0	43	0 A B
85	81	1	33	0 A 1
86	70	0	0101100x	0 2 C
87	70	1	0110001x	0 3 1
88	86	0	0111001x	0 3 9
89	86	1	0101101x	0 2 D
90	89	0	44	0 A C
91	89	1	34	0 A 2
92	74	0	35	0 A 3
93	74	1	1000001x	0 4 1
94	57	0	0111000x	0 3 8
95	57	1	0110000x	0 3 0
96	95	0	40	0 A 8
97	95	1	36	0 A 4
98	87	0	37	0 A 5
99	87	1	1100010x	0 6 2
100	47	0	0111101x	0 3 D
101	47	1	0110011x	0 3 3
102	101	0	0111100x	0 3 C
103	101	1	0110100x	0 3 4
104	103	0	39	0 A 7
105	103	1	38	0 A 6
106	69	0	0110111x	0 3 7
107	69	1	0110110x	0 3 6
108	107	0	41	0 A 9
109	107	1	1101010x	0 6 A
110	106	0	47	0 A F
111	106	1	42	0 A A
112	94	0	50	0 B 2
113	94	1	45	0 A D
114	88	0	51	0 B 3
115	88	1	46	0 A E
116	82	0	1001000x	0 4 8
117	82	1	0111011x	0 3 B
118	117	0	52	0 B 4
119	117	1	48	0 B 0
120	102	0	54	0 B 6
121	102	1	49	0 B 1
122	100	0	0111110x	0 3 E
123	100	1	1010101x	0 5 5
124	122	0	0111111x	0 3 F
125	122	1	1110001x	0 7 1
126	124	0	1001001x	0 4 9
127	124	1	1000000x	0 4 0

128	127	0	57	0 B 9
129	127	1	53	0 B 5
130	93	0	1000010x	0 4 2
131	93	1	73	0 C 9
132	130	0	1011100x	0 5 C
133	130	1	1000011x	0 4 3
134	133	0	1000100x	0 4 4
135	133	1	125	0 F D
136	134	0	79	0 C F
137	134	1	55	0 B 7
138	73	0	1001100x	0 4 C
139	73	1	1000110x	0 4 6
140	139	0	1000111x	0 4 7
141	139	1	74	0 C A
142	140	0	59	0 B B
143	140	1	56	0 B 8
144	116	0	61	0 B D
145	116	1	58	0 B A
146	126	0	62	0 B E
147	126	1	60	0 B C
148	79	0	1001110x	0 4 E
149	79	1	1001011x	0 4 E
150	149	0	64	0 C 0
151	149	1	63	0 B F
152	138	0	1010011x	0 5 3
153	138	1	1001101x	0 4 D
154	153	0	66	0 C 2
155	153	1	65	0 C 1
156	148	0	76	0 C C
157	148	1	67	0 C 3
158	66	0	1011001x	0 5 9
159	66	1	1010000x	0 5 0
160	159	0	1010110x	0 5 6
161	159	1	1010001x	0 5 1
162	161	0	1010100x	0 5 4
163	161	1	1010010x	0 5 2
164	163	0	70	0 C 6
165	163	1	68	0 C 4
166	152	0	72	0 C 8
167	152	1	69	0 C 5
168	162	0	75	0 C B
169	162	1	71	0 C 7
170	123	0	1011111x	0 5 F
171	123	1	77	0 C D
172	160	0	1011000x	0 5 8
173	160	1	1010111x	0 5 7
174	173	0	80	0 D 0
175	173	1	78	0 C E
176	172	0	82	0 D 2
177	172	1	81	0 D 1
178	158	0	1100000x	0 6 0
179	158	1	1011010x	0 5 A
180	179	0	1011110x	0 5 E
181	179	1	1011011x	0 5 B
182	181	0	84	0 D 4
183	181	1	83	0 D 3
184	132	0	1100101x	0 6 5
185	132	1	1011101x	0 5 D
186	185	0	88	0 D 8
187	185	1	85	0 D 5
188	180	0	89	0 D 9
189	180	1	86	0 D 6
190	170	0	1100110x	0 6 6
191	170	1	87	0 D 7
192	178	0	1100100x	0 6 4
193	178	1	1100001x	0 6 1
194	193	0	91	0 D B
195	193	1	90	0 D A
196	99	0	1101100x	0 6 C
197	99	1	1100011x	0 6 3
198	197	0	95	0 D F
199	197	1	92	0 D C
200	192	0	96	0 E 0
201	192	1	93	0 D D

202	184	0	97	0 E 1
203	184	1	94	0 D E
204	190	0	1101110x	0 6 E
205	190	1	1100111x	0 6 7
206	205	0	1101001x	0 6 9
207	205	1	1101000x	0 6 8
208	207	0	99	0 E 3
209	207	1	98	0 E 2
210	206	0	102	0 E 6
211	206	1	100	0 E 4
212	109	0	1101101x	0 6 D
213	109	1	1101011x	0 6 B
214	213	0	103	0 E 7
215	213	1	101	0 E 5
216	196	0	114	0 F 2
217	196	1	104	0 E 8
218	212	0	113	0 F 1
219	212	1	105	0 E 9
220	204	0	1110000x	0 7 0
221	204	1	1101111x	0 6 F
222	221	0	107	0 E B
223	221	1	106	0 E A
224	220	0	109	0 E D
225	220	1	108	0 E C
226	125	0	1111001x	0 7 9
227	125	1	1110010x	0 7 2
228	227	0	1110110x	0 7 6
229	227	1	1110011x	0 7 3
230	229	0	1110101x	0 7 5
231	229	1	1110100x	0 7 4
232	231	0	111	0 E F
233	231	1	110	0 E E
234	230	0	115	0 F 3
235	230	1	112	0 F 0
236	228	0	1111000x	0 7 8
237	228	1	1110111x	0 7 7
238	237	0	117	0 F 5
239	237	1	116	0 F 4
240	236	0	119	0 F 7
241	236	1	118	0 F 6
242	226	0	1111101x	0 7 D
243	226	1	1111010x	0 7 A
244	243	0	1111100x	0 7 C
245	243	1	1111011x	0 7 B
246	245	0	121	0 F 9
247	245	1	120	0 F 8
248	244	0	123	0 F B
249	244	1	122	0 F A
250	242	0	1111111x	0 7 F
251	242	1	1111110x	0 7 E
252	251	0	126	0 F E
253	251	1	124	0 F C
254	250	0	128	1 B 0
255	250	1	127	0 F F

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T A B L E 4

\*\*\* Entry \* Father \* Bit \* Value or Sons \* ROM Data: EOB,Z,E,T,D6-D0 \*\*\*

0	none	0	0000011x	0 0 3
1	none	1	0000001x	0 0 1
2	1	0	0000100x	0 0 4
3	1	1	0000010x	0 0 2
4	3	0	0001000x	0 0 8
5	3	1	0	2 8 0
6	0	0	0000101x	0 0 5
7	0	1	1	0 8 1
8	2	0	0000110x	0 0 6
9	2	1	2	0 8 2
10	6	0	3	0 8 3
11	6	1	0000111x	0 0 7
12	8	0	0001110x	0 0 E
13	8	1	4	0 8 4

14	11	0	0001011x	0 0 B
15	11	1	5	0 8 5
16	4	0	0001010x	0 0 A
17	4	1	0001001x	0 0 9
18	17	0	6	0 8 6
19	17	1	0001100x	0 0 C
20	16	0	7	0 8 7
21	16	1	0001101x	0 0 D
22	14	0	0010100x	0 1 4
23	14	1	8	0 8 8
24	19	0	9	0 8 9
25	19	1	0010000x	0 1 0
26	21	0	10	0 8 A
27	21	1	0010111x	0 1 7
28	12	0	0001111x	0 0 F
29	12	1	0010001x	0 1 1
30	28	0	12	0 8 C
31	28	1	11	0 8 B
32	25	0	13	0 8 D
33	25	1	0010110x	0 1 6
34	29	0	0010011x	0 1 3
35	29	1	0010010x	0 1 2
36	35	0	0100000x	0 2 0
37	35	1	14	0 8 E
38	34	0	15	0 8 F
39	34	1	0100010x	0 2 2
40	22	0	0010101x	0 1 5
41	22	1	0011010x	0 1 A
42	40	0	0011101x	0 1 D
43	40	1	16	0 9 0
44	33	0	0100110x	0 2 6
45	33	1	17	0 9 1
46	27	0	0011001x	0 1 9
47	27	1	0011000x	0 1 8
48	47	0	0011110x	0 1 E
49	47	1	18	0 9 2
50	46	0	0011111x	0 1 F
51	46	1	19	0 9 3
52	41	0	0011100x	0 1 C
53	41	1	0011011x	0 1 B
54	53	0	22	0 9 6
55	53	1	20	0 9 4
56	52	0	21	0 9 5
57	52	1	0100100x	0 2 4
58	42	0	23	0 9 7
59	42	1	0100101x	0 2 5
60	48	0	24	0 9 8
61	48	1	0101000x	0 2 8
62	50	0	25	0 9 9
63	50	1	0110100x	0 3 4
64	36	0	0100001x	0 2 1
65	36	1	0101001x	0 2 9
66	64	0	0111001x	0 3 9
67	64	1	26	0 9 A
68	39	0	0101100x	0 2 C
69	39	1	0100011x	0 2 3
70	69	0	0110000x	0 3 4
71	69	1	27	0 9 B
72	57	0	0101110x	0 2 E
73	57	1	28	0 9 C
74	59	0	29	0 9 D
75	59	1	0101111x	0 2 F
76	44	0	0100111x	0 2 7
77	44	1	0110001x	0 3 1
78	76	0	0110011x	0 3 3
79	76	1	30	0 9 E
80	61	0	31	0 9 F
81	61	1	0110111x	0 3 7
82	65	0	0101010x	0 2 A
83	65	1	0101011x	0 2 B
84	82	0	33	0 A 1
85	82	1	32	0 A 0
86	83	0	34	0 A 2
87	83	1	0111101x	0 3 D
88	68	0	0111111x	0 3 F

89	68	1	0101101x	0 2 D
90	89	0	35	0 A 3
91	89	1	1001111x	0 4 F
92	72	0	40	0 A 8
93	72	1	36	0 A 4
94	75	0	37	0 A 5
95	75	1	1000010x	0 4 2
96	70	0	128	1 8 0
97	70	1	38	0 A 6
98	77	0	0111011x	0 3 B
99	77	1	0110010x	0 3 2
100	99	0	39	0 A 7
101	99	1	1001001x	0 4 9
102	78	0	41	0 A 9
103	78	1	1000100x	0 4 4
104	63	0	0110110x	0 3 6
105	63	1	0110101x	0 3 5
106	105	0	42	0 A A
107	105	1	1001011x	0 4 B
108	104	0	45	0 A D
109	104	1	43	0 A B
110	81	0	0111000x	0 3 8
111	81	1	1011100x	0 5 C
112	110	0	1100100x	0 6 4
113	110	1	44	0 A C
114	66	0	1001101x	0 4 D
115	66	1	0111010x	0 3 A
116	115	0	46	0 A E
117	115	1	1000011x	0 4 3
118	98	0	1000001x	0 4 1
119	98	1	0111100x	0 3 C
120	119	0	47	0 A F
121	119	1	1010100x	0 5 4
122	87	0	50	0 B 2
123	87	1	0111110x	0 3 E
124	123	0	48	0 B 0
125	123	1	1100000x	0 6 0
126	88	0	1000000x	0 4 0
127	88	1	1000101x	0 4 5
128	126	0	54	0 B 6
129	126	1	49	0 B 1
130	118	0	52	0 B 4
131	118	1	51	0 B 3
132	95	0	53	0 B 5
133	95	1	1011001x	0 5 9
134	117	0	55	0 B 7
135	117	1	71	0 C 7
136	103	0	1000111x	0 4 7
137	103	1	56	0 B 8
138	127	0	1010111x	0 5 7
139	127	1	1000110x	0 4 6
140	139	0	57	0 B 9
141	139	1	1100001x	0 6 1
142	136	0	1011000x	0 5 8
143	136	1	1001000x	0 4 8
144	143	0	68	0 C 4
145	143	1	58	0 B A
146	101	0	1001010x	0 4 A
147	101	1	1101011x	0 6 B
148	146	0	59	0 B B
149	146	1	1111100x	0 7 C
150	107	0	1010010x	0 5 2
151	107	1	1001100x	0 4 C
152	151	0	63	0 B F
153	151	1	60	0 B C
154	114	0	1010011x	0 5 3
155	114	1	1001110x	0 4 E
156	155	0	64	0 C 0
157	155	1	61	0 B D
158	91	0	1010000x	0 5 0
159	91	1	1010110x	0 5 6
160	158	0	1010101x	0 5 5
161	158	1	1010001x	0 5 1
162	161	0	69	0 C 5
163	161	1	62	0 B E

164	150	0
165	150	1
166	154	0
167	154	1
168	121	0
169	121	1
170	160	0
171	160	1
172	159	0
173	159	1
174	138	0
175	138	1
176	142	0
177	142	1
178	133	0
179	133	1
180	178	0
181	178	1
182	101	0
183	181	1
184	111	0
185	111	1
186	185	0
187	185	1
188	187	0
189	187	1
190	186	0
191	186	1
192	125	0
193	125	1
194	141	0
195	141	1
196	184	0
197	184	1
198	197	0
199	197	1
200	112	0
201	112	1
202	200	0
203	200	1
204	202	0
205	202	1
206	204	0
207	204	1
208	179	0
209	179	1
210	196	0
211	196	1
212	180	0
213	180	1
214	147	0
215	147	1
216	215	0
217	215	1
218	217	0
219	217	1
220	208	0
221	208	1
222	221	0
223	221	1
224	223	0
225	223	1
226	216	0
227	216	1
228	201	0
229	201	1
230	214	0
231	214	1
232	231	0
233	231	1
234	222	0
235	222	1
236	220	0
237	220	1
238	237	0

72
65
70
66
75
67
80
73
83
74
81
76
78
77
1011010x
1101000x
1101010x
1011011x
79
1111010x
1100010x
1011101x
1011111x
1011110x
84
82
87
85
106
86
92
88
1101001x
1100011x
91
89
1100101x
1110010x
1100110x
123
1100111x
127
98
90
1101110x
93
102
94
96
95
1110011x
1101100x
1110001x
1101101x
100
97
1110110x
1101111x
1110101x
1110000x
103
99
105
101
114
104
1111001x
1110100x
111
107
109
100
1111000x
1110111x
112

0 C 8
0 C 1
0 C 6
0 C 2
0 C 8
0 C 3
0 D 0
0 C 9
0 D 3
0 C A
0 D 1
0 C C
0 C E
0 C D
0 5 A
0 6 8
0 6 A
0 5 B
0 C F
0 7 A
0 6 2
0 5 D
0 5 F
0 5 E
0 D 4
0 D 2
0 D 7
0 D 5
0 E A
0 D 6
0 D C
0 D 8
0 6 9
0 6 3
0 D 8
0 D 9
0 6 5
0 7 2
0 6 6
0 F E
0 6 7
0 F F
0 E 2
0 D A
0 6 E
0 D D
0 E 6
0 D E
0 E 0
0 D F
0 7 3
0 6 C
0 7 1
0 6 D
0 E 4
0 E 1
0 7 6
0 6 F
0 7 5
0 7 0
0 E 7
0 E 3
0 E 9
0 E 5
0 F 2
0 E 8
0 7 9
0 7 4
0 E F
0 E B
0 E D
0 E C
0 7 8
0 7 7
0 F 0

239	237	1	110	0 E E
240	236	0	117	0 F 5
241	236	1	113	0 F 1
242	230	0	116	0 F 4
243	230	1	115	0 F 3
244	183	0	1111110x	0 7 E
245	183	1	1111011x	0 7 B
246	245	0	119	0 F 7
247	245	1	118	0 F 6
248	149	0	1111111x	0 7 F
249	149	1	1111101x	0 7 D
250	249	0	124	0 F C
251	249	1	120	0 F 6
252	244	0	122	0 F A
253	244	1	121	0 F 9
254	248	0	126	0 F E
255	248	1	125	0 F D

\*\*\*\*\*  
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 T A B L E 5

Entry \* Father \* Bit \* Value or Sons \* ROM Data: EOB,Z,E,T,D6-D0 \*\*\*

0	none	0	0000011x	0 0 3
1	none	1	0000001x	0 0 1
2	1	0	0000010x	0 0 2
3	1	1	0000101x	0 0 5
4	2	0	0	2 8 0
5	2	1	1	0 8 1
6	0	0	0001000x	0 0 8
7	0	1	0000100x	0 0 4
8	7	0	2	0 8 2
9	7	1	0000111x	0 0 7
10	3	0	0000110x	0 0 6
11	3	1	0001011x	0 0 8
12	10	0	0001101x	0 0 D
13	10	1	3	0 8 3
14	9	0	0001110x	0 0 E
15	9	1	4	0 8 4
16	6	0	0001010x	0 0 A
17	6	1	0001001x	0 0 9
18	17	0	5	0 8 5
19	17	1	0001111x	0 0 F
20	16	0	6	0 8 6
21	16	1	0010000x	0 1 0
22	11	0	0010010x	0 1 2
23	11	1	0001100x	0 0 C
24	23	0	7	0 8 7
25	23	1	0010001x	0 1 1
26	12	0	8	0 8 8
27	12	1	0010100x	0 1 4
28	14	0	9	0 8 9
29	14	1	0011011x	0 1 B
30	19	0	0010110x	0 1 6
31	19	1	10	0 8 A
32	21	0	11	0 8 B
33	21	1	0011110x	0 1 E
34	25	0	12	0 8 C
35	25	1	0010111x	0 1 7
36	22	0	0010101x	0 1 5
37	22	1	0010011x	0 1 3
38	37	0	13	0 8 D
39	37	1	0011001x	0 1 9
40	27	0	0100010x	0 2 2
41	27	1	14	0 8 E
42	36	0	15	0 8 F
43	36	1	0011000x	0 1 8
44	30	0	16	0 9 0
45	30	1	0011010x	0 1 A
46	35	0	17	0 9 1
47	35	1	0101110x	0 2 E
48	43	0	0100000x	0 2 0
49	43	1	18	0 9 2

50	39	0	0100110x	0 2 6
51	39	1	19	0 9 3
52	45	0	0101000x	0 2 8
53	45	1	20	0 9 4
54	29	0	0011101x	0 1 D
55	29	1	0011100x	0 1 C
56	55	0	21	0 9 5
57	55	1	0100001x	0 2 1
58	54	0	22	0 9 6
59	54	1	0110100x	0 3 4
60	33	0	0011111x	0 1 F
61	33	1	0100100x	0 2 4
62	60	0	25	0 9 9
63	60	1	23	0 9 7
64	48	0	0110011x	0 3 3
65	48	1	24	0 9 8
66	57	0	0101101x	0 2 D
67	57	1	26	0 9 A
68	40	0	0101001x	0 2 9
69	40	1	0100011x	0 2 3
70	69	0	27	0 9 B
71	69	1	28	0 9 C
72	61	0	0101100x	0 2 C
73	61	1	0100101x	0 2 5
74	73	0	29	0 9 D
75	73	1	1001010x	0 4 A
76	50	0	0101011x	0 2 B
77	50	1	0100111x	0 2 7
78	77	0	30	0 9 E
79	77	1	0111000x	0 3 8
80	52	0	31	0 9 F
81	52	1	0110110x	0 3 6
82	68	0	0111001x	0 3 9
83	68	1	0101010x	0 2 A
84	83	0	37	0 A 5
85	83	1	32	0 A 0
86	76	0	128	1 8 0
87	76	1	33	0 A 1
88	72	0	34	0 A 2
89	72	1	0110000x	0 3 0
90	66	0	35	0 A 3
91	66	1	1011001x	0 5 9
92	47	0	0110001x	0 3 1
93	47	1	0101111x	0 2 F
94	93	0	36	0 A 4
95	93	1	1000100x	0 4 4
96	89	0	38	0 A 6
97	89	1	43	0 A B
98	92	0	0110010x	0 3 2
99	92	1	0111011x	0 3 B
100	98	0	63	0 B F
101	98	1	39	0 A 7
102	64	0	40	0 A 8
103	64	1	0111100x	0 3 C
104	59	0	0110101x	0 3 5
105	59	1	0111101x	0 3 D
106	104	0	41	0 A 9
107	104	1	1000011x	0 4 3
108	81	0	1000001x	0 4 1
109	81	1	0110111x	0 3 7
110	109	0	51	0 B 3
111	109	1	42	0 A A
112	79	0	44	0 A C
113	79	1	1001111x	0 4 F
114	82	0	0111010x	0 3 A
115	82	1	47	0 A F
116	114	0	45	0 A D
117	114	1	1010110x	0 5 6
118	99	0	1001000x	0 4 8
119	99	1	46	0 A E
120	103	0	1001101x	0 4 D
121	103	1	48	0 B 0
122	105	0	1000000x	0 4 0
123	105	1	0111110x	0 3 E
124	123	0	1000110x	0 4 6
125	123	1	0111111x	0 3 F
126	125	0	49	0 B 1

127	125	1	1110111x	0 7 7
128	122	0	50	0 B 2
129	122	1	1011000x	0 5 8
130	108	0	1000010x	0 4 2
131	108	1	52	0 B 4
132	130	0	53	0 B 5
133	130	1	1010010x	0 5 2
134	107	0	58	0 B A
135	107	1	54	0 B 6
136	95	0	1000111x	0 4 7
137	95	1	1000101x	0 4 5
138	137	0	55	0 B 7
139	137	1	1110010x	0 7 2
140	124	0	60	0 B C
141	124	1	56	0 B 8
142	136	0	1010100x	0 5 4
143	136	1	57	0 B 9
144	118	0	1001001x	0 4 9
145	118	1	1101011x	0 6 B
146	144	0	59	0 B E
147	144	1	1110101x	0 7 5
148	75	0	1001110x	0 4 E
149	75	1	1001011x	0 4 B
150	149	0	1010001x	0 5 1
151	149	1	1001100x	0 4 C
152	151	0	66	0 C 2
153	151	1	61	0 B D
154	120	0	64	0 C 0
155	120	1	62	0 B E
156	148	0	1011101x	0 5 D
157	148	1	65	0 C 1
158	113	0	1011100x	0 5 C
159	113	1	1010000x	0 5 0
160	159	0	73	0 C 9
161	159	1	67	0 C 3
162	150	0	69	0 C 5
163	150	1	68	0 C 4
164	133	0	1010011x	0 5 3
165	133	1	126	0 F E
166	164	0	82	0 D 2
167	164	1	70	0 C 6
168	142	0	1100100x	0 6 4
169	142	1	1010101x	0 5 5
170	169	0	71	0 C 7
171	169	1	1111110x	0 7 E
172	117	0	1010111x	0 5 7
173	117	1	76	0 C C
174	172	0	72	0 C 8
175	172	1	1011111x	0 5 F
176	129	0	84	0 D 4
177	129	1	74	0 C A
178	91	0	1100010x	0 6 2
179	91	1	1011010x	0 5 A
180	179	0	1011110x	0 5 E
181	179	1	1011011x	0 5 B
182	181	0	77	0 C D
183	181	1	75	0 C B
184	158	0	100	0 E C
185	158	1	78	0 C E
186	156	0	1100110x	0 6 6
187	156	1	79	0 C F
188	180	0	83	0 D 3
189	180	1	80	0 D 0
190	175	0	1100000x	0 6 0
191	175	1	1101000x	0 6 8
192	190	0	1100001x	0 6 1
193	190	1	1111100x	0 7 C
194	192	0	91	0 D B
195	192	1	81	0 D 1
196	178	0	1100101x	0 6 5
197	178	1	1100011x	0 6 3
198	197	0	86	0 D 6
199	197	1	85	0 D 5
200	168	0	93	0 D D
201	168	1	87	0 D 7
202	196	0	102	0 E 6

4,541,012

59

60

203	196	1	88	0 D 8
204	186	0	1101101x	0 6 D
205	186	1	1100111x	0 6 7
206	205	0	90	0 D A
207	205	1	89	0 D 9
208	191	0	1110000x	0 7 0
209	191	1	1101001x	0 6 9
210	209	0	1101110x	0 6 E
211	209	1	1101010x	0 6 A
212	211	0	95	0 D F
213	211	1	92	0 D C
214	145	0	1101111x	0 6 F
215	145	1	1101100x	0 6 C
216	215	0	99	0 E 3
217	215	1	94	0 D E
218	204	0	98	0 E 2
219	204	1	96	0 E 0
220	210	0	103	0 E 7
221	210	1	97	0 E 1
222	214	0	101	0 E 5
223	214	1	100	0 E 4
224	208	0	1111011x	0 7 B
225	208	1	1110001x	0 7 1
226	225	0	111	0 E F
227	225	1	104	0 E 8
228	139	0	1111000x	0 7 8
229	139	1	1110011x	0 7 3
230	229	0	1110110x	0 7 6
231	229	1	1110100x	0 7 4
232	231	0	106	0 E A
233	231	1	105	0 E 9
234	147	0	109	0 E D
235	147	1	107	0 E B
236	230	0	113	0 F 1
237	230	1	110	0 E E
238	127	0	118	0 F 6
239	127	1	112	0 F 0
240	228	0	1111010x	0 7 A
241	228	1	1111001x	0 7 9
242	241	0	115	0 F 3
243	241	1	114	0 F 2
244	240	0	120	0 F 8
245	240	1	116	0 F 4
246	224	0	119	0 F 7
247	224	1	117	0 F 5
248	193	0	1111111x	0 7 F
249	193	1	1111101x	0 7 D
250	249	0	123	0 F B
251	249	1	121	0 F 9
252	171	0	125	0 F D
253	171	1	122	0 F A
254	248	0	127	0 F F
255	248	1	124	0 F C

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T A B L E 6

\*\*\* Entry \* Father \* Bit \* Value or Sons \* ROM Data: EOB.Z,E,T,D6-D0 \*\*\*

0	none	0	0000011x	0 0 3
1	none	1	0000001x	0 0 1
2	1	0	0000010x	0 0 2
3	1	1	0000101x	0 0 5
4	2	0	0000111x	0 0 7
5	2	1	0	2 8 0
6	0	0	0000100x	0 0 4
7	0	1	0001000x	0 0 8
8	6	0	0010000x	0 1 0
9	6	1	1	0 8 1
10	3	0	0001011x	0 0 B
11	3	1	0000110x	0 0 6
12	11	0	2	0 8 2
13	11	1	0001010x	0 0 A
14	4	0	3	0 8 3
15	4	1	0001110x	0 0 E
16	7	0	0001001x	0 0 9

17	7	1	0010101x	0 1 5
18	16	0	0001111x	0 0 F
19	16	1	4	0 8 4
20	13	0	0011111x	0 1 F
21	13	1	5	0 8 5
22	10	0	0001101x	0 0 D
23	10	1	0001100x	0 0 C
24	23	0	0010100x	0 1 4
25	23	1	6	0 8 6
26	22	0	0010011x	0 1 3
27	22	1	7	0 8 7
28	15	0	8	0 8 8
29	15	1	0011011x	0 1 B
30	18	0	0100101x	0 2 5
31	18	1	9	0 8 9
32	8	0	0010001x	0 1 1
33	8	1	0010010x	0 1 2
34	32	0	0011101x	0 1 D
35	32	1	10	0 8 A
36	33	0	0011100x	0 1 C
37	33	1	11	0 8 B
38	26	0	0101101x	0 2 D
39	26	1	12	0 8 C
40	24	0	0100010x	0 2 2
41	24	1	13	0 8 D
42	17	0	0010110x	0 1 6
43	17	1	0011000x	0 1 8
44	42	0	0011110x	0 1 E
45	42	1	0010111x	0 1 7
46	45	0	14	0 8 E
47	45	1	0100001x	0 2 1
48	43	0	0011010x	0 1 A
49	43	1	0011001x	0 1 9
50	49	0	15	0 8 F
51	49	1	16	0 9 0
52	48	0	17	0 9 1
53	48	1	0101001x	0 2 9
54	29	0	0100011x	0 2 3
55	29	1	18	0 9 2
56	36	0	19	0 9 3
57	36	1	0101000x	0 2 8
58	34	0	0101010x	0 2 A
59	34	1	20	0 9 4
60	44	0	0101111x	0 2 F
61	44	1	21	0 9 5
62	20	0	0100100x	0 2 4
63	20	1	0100000x	0 2 0
64	63	0	22	0 9 6
65	63	1	0100111x	0 2 7
66	47	0	26	0 9 A
67	47	1	23	0 9 7
68	40	0	24	0 9 8
69	40	1	0111011x	0 3 B
70	54	0	0110001x	0 3 1
71	54	1	25	0 9 9
72	62	0	27	0 9 B
73	62	1	0101100x	0 2 C
74	30	0	0101011x	0 2 B
75	30	1	0100110x	0 2 6
76	75	0	29	0 9 D
77	75	1	28	0 9 C
78	65	0	0110110x	0 3 6
79	65	1	30	0 9 E
80	57	0	0110100x	0 3 4
81	57	1	31	0 9 F
82	53	0	0110010x	0 3 2
83	53	1	32	0 A 0
84	58	0	0111000x	0 3 8
85	58	1	33	0 A 1
86	74	0	0111001x	0 3 9
87	74	1	34	0 A 2
88	73	0	0110101x	0 3 5
89	73	1	35	0 A 3
90	38	0	0101110x	0 2 E
91	38	1	0111111x	0 3 F
92	90	0	36	0 A 4

93	90	1	1000010x	0 4 2
94	60	0	01100011x	0 3 3
95	60	1	01100000x	0 3 0
96	95	0	39	0 A 7
97	95	1	37	0 A 5
98	70	0	38	0 A 6
99	70	1	0110111x	0 3 7
100	82	0	1001010x	0 4 A
101	82	1	40	0 A B
102	94	0	43	0 A B
103	94	1	41	0 A 9
104	80	0	45	0 A D
105	80	1	42	0 A A
106	88	0	44	0 A C
107	88	1	0111110x	0 3 E
108	78	0	47	0 A F
109	78	1	46	0 A E
110	99	0	1001100x	0 4 C
111	99	1	48	0 B 0
112	84	0	0111101x	0 3 D
113	84	1	49	0 B 1
114	86	0	128	1 8 0
115	86	1	0111010x	0 3 A
116	115	0	70	0 C 6
117	115	1	50	0 B 2
118	69	0	1000100x	0 4 4
119	69	1	0111100x	0 3 C
120	119	0	1100101x	0 6 5
121	119	1	51	0 B 3
122	112	0	52	0 B 4
123	112	1	1000111x	0 4 7
124	107	0	1011000x	0 5 8
125	107	1	53	0 B 5
126	91	0	1000000x	0 4 0
127	91	1	1010100x	0 5 4
128	126	0	1000001x	0 4 1
129	126	1	1101001x	0 6 9
130	128	0	55	0 B 7
131	128	1	54	0 B 6
132	93	0	1001001x	0 4 9
133	93	1	1000011x	0 4 3
134	133	0	57	0 B 9
135	133	1	56	0 B 8
136	118	0	1001101x	0 4 D
137	118	1	1000101x	0 4 5
138	137	0	1000110x	0 4 6
139	137	1	1111000x	0 7 8
140	138	0	65	0 C 1
141	138	1	58	0 B A
142	123	0	1001000x	0 4 8
143	123	1	96	0 E 0
144	142	0	73	0 C 9
145	142	1	59	0 B B
146	132	0	63	0 B F
147	132	1	60	0 B C
148	100	0	1001011x	0 4 E
149	100	1	61	0 B D
150	148	0	79	0 C F
151	148	1	62	0 B E
152	110	0	1010000x	0 5 0
153	110	1	64	0 C 0
154	136	0	1001111x	0 4 F
155	136	1	1001110x	0 4 E
156	155	0	67	0 C 3
157	155	1	66	0 C 2
158	154	0	69	0 C 5
159	154	1	68	0 C 4
160	152	0	1010001x	0 5 1
161	152	1	1011111x	0 5 F
162	160	0	1011100x	0 5 C
163	160	1	1010010x	0 5 2
164	163	0	1010011x	0 5 3
165	163	1	1111100x	0 7 C
166	164	0	80	0 D 0
167	164	1	71	0 C 7
168	127	0	1011010x	0 5 A

169	127	1	1010101x	0 5 5
170	169	0	1010111x	0 5 7
171	169	1	1010110x	0 5 6
172	171	0	74	0 C A
173	171	1	72	0 C B
174	170	0	76	0 C C
175	170	1	75	0 C B
176	124	0	1100011x	0 6 3
177	124	1	1011001x	0 5 9
178	177	0	85	0 D 5
179	177	1	77	0 C D
180	168	0	1100100x	0 6 4
181	168	1	1011011x	0 5 8
182	181	0	82	0 D 2
183	181	1	78	0 C E
184	162	0	1011110x	0 5 E
185	162	1	1011101x	0 5 D
186	185	0	83	0 D 3
187	185	1	81	0 D 1
188	184	0	86	0 D 6
189	184	1	84	0 D 4
190	161	0	1110001x	0 7 1
191	161	1	1100000x	0 6 0
192	191	0	1101110x	0 6 E
193	191	1	1100001x	0 6 1
194	193	0	1101000x	0 6 8
195	193	1	1100010x	0 6 2
196	195	0	91	0 D B
197	195	1	87	0 D 7
198	176	0	89	0 D 9
199	176	1	88	0 D 8
200	180	0	92	0 D C
201	180	1	90	0 D A
202	120	0	1101100x	0 6 C
203	120	1	1100110x	0 6 6
204	203	0	1101011x	0 6 B
205	203	1	1100111x	0 6 7
206	205	0	97	0 E 1
207	205	1	93	0 D D
208	194	0	101	0 E 5
209	194	1	94	0 D E
210	129	0	1111111x	0 7 F
211	129	1	1101010x	0 6 A
212	211	0	113	0 F 1
213	211	1	95	0 D F
214	204	0	99	0 E 3
215	204	1	98	0 E 2
216	202	0	1110101x	0 7 5
217	202	1	1101101x	0 6 D
218	217	0	105	0 E 9
219	217	1	100	0 E 4
220	192	0	1110000x	0 7 0
221	192	1	1101111x	0 6 F
222	221	0	103	0 E 7
223	221	1	102	0 E 6
224	220	0	106	0 E A
225	220	1	104	0 E 8
226	190	0	1110110x	0 7 6
227	190	1	1110010x	0 7 2
228	227	0	1110100x	0 7 4
229	227	1	1110011x	0 7 3
230	229	0	108	0 E C
231	229	1	107	0 E B
232	228	0	112	0 F 0
233	228	1	109	0 E D
234	216	0	111	0 E F
235	216	1	110	0 E E
236	226	0	1111010x	0 7 A
237	226	1	1110111x	0 7 7
238	237	0	115	0 F 3
239	237	1	114	0 F 2
240	139	0	1111011x	0 7 B
241	139	1	1111001x	0 7 9
242	241	0	117	0 F 5
243	241	1	116	0 F 4
244	236	0	120	0 F 8
245	236	1	118	0 F 6

246	240	0	122	0 F A
247	240	1	119	0 F 7
248	165	0	1111110x	0 7 E
249	165	1	1111101x	0 7 D
250	249	0	123	0 F B
251	249	1	121	0 F 9
252	248	0	126	0 F E
253	248	1	124	0 F C
254	210	0	127	0 F F
255	210	1	125	0 F D

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T A B L E 7

Entry \* Father \* Bit \* Value or Sons \* ROM Data: EOB,Z,E,T,D6-D0 \*\*\*

0	none	0	0000111x	0 0 7
1	none	1	0000001x	0 0 1
2	1	0	0000100x	0 0 4
3	1	1	0000010x	0 0 2
4	3	0	0000011x	0 0 3
5	3	1	0001100x	0 0 C
6	4	0	0001111x	0 0 F
7	4	1	0	2 8 0
8	2	0	0000101x	0 0 5
9	2	1	0010000x	0 1 0
10	8	0	0000110x	0 0 6
11	8	1	0001011x	0 0 B
12	10	0	0011110x	0 1 E
13	10	1	1	0 8 1
14	0	0	0010101x	0 1 5
15	0	1	0001000x	0 0 8
16	15	0	0011010x	0 1 A
17	15	1	0001001x	0 0 9
18	17	0	0010011x	0 1 3
19	17	1	0001010x	0 0 A
20	19	0	0011111x	0 1 F
21	19	1	2	0 8 2
22	11	0	3	0 8 3
23	11	1	0011001x	0 1 9
24	5	0	0001101x	0 0 D
25	5	1	0001110x	0 0 E
26	24	0	4	0 8 4
27	24	1	6	0 8 6
28	25	0	0010100x	0 1 4
29	25	1	5	0 8 5
30	6	0	7	0 8 7
31	6	1	0100011x	0 2 3
32	9	0	0010001x	0 1 1
33	9	1	0010010x	0 1 2
34	32	0	8	0 8 8
35	32	1	9	0 8 9
36	33	0	10	0 8 A
37	33	1	0011101x	0 1 D
38	18	0	11	0 8 B
39	18	1	0100101x	0 2 5
40	28	0	0101110x	0 2 E
41	28	1	12	0 8 C
42	14	0	0100000x	0 2 0
43	14	1	0010110x	0 1 6
44	43	0	0010111x	0 1 7
45	43	1	0011000x	0 1 8
46	44	0	14	0 8 E
47	44	1	13	0 8 D
48	45	0	0101011x	0 2 B
49	45	1	15	0 8 F
50	23	0	16	0 9 0
51	23	1	24	0 9 8
52	16	0	0011011x	0 1 B
53	16	1	0100110x	0 2 6
54	52	0	0101010x	0 2 A
55	52	1	0011100x	0 1 C
56	55	0	17	0 9 1
57	55	1	29	0 9 D
58	37	0	0110111x	0 3 7
59	37	1	18	0 9 2

60	12	0	28	0 9 C
61	12	1	19	0 9 3
62	20	0	20	0 9 4
63	20	1	0110000x	0 3 0
64	42	0	0101000x	0 2 8
65	42	1	0100001x	0 2 1
66	65	0	0101111x	0 2 F
67	65	1	0100010x	0 2 2
68	67	0	39	0 A 7
69	67	1	21	0 9 5
70	31	0	33	0 A 1
71	31	1	0100100x	0 2 4
72	71	0	53	0 B 5
73	71	1	22	0 9 6
74	39	0	23	0 9 7
75	39	1	26	0 9 A
76	53	0	0100111x	0 2 7
77	53	1	0101101x	0 2 D
78	76	0	0110001x	0 3 1
79	76	1	25	0 9 9
80	64	0	0101100x	0 2 C
81	64	1	0101001x	0 2 9
82	81	0	27	0 9 B
83	81	1	52	0 B 4
84	54	0	35	0 A 3
85	54	1	30	0 9 E
86	48	0	31	0 9 F
87	48	1	0110110x	0 3 6
88	80	0	40	0 A 8
89	80	1	32	0 A 0
90	77	0	34	0 A 2
91	77	1	0110010x	0 3 2
92	40	0	36	0 A 4
93	40	1	0110011x	0 3 3
94	66	0	0110101x	0 3 5
95	66	1	37	0 A 5
96	63	0	38	0 A 6
97	63	1	0110100x	0 3 4
98	78	0	42	0 A A
99	78	1	41	0 A 9
100	91	0	43	0 A B
101	91	1	0111000x	0 3 8
102	93	0	44	0 A C
103	93	1	47	0 A F
104	97	0	45	0 A D
105	97	1	46	0 A E
106	94	0	48	0 B 0
107	94	1	0111001x	0 3 9
108	87	0	50	0 B 2
109	87	1	49	0 B 1
110	58	0	51	0 B 3
111	58	1	0111100x	0 3 C
112	101	0	0111111x	0 3 F
113	101	1	54	0 B 6
114	107	0	0111011x	0 3 B
115	107	1	0111010x	0 3 A
116	115	0	55	0 B 7
117	115	1	58	0 B A
118	114	0	1001001x	0 4 9
119	114	1	56	0 B 8
120	111	0	0111101x	0 3 D
121	111	1	128	1 8 0
122	120	0	57	0 B 9
123	120	1	0111110x	0 3 E
124	123	0	60	0 B C
125	123	1	59	0 B B
126	112	0	1000001x	0 4 1
127	112	1	1000000x	0 4 0
128	127	0	61	0 B D
129	127	1	63	0 B F
130	126	0	1000010x	0 4 2
131	126	1	62	0 B E
132	130	0	1000111x	0 4 7
133	130	1	1000011x	0 4 3
134	133	0	1000100x	0 4 4
135	133	1	1101101x	0 6 D

136	134	0	64	0 C 0
137	134	1	1000101x	0 4 5
138	137	0	1000110x	0 4 6
139	137	1	1111100x	0 7 C
140	138	0	65	0 C 1
141	138	1	1111111x	0 7 F
142	132	0	1010000x	0 5 0
143	132	1	1001000x	0 4 8
144	143	0	69	0 C 5
145	143	1	66	0 C 2
146	118	0	1001010x	0 4 A
147	118	1	1010101x	0 5 5
148	146	0	1011011x	0 5 B
149	146	1	1001011x	0 4 B
150	149	0	1010001x	0 5 1
151	149	1	1001100x	0 4 C
152	151	0	1001101x	0 4 D
153	151	1	105	0 E 9
154	152	0	1001111x	0 4 F
155	152	1	1001110x	0 4 E
156	155	0	68	0 C 4
157	155	1	67	0 C 3
158	154	0	71	0 C 7
159	154	1	70	0 C 6
160	142	0	76	0 C C
161	142	1	72	0 C 8
162	150	0	1011000x	0 5 8
163	150	1	1010010x	0 5 2
164	163	0	1010100x	0 5 4
165	163	1	1010011x	0 5 3
166	165	0	74	0 C A
167	165	1	73	0 C 9
168	164	0	78	0 C E
169	164	1	75	0 C B
170	147	0	1011111x	0 5 F
171	147	1	1010110x	0 5 6
172	171	0	1100007x	0 6 1
173	171	1	1010111x	0 5 7
174	173	0	80	0 D 0
175	173	1	77	0 C D
176	162	0	1011010x	0 5 A
177	162	1	1011001x	0 5 9
178	177	0	81	0 D 1
179	177	1	79	0 C F
180	176	0	83	0 D 3
181	176	1	82	0 D 2
182	148	0	1100101x	0 6 5
183	148	1	1011100x	0 5 C
184	183	0	1100010x	0 6 2
185	183	1	1011101x	0 5 D
186	185	0	1100000x	0 6 0
187	185	1	1011110x	0 5 E
188	187	0	85	0 D 5
189	187	1	84	0 D 4
190	170	0	86	0 D 6
191	170	1	1101000x	0 6 8
192	186	0	89	0 D 9
193	186	1	87	0 D 7
194	172	0	90	0 D A
195	172	1	88	0 D 8
196	184	0	1100100x	0 6 4
197	184	1	1100011x	0 6 3
198	197	0	92	0 D C
199	197	1	91	0 D B
200	196	0	94	0 D E
201	196	1	93	0 D D
202	182	0	1101010x	0 6 A
203	182	1	1100110x	0 6 6
204	203	0	1101001x	0 6 9
205	203	1	1100111x	0 6 7
206	205	0	97	0 E 1
207	205	1	95	0 D F
208	191	0	101	0 E 5
209	191	1	96	0 E 0
210	204	0	99	0 E 3

211	204	1	98	0 E 2
212	202	0	1101100x	0 6 C
213	202	1	1101011x	0 6 B
214	213	0	102	0 E 6
215	213	1	100	0 E 4
216	212	0	104	0 E 8
217	212	1	103	0 E 7
218	135	0	1110101x	0 7 5
219	135	1	1101110x	0 6 E
220	219	0	1110010x	0 7 2
221	219	1	1101111x	0 6 F
222	221	0	1110001x	0 7 1
223	221	1	1110000x	0 7 0
224	223	0	107	0 E B
225	223	1	106	0 E A
226	222	0	109	0 E D
227	222	1	108	0 E C
228	220	0	1110100x	0 7 4
229	220	1	1110011x	0 7 3
230	229	0	111	0 E F
231	229	1	110	0 E E
232	228	0	113	0 F 1
233	228	1	112	0 F 0
234	218	0	1111001x	0 7 9
235	218	1	1110110x	0 7 6
236	235	0	1111000x	0 7 8
237	235	1	1110111x	0 7 7
238	237	0	115	0 F 3
239	237	1	114	0 F 2
240	236	0	117	0 F 5
241	236	1	116	0 F 4
242	234	0	1111011x	0 7 B
243	234	1	1110110x	0 7 A
244	243	0	119	0 F 7
245	243	1	118	0 F 6
246	242	0	121	0 F 9
247	242	1	120	0 F 8
248	139	0	1111110x	0 7 E
249	139	1	1111011x	0 7 D
250	249	0	123	0 F B
251	249	1	122	0 F A
252	248	0	125	0 F D
253	248	1	124	0 F C
254	141	0	127	0 F F
255	141	1	126	0 F E

\*\*\*\*\*  
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 T A B L E B

\*\* Entry \* Father \* Bit \* Value or Sons \* ROM Data: EOB,Z,E,T,D6-D0 \*

0	none	0	0000001x	0 0 1
1	none	1	0000010x	0 0 2
2	0	0	0000101x	0 0 5
3	0	1	0	0 8 0
4	1	0	0000011x	0 0 3
5	1	1	128	4 8 0
6	4	0	1	0 8 1
7	4	1	0000100x	0 0 4
8	7	0	0001000x	0 0 8
9	7	1	2	0 8 2
10	2	0	0000111x	0 0 7
11	2	1	0000110x	0 0 6
12	11	0	3	0 8 3
13	11	1	0001011x	0 0 B
14	10	0	4	0 8 4
15	10	1	0001001x	0 0 9
16	8	0	5	0 8 5
17	8	1	0001010x	0 0 A
18	15	0	0001110x	0 0 E
19	15	1	6	0 8 6
20	17	0	8	0 8 8
21	17	1	7	0 8 7
22	13	0	0001101x	0 0 D
23	13	1	0001100x	0 0 C
24	23	0	9	0 8 9

25	23	1	00011111x	0 0 F
26	22	0	00100000x	0 1 0
27	22	1	10	0 8 A
28	18	0	00100001x	0 1 1
29	18	1	11	0 8 B
30	25	0	00100011x	0 1 3
31	25	1	12	0 8 C
32	26	0	14	0 8 E
33	26	1	13	0 8 D
34	28	0	0010101x	0 1 5
35	28	1	0010010x	0 1 2
36	35	0	15	0 8 F
37	35	1	00110000x	0 1 8
38	30	0	00101000x	0 1 4
39	30	1	0011011x	0 1 B
40	38	0	16	0 9 0
41	38	1	0011010x	0 1 A
42	34	0	0010111x	0 1 7
43	34	1	0010110x	0 1 6
44	43	0	20	0 9 4
45	43	1	17	0 9 1
46	42	0	18	0 9 2
47	42	1	22	0 9 6
48	37	0	0011110x	0 1 E
49	37	1	0011001x	0 1 9
50	49	0	0100111x	0 2 7
51	49	1	19	0 9 3
52	41	0	26	0 9 A
53	41	1	21	0 9 5
54	39	0	0011101x	0 1 D
55	39	1	0011100x	0 1 C
56	55	0	25	0 9 9
57	55	1	23	0 9 7
58	54	0	0011111x	0 1 F
59	54	1	24	0 9 8
60	48	0	27	0 9 B
61	48	1	0100011x	0 2 3
62	58	0	0100001x	0 2 1
63	58	1	0100000x	0 2 0
64	63	0	28	0 9 C
65	63	1	0101011x	0 2 B
66	62	0	30	0 9 E
67	62	1	0100010x	0 2 2
68	67	0	0110001x	0 3 1
69	67	1	29	0 9 D
70	61	0	0100100x	0 2 4
71	61	1	1010111x	0 5 7
72	70	0	0100101x	0 2 5
73	70	1	0100110x	0 2 6
74	72	0	31	0 9 F
75	72	1	0101101x	0 2 D
76	73	0	32	0 A 0
77	73	1	1110110x	0 7 6
78	50	0	0111000x	0 3 8
79	50	1	0101000x	0 2 8
80	79	0	0101001x	0 2 9
81	79	1	35	0 A 3
82	80	0	0101110x	0 2 E
83	80	1	0101010x	0 2 A
84	83	0	36	0 A 4
85	83	1	33	0 A 1
86	65	0	0101100x	0 2 C
87	65	1	34	0 A 2
88	86	0	38	0 A 6
89	86	1	37	0 A 5
90	75	0	39	0 A 7
91	75	1	1111101x	0 7 D
92	82	0	0110101x	0 3 5
93	82	1	0101111x	0 2 F
94	93	0	0110100x	0 3 4
95	93	1	0110000x	0 3 0
96	95	0	44	0 A C
97	95	1	40	0 A 8
98	68	0	0110011x	0 3 3
99	68	1	0110010x	0 3 2
100	99	0	42	0 A A

101	99	1	41	0	A	9
102	98	0	47	0	A	F
103	98	1	43	0	A	B
104	94	0	46	0	A	E
105	94	1	45	0	A	D
106	92	0	0110111x	0	3	7
107	92	1	0110110x	0	3	6
108	107	0	49	0	B	1
109	107	1	48	0	B	0
110	106	0	51	0	B	3
111	106	1	50	0	B	2
112	78	0	1001000x	0	4	8
113	78	1	0111001x	0	3	9
114	113	0	1000001x	0	4	1
115	113	1	0111010x	0	3	A
116	115	0	0111110x	0	3	E
117	115	1	0111011x	0	3	B
118	117	0	0111101x	0	3	D
119	117	1	0111100x	0	3	C
120	119	0	53	0	B	5
121	119	1	52	0	B	4
122	118	0	55	0	B	7
123	118	1	54	0	B	6
124	116	0	1000000x	0	4	0
125	116	1	0111111x	0	3	F
126	125	0	57	0	B	9
127	125	1	56	0	B	8
128	124	0	59	0	B	B
129	124	1	58	0	B	A
130	114	0	1000101x	0	4	5
131	114	1	1000010x	0	4	2
132	131	0	1000100x	0	4	4
133	131	1	1000011x	0	4	3
134	133	0	61	0	B	D
135	133	1	60	0	B	C
136	132	0	63	0	B	F
137	132	1	62	0	B	E
138	130	0	1000111x	0	4	7
139	130	1	1000110x	0	4	6
140	139	0	65	0	C	1
141	139	1	64	0	C	0
142	138	0	67	0	C	3
143	138	1	66	0	C	2
144	112	0	1010000x	0	5	0
145	112	1	1001001x	0	4	9
146	145	0	1001101x	0	4	D
147	145	1	1001010x	0	4	A
148	147	0	1001100x	0	4	C
149	147	1	1001011x	0	4	E
150	149	0	69	0	C	5
151	149	1	68	0	C	4
152	148	0	71	0	C	7
153	148	1	70	0	C	6
154	146	0	1001111x	0	4	F
155	146	1	1001110x	0	4	E
156	155	0	73	0	C	9
157	155	1	72	0	C	8
158	154	0	75	0	C	B
159	154	1	74	0	C	A
160	144	0	1010100x	0	5	4
161	144	1	1010001x	0	5	1
162	161	0	1010011x	0	5	3
163	161	1	1010010x	0	5	2
164	163	0	77	0	C	D
165	163	1	76	0	C	C
166	162	0	79	0	C	F
167	162	1	78	0	C	E
168	160	0	1010110x	0	5	6
169	160	1	1010101x	0	5	5
170	169	0	81	0	D	1
171	169	1	80	0	D	0
172	168	0	83	0	D	3
173	168	1	82	0	D	2
174	71	0	1100111x	0	6	7
175	71	1	1011000x	0	5	8
176	175	0	1100000x	0	6	0
177	175	1	1011001x	0	5	9

79				
178	177	0	1011101x	0 5 D
179	177	1	1011010x	0 5 A
180	179	0	1011100x	0 5 C
181	179	1	1011011x	0 5 B
182	181	0	85	0 D 5
183	181	1	84	0 D 4
184	180	0	87	0 D 7
185	180	1	86	0 D 6
186	178	0	1011111x	0 5 F
187	178	1	1011110x	0 5 E
188	187	0	89	0 D 9
189	187	1	88	0 D 8
190	186	0	91	0 D B
191	186	1	90	0 D A
192	176	0	1100100x	0 6 4
193	176	1	1100001x	0 6 1
194	193	0	1100011x	0 6 3
195	193	1	1100010x	0 6 2
196	195	0	93	0 D D
197	195	1	92	0 D C
198	194	0	95	0 D F
199	194	1	94	0 D E
200	192	0	1100110x	0 6 6
201	192	1	1100101x	0 6 5
202	201	0	97	0 E 1
203	201	1	96	0 E 0
204	200	0	99	0 E 3
205	200	1	98	0 E 2
206	174	0	1101111x	0 6 F
207	174	1	1101000x	0 6 8
208	207	0	1101100x	0 6 C
209	207	1	1101001x	0 6 9
210	209	0	1101011x	0 6 B
211	209	1	1101010x	0 6 A
212	211	0	101	0 E 5
213	211	1	100	0 E 4
214	210	0	103	0 E 7
215	210	1	102	0 E 6
216	208	0	1101110x	0 6 E
217	208	1	1101101x	0 6 D
218	217	0	105	0 E 9
219	217	1	104	0 E 8
220	216	0	107	0 E B
221	216	1	106	0 E A
222	206	0	1110011x	0 7 3
223	206	1	1110000x	0 7 0
224	223	0	1110010x	0 7 2
225	223	1	1110001x	0 7 1
226	225	0	109	0 E D
227	225	1	108	0 E C
228	224	0	111	0 E F
229	224	1	110	0 E E
230	222	0	1110101x	0 7 5
231	222	1	1110100x	0 7 4
232	231	0	113	0 F 1
233	231	1	112	0 F 0
234	230	0	115	0 F 3
235	230	1	114	0 F 2
236	77	0	1111010x	0 7 A
237	77	1	1110111x	0 7 7
238	237	0	1111001x	0 7 9
239	237	1	1111000x	0 7 8
240	239	0	117	0 F 5
241	239	1	116	0 F 4
242	238	0	119	0 F 7
243	238	1	118	0 F 6
244	236	0	1111100x	0 7 C
245	236	1	1111011x	0 7 B
246	245	0	121	0 F 9
247	245	1	120	0 F 8
248	244	0	123	0 F B
249	244	1	122	0 F A
250	91	0	1111111x	0 7 F
251	91	1	1111110x	0 7 E
252	251	0	125	0 F D
253	251	1	124	0 F C
254	250	0	127	0 F F
255	250	1	126	0 F E

What is claimed is:

1. A method for processing time domain information signals having a successive field format to effect substantial compression of said signals, said method comprising the steps of:

comparing corresponding blocks of time domain information signals from successive fields to form a block difference signal;

converting a block of said time domain information signals to transform domain signals including a D.C. coefficient representing the average intensity of a converted block and a plurality of discrete transform coefficients when said block difference signal exceeds a first variable parametric value;

varying said first variable parametric value in accordance with the number of blocks selected for conversion; and

encoding said transform domain coefficients for subsequent utilization.

2. The method of claim 1 wherein said step of comparing includes the steps of storing successive fields of said time domain information signals in a first memory device on a pixel by pixel basis, and retrieving said corresponding blocks from said memory device on a pixel by pixel basis.

3. The method of claim 2 further including the step of replacing a block of pixel elements in said memory device with the corresponding block in a successive field when said difference exceeds said first variable parametric value.

4. The method of claim 2 wherein said step of storing includes the step of merging successive fields on a pixel by pixel basis.

5. The method of claim 4 wherein said step of merging is performed by summing corresponding pixels from successive fields in accordance with a predetermined weighting factor.

6. The method of claim 5 wherein the pixels from the first appearing merged field are weighted by a factor of  $\frac{3}{4}$  and the pixels from the later appearing field are weighted by a factor of  $\frac{1}{4}$ .

7. The method of claim 1 wherein said step of converting is performed by transforming said block along a first direction and subsequently transforming said block along the orthogonal direction.

8. The method of claim 7 wherein said first direction corresponds to a horizontal line of raster scan information and said orthogonal direction corresponds to a vertical column of raster scan information.

9. The method of claim 7 wherein said step of converting includes the step of storing said transform coefficients in diagonal format in a second memory device.

10. The method of claim 9 further including the step of storing the field address of each transformed block in said second memory device.

11. A method for processing time domain information signals having a successive field format to effect substantial compression of said signals, said method comprising the steps of:

comparing corresponding blocks of time domain information signals from successive fields to form a block difference signal, said step of comparing including the steps of storing successive fields of said time domain information signals in a first memory device on a pixel by pixel basis, retrieving said corresponding blocks from said memory device on a pixel by pixel basis, forming the difference between corresponding pixels from said successive

blocks, squaring the resulting pixel difference signals, summing the squares of said resulting pixel difference signals, and dividing the resulting sum by a number of pixels per block to form said block difference signal;

converting a block of said time domain information signals to transform domain signals including a D.C. coefficient representing the average intensity of a converted block and a plurality of discrete transform coefficients when said block difference signal exceeds a first variable parametric value; and encoding said transform domain coefficients for subsequent utilization.

12. The method of claim 11 wherein each block comprises a total of 64 pixels grouped in an 8 by 8 array.

13. A method for processing time domain information signals having a successive field format to effect substantial compression of said signals, said method comprising the steps of:

comparing corresponding blocks of time domain information signals from successive fields to form a block difference signal;

converting a block of said time domain information signals to transform domain signals including a D.C. coefficient representing the average intensity of a converted block and a plurality of discrete transform coefficients when said block difference signal exceeds a first variable parametric value; and

encoding said transform domain coefficients for subsequent utilization, including the steps of providing a plurality of different code tables, dividing each of said plurality of discrete transform coefficients by a second variable parametric value to obtain a corresponding quantized coefficient, calculating the predictive value of each quantized coefficient, selecting one of said plurality of code tables in accordance with the predictive value, and generating a code representing said quantized coefficient from said selected table.

14. The method of claim 13 wherein said step of calculating is performed in accordance with the formula  $PM_K = \frac{1}{4}C_K + \frac{3}{4}PM_{K-1}$ , where  $PM_K$  is the predictive mean value of the  $K^{th}$  quantized coefficient,  $C_K$  is the value of the  $K^{th}$  quantized coefficient and  $PM_{K-1}$  is the predictive mean value of the  $K-1^{th}$  quantized coefficient.

15. The method of claim 13 wherein said step of encoding includes the steps of providing a dedicated code table for encoding each DC coefficient and selecting said dedicated table for each said DC coefficient.

16. The method of claim 13 wherein said time domain information signals are color video signals having quadrature components, and wherein said step of encoding includes the steps of providing individual code tables for said quadrature components, calculating the average value of each quadrature component for the converted block, and selecting a code value representing said average value from the corresponding individual quadrature component table.

17. The method of claim 13 wherein said step of encoding further includes the step of generating an address code specifying the field address of the converted block.

18. The method of claim 17 wherein said step of generating includes the steps of providing an address code table having code values arranged in accordance with the following formula:

If  $\Delta_k = 1$ , code 1 bit ( $\Delta_k$ )

If  $\Delta_k < 32$ , code 1 bit zero + 5 bits ( $\Delta_k$ )

If  $\Delta_k \geq 32$ , code 6 bits zero + 10 bits ( $\Delta_k$ )

where

$$\Delta_k = A_k - A_{k-1}$$

$A_k$  = numerical address of current block

$A_{k-1}$  = numerical address of most recently encoded block,

and selecting said address code table for each said address code.

19. The method of claim 13 wherein said step of encoding further includes the steps of comparing said predictive value with a preselected fixed threshold value, and generating a run length code specifying the total number of successive quantized coefficients of zero value when said predictive value lies below said preselected fixed threshold value.

20. The method of claim 19 wherein said step of encoding further includes the step of generating an end of block code when the predictive values for successive remaining quantized coefficients in the converted block lie below said preselected fixed threshold value.

21. The method of claim 19 wherein said codes are multi-bit binary codes, and wherein said method further includes the steps of transferring said codes to a buffer in the order of generation, monitoring the number of bits transferred to said buffer, and varying said first and second parametric values in accordance with said number of transferred bits in order to minimize buffer overflow.

22. The method of claim 21 wherein said second parametric value is varied in accordance with the formula:

$$D = D'_K + K_D \cdot \text{BFN}(B_K - N/2)$$

where

$$\text{BFN}(X) = (X/N - |X|)$$

$D_K$  = Distortion parameter for block K

$D'_K$  = Filtered distortion parameter

$$D'_K = T \cdot D'_{K-1} + (1-T)D_{K-1}$$

where

T = a constant (close to 1)

$K_D$  = a constant

$B_K$  = # of bits in buffer for block K

N = Max. number of bits.

23. The method of claim 22 wherein said first parametric value is varied in accordance with the alternate formula:

$$T_K = T_{INIT}$$

for  $B_{LOW} \leq B_K \leq B_{HIGH}$

$$T_K = T_{INIT} + K_R \cdot \text{BFN}(B_{LOW} - B_K)$$

for  $B_K < B_{LOW}$

$$T_K = T_{INIT} + K_R \cdot \text{BFN}(B_K - B_{HIGH})$$

for  $B_K > B_{HIGH}$

where

$T_K$  = replenishment threshold for block K

$T_{INIT}$  = initial threshold (about 5 for 8-bit input data)

$K_R$  = multiplier constant (about 25-75)

$B_{LOW}$  = low cutoff (about 0.1 of buffer)

$B_{HIGH}$  = high cutoff (about 0.75 of buffer).

24. The method of claim 13 wherein each of said code tables comprises a Huffman code table.

25. A method of encoding transform coefficients representing time domain information signals having a successive field format prior to transmission over a

communication link in order to effect substantial compression of said signals, said transform coefficients being arranged in a plurality of groups, each group representing an N by N block of field information signals, said method comprising the steps of:

(a) providing a plurality of code tables:

(b) generating a block address code from a first dedicated one of said code tables, said block address code representing the field address of the block represented by a group of said transform coefficients;

(c) generating a DC coefficient code representing the average intensity of said block from a second dedicated one of said plurality of code tables; and

(d) generating a succession of codes representing the remaining transform coefficients corresponding to said block by calculating the predictive value of each said remaining transform coefficient, selecting one of said plurality of code tables in accordance with said predictive value, and generating a code representing the corresponding transform coefficient from said selected table.

26. The method of claim 25 wherein said step of calculating is performed in accordance with the formula  $PM_K = \frac{1}{4} C_K + \frac{3}{4} PM_{K-1}$ , where  $PM_K$  is the predictive mean value of the K<sup>th</sup> coefficient,  $C_K$  is the actual value of the K<sup>th</sup> coefficient and  $PM_{K-1}$  is the predictive mean value of the K-1<sup>th</sup> coefficient.

27. The method of claim 25 wherein said time domain information signals are color video signals having quadrature components, and wherein said method of encoding includes the steps of providing individual code tables for said quadrature components, calculating the average value of each quadrature component for said block, and selecting a code value representing said average value from the corresponding individual quadrature component table.

28. The method of claim 25 wherein said method of encoding further includes the steps of comparing each said predictive value with a preselected threshold value, and generating a zero run length code specifying the total number of successive predictive values lying below said preselected threshold value.

29. The method of claim 28 wherein said codes are multi-bit binary codes, wherein said method of encoding further includes dividing each of said remaining transform coefficients by a variable parametric value to obtain corresponding quantized remaining coefficients for use in forming the predictive values, and wherein said method further includes the steps of transferring said codes to a buffer in the order of generation, monitoring the number of bits transferred to said buffer, and varying said variable parametric value in accordance with the following formula:

$$D = D'_K + K_D \cdot \text{BFN}(B_K - N/2)$$

where

$$\text{BFN}(X) = X/(N - |X|)$$

$D_K$  = Distortion parameter for block K

$D'_K$  = Filtered distortion parameter

$$D'_K = T \cdot D'_{K-1} + (1-T)D_{K-1}$$

where

T = a constant (close to 1)

$K_D$  = a constant

$B_K$  = # of bits in buffer for block K

N = Max. number of bits.

30. The method of claim 28 further including the step

of generating an end of block code when the predictive values for successive remaining transform coefficients in said block lie below said preselected threshold value.

31. The method of claim 25 wherein said transform coefficients comprise discrete cosine transform coefficients. 5

32. A method for processing time domain information signals for transmission over a communication link, said time domain information signals having a successive field format, said method comprising the steps of: 10

comparing corresponding sub-field blocks of time domain information signals from successive fields to form a block difference signal;

converting a sub-field block of said time domain information signals to a transform domain signal represented by a D.C. coefficient representing the average intensity of the converted block and a plurality of discrete transform coefficients when said block difference signal between the corresponding blocks exceeds a first variable parametric value; and 15 20

generating a frame sync code signal indicating the beginning of a frame;

generating a first control code signal  $B_K$  representative of the fullness of a transmission rate buffer at the beginning of said frame; 25

generating a second control code signal  $D_K$  representative of a second variable parametric value at the beginning of said frame; and 30

generating a plurality of block replenishment code symbols each representative of the value of transform coefficients corresponding to individual sub-

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field blocks having interfield block differences greater than said first variable parametric value, each said block replenishment code symbol including a block address code specifying the field address of the corresponding block, a D.C. code term representative of said D.C. coefficient of the corresponding block, and a plurality of coefficient code terms representative of the value of said plurality of discrete transform coefficients as quantified according to said second control code signal  $D_K$  for the corresponding block.

33. The method of claim 32 wherein said time domain information signals are color video signals having quadrature components, and wherein said step of generating block replenishment code symbols includes the step of providing first and second color code terms in each of said plurality of said block replenishment code symbols representing the average value of each quadrature component for said corresponding block between said block address code and said DC code term.

34. The method of claim 32 wherein said step of generating block replenishment code symbols includes the step of providing a run length code term specifying the total number of successive transform coefficient zero values having a predictive mean value less than a preselected fixed threshold value.

35. The method of claim 32 wherein said step of generating block replenishment code symbols includes a step of providing an end of block code term when the predictive values for successive remaining transform coefficients in said corresponding block lie below a preselected fixed threshold value.

\* \* \* \* \*

UNITED STATES PATENT AND TRADEMARK OFFICE  
CERTIFICATE OF CORRECTION

PATENT NO. : 4,541,012  
DATED : September 10, 1985  
INVENTOR(S) : ANDREW G. TESCHER et al

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title page, item [75] should read:

Inventors: Andrew G. Tescher, Claremont, Calif.,  
Eric R. Hamilton, Los Gatos, Calif.,  
Robert D. Widergren, Saratoga, Calif., and  
Stanley C. Fralick, Saratoga, Calif.

Column 3, line 19, "varible" should be --variable--.

Column 3, line 48, "availablef" should be --variable--.

Column 11, line 32, formula should read:

$$I_{AV} \text{ BLOCK } K = (I_{AV1} + I_{AV2} + \dots + I_{AV8}) / 8$$

Column 11, line 45, formula should read:

$$Q_{AV} \text{ BLOCK } K = (A_{AV1} + Q_{AV2} + \dots + Q_{AV8}) / 8$$

Column 83, line 51 should read: --for  $B_{LOW} \leq B_K \leq B_{HIGH}$ --

Column 85, line 5, "consine" should be --cosine--.

Signed and Sealed this

Sixth Day of May 1986

[SEAL]

Attest:

DONALD J. QUIGG

Attesting Officer

Commissioner of Patents and Trademarks