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ITU-T T.81 (JPEG-1)-based still-image coding using an alternative arithmetic coder

ITU-T Recommendation T.851

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ITU-T T.81 (JPEG-1)-based still-image coding using an alternative arithmetic coder

Summary

This Recommendation defines a format for digital compression and coding of still images supporting the use of an alternative arithmetic coder called the "Q15-coder" and an alternative baseline compared to ITU-T Rec. T.81 | ISO/IEC 10918-1 (JPEG-1). Support of the Huffman entropy coding method specified in ITU-T Rec. T.81 (JPEG-1) is not required in this Recommendation.

The Q15-coder resolves the carry in the decoder instead of in the encoder, and so has a low latency compared to the QM-coder arithmetic coder incorporated in T.81, which has a potential latency of the rest of the entire entropy-coded segment.

This Recommendation also specifies a DCT with input precision of 16 bits, which is greater than the precision of the T.81 (JPEG-1) DCT.

Source

ITU-T Recommendation T.851 was approved on 13 September 2005 by ITU-T Study Group 16 (2005-2008) under the ITU-T Recommendation A.8 procedure.

Keywords

Alternative baseline, Q15-coder, still-image coding, still-image compression, still images.

FOREWORD

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NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

Introduction

ITU-T Rec. T.81 | ISO/IEC 10918-1 (T.81) specifies a process for digital compression and coding of continuous-tone still images.

T.81 contains two entropy coders: Huffman coding and an arithmetic coder called the "QM-coder". The Huffman coding method is required in the T.81 baseline. For all other encoding processes (extended sequential, progressive, hierarchical, and lossless), the use of all defined entropy coders is allowed.

This Recommendation defines a still-image coding method based on ITU-T Rec. T.81 (JPEG-1) which makes use of an alternative arithmetic encoder called the "Q15-coder", and defines an "alternative baseline" compared to ITU-T Rec. T.81. In this Recommendation, support for Huffman coding is not required.

NOTE – Images encoded according to this Recommendation can be losslessly transcoded to or from any of the entropy coding methods of ITU-T Rec. T.81, including the baseline Huffman coding of ITU-T Rec. T.81.

All decoders which support any DCT-based process defined in Table 1 shall also be capable of decoding bitstream conforming to the alternative baseline.

Interoperability with the Huffman-based baseline of T.81 is not required by this Recommendation, but might be required by an application incorporating this Recommendation. An application specification might require a dual-mode entropy codec, or a server-based transcoding facility.

ITU-T Recommendation T.851

ITU-T T.81 (JPEG-1)-based still-image coding using an alternative arithmetic coder

1 Scope

This Recommendation is applicable to continuous-tone, greyscale or colour, digital still-image data. According to the principles of ITU-T Rec. T.80, it enhances T.81 technologies by providing an additional arithmetic coder.

This Recommendation:

- defines an arithmetic coder ("Q15-coder") for use with T.81 technologies;
- extends the DCT input precision to 16 bits;
- provides an alternative baseline in which no Huffman coding is required.

The provisions of ITU-T Rec. T.81 | ISO/IEC 10918-1 shall apply to this Recommendation with the exceptions, additions, and deletions given in this Recommendation.

2 References

2.1 Normative references

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

– ITU-T Recommendation T.80 (1992), *Common components for image compression and communication – Basic Principles*.

– ITU-T Recommendation T.81 (1992) | ISO/IEC 10918-1:1994, *Information technology — Digital compression and coding of continuous-tone still images: Requirements and guidelines (often called "JPEG-1")*.

2.2 Informative references

Additional arithmetic coding references:

– MARKS (K.M.): A JBIG-ABIC compression engine for digital document processing, *IBM J. Res. Develop.*, Vol. 42, No. 6, pp. 753-758, 1998.

– KAMPF (F.A.): Performance as a function of compression, *IBM J. Res. Develop.*, Vol. 42, No. 6, pp. 759-766, 1998.

– SLATTERY (M.S.) and MITCHELL (J.L.): The Qx-coder, *IBM J. Res. Develop.*, Vol. 42, No. 6, pp. 767-784, 1998.

3 Definitions

This Recommendation defines the following terms:

3.1 alternative baseline (sequential): A particular sequential DCT-based encoding and decoding process specified in this Recommendation.

3.2 bit stuffing: A procedure in which the arithmetic encoder inserts a bit in the next byte into the entropy-coded segment following the generation of an encoded hexadecimal X'FF' byte. This procedure replaces byte stuffing.

4 Abbreviations

This Recommendation uses the following abbreviations:

IEC International Electrotechnical Commission

ISO International Organization for Standardization

JPEG Joint Photographic Experts Group (The joint ITU-T | ISO/IEC committee responsible for developing joint text standards for continuous-tone still picture coding)

5 Conventions

In this Recommendation the following conventions are used:

– "shall" indicates a mandatory requirement.

– "should" indicates a suggested but optional course of action.

– "may" indicates an optional course of action rather than a recommendation that something take place.

For the purposes of this Recommendation, the following additional symbols apply:

a the ASCII text letter "a" (X'61')

c the ASCII text letter "c" (X'63')

JPG marker used for JPEG extensions including Q15-coding

Lj length of parameters in the JPG segment for JPEG extensions

2 the ASCII text number "2" (X'32')

6 General

The provisions of ITU-T Rec. T.81 | ISO/IEC 10918-1 shall apply to this Recommendation with the exceptions, additions, and deletions given in this Recommendation.

Every instance where an arithmetic coder is used in ITU-T Rec. T.81 | ISO/IEC 10918-1, the arithmetic coder defined in this Recommendation shall be used instead. For the purposes of this Recommendation, Table 1/T.81 | ISO/IEC 10918-1 shall be considered to be extended with the additions in Table 1 below, in which an alternative baseline and a set of alternative processes are defined.

Table 1/T.851 – Summary: Essential characteristics of additional coding processes

Alternative-Baseline Process (required for all DCT-based decoding processes)
• DCT-based process • Source image: 8-bit samples within each component • Sequential • Q15-arithmetic coding • Decoders shall process scans with 1, 2, 3, and 4 components • Interleaved and non-interleaved scans

Alternative Extended DCT-based Processes
• DCT-based process • Source image: 8-bit through 16-bit samples • Sequential or progressive • Arithmetic coding (Q15-coder): 4 AC and 4 DC tables • Decoders shall process scans with 1, 2, 3, and 4 components • Interleaved and non-interleaved scans

Alternative Lossless Processes
• Predictive process (not DCT-based) • Source image: P-bit samples ($2 \leq P \leq 16$) • Sequential • Arithmetic coding (Q15-coder): 4 DC tables • Decoders shall process scans with 1, 2, 3, and 4 components • Interleaved and non-interleaved scans

Alternative Hierarchical Processes
• Multiple frames (non-differential and differential) • Uses alternate extended DCT-based or alternate lossless processes • Decoders shall process scans with 1, 2, 3, and 4 components • Interleaved and non-interleaved scans

7 Alternative baseline

For conformance with the alternative baseline defined in this Recommendation, any DCT-based decoder shall also embody the alternative-baseline sequential decoding process.

The alternative-baseline sequential process shall start with the JPG extension marker with the parameters "ac2" (e.g., specifies use of the Q15-coder). The precision P shall be 8 for the input and reconstructed samples within each component. Only one Start of Frame (SOF9) is allowed. The decoders shall process interleaved and non-interleaved scans with 1, 2, 3, and 4 components. The quantization values shall be expressed in one byte (Pq = 0).

8 Compressed data formats

Table B.1/T.81 | ISO/IEC 10918-1 shall be replaced with Table 2 above.

NOTE – The JPG marker has moved from under "Frame markers", where it was listed in ITU-T Rec. T.81 | ISO/IEC 10918-1 as "reserved for JPEG extensions", to the group of "Other markers" where it now indicates "JPEG extensions".

Table 2/T.851 – Marker code assignments

Code Assignment	Symbol	Description
Start Of Frame markers, non-differential, Q15-coder arithmetic coding		
X'FFC9' X'FFCA' X'FFCB'	SOF_9 SOF_{10} SOF_{11}	Extended sequential DCT Progressive DCT Lossless (sequential)
Start Of Frame markers, differential, Q15-coder arithmetic coding		
X'FFCD' X'FFCE' X'FFCF'	SOF_{13} SOF_{14} SOF_{15}	Differential sequential DCT Differential progressive DCT Differential lossless (sequential)
Huffman table specification		
X'FFC4'	DHT	Define Huffman table(s)
Q15-coder arithmetic coding conditioning specification		
X'FFCC'	DAC	Define Q15 arithmetic coding conditioning(s)
Restart interval termination		
X'FFD0' through X'FFD7'	RST_m (Note)	Restart with modulo 8 count "m"
Other markers		
X'FFC8' X'FFD9' X'FFDA' X'FFDB' X'FFDC' X'FFDD' X'FFDE' X'FFDF' X'FFE0' through X'FFEF' X'FFF0' through X'FFFD' X'FFFE'	JPG EOI (Note) SOS DQT DNL DRI DHP EXP APP_n JPG_n COM	JPEG extensions End of image Start of scan Define quantization table(s) Define number of lines Define restart interval Define hierarchical progression Expand reference component(s) Reserved for application segments Reserved for JPEG extensions Comment
Reserved markers		
X'FF00' through X'FF99' X'FFA0' through X'FFBF'	 RES	May be generated by Q15-coder Reserved
NOTE – Marker which is not the start of a marker segment.		

8.1 JPG extensions marker syntax

The JPG marker (X'FFC8') is used to specify extensions to ITU-T Rec. T.81 | ISO/IEC 10918-1. The first extension is defined as a replacement to the SOI marker and indicates that the arithmetic coding defined by Annex D/T.81 | ISO/IEC 10918-1 shall be replaced by the arithmetic coder defined in clause 10.

Figure 8-1 specifies the marker segment which defines the extensions defined in this Recommendation. Table 3 gives the parameter sizes and values for the JPG extensions.

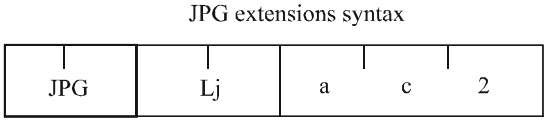

Figure 8-1/T.851 – JPG extensions syntax

The marker and parameters shown in Figure 8-1 are defined below. The size and allowed values of each parameter are given in Table 3.

– **JPG**: JPG extensions – Marks the beginning of the parameters which define the JPG extensions.

– **Lj**: JPG extensions segment length – Specifies the length of the parameters in the JPG segment shown in Figure 8-1.

– **"ac2"**: ASCII characters (X'616332') – Used for the Q15-coder specified in clause 10.

Table 3/T.851 – JPEG extensions marker (JPG) parameter sizes and values

Parameter	Size (bits)	Value
JPG	16	X'FFC8'
Lj	16	5
a	8	X'61'
c	8	X'63'
2	8	X'32'
NOTE – The byte order for these fields is defined in ITU-T Rec. T.81 | ISO/IEC 10918-1.		

Other future extensions may change the value of Lj. If the first three bytes are "ac2", any information following shall not change the decoding process. If the first three parameters are not "ac2", the extension may be incompatible.

In Figure B.17/T.81 | ISO/IEC 10918-1, this JPG extension marker segment shall replace the SOI marker when coding with the arithmetic coders defined in clause 10.

8.2 Extended DCT precision

ITU-T Rec. T.81 | ISO/IEC 10918-1 only allows for the source input to the DCT functions to be 8 or 12 bits/component sample. This Recommendation allows the source input to the DCT functions to be 8 through 16 bits/component sample for all DCT-based processes except the extended baseline which only allows 8 bits/component sample. The sample precision parameter P in frame headers for DCT-based processes following the JPEG extension marker shall have values in the range of 8 through 16. The inputs shall be unsigned numbers for non-differential frames. The level shift specified in A.3.1/T.81 | ISO/IEC 10918-1 subtracts 2^{P-1} from them to convert them to the signed representation before computing the FDCT. The allowed maximum range for successive approximation bit position high (Ah) and low (Al) parameters in the Scan Header is extended to 15. The arithmetic coding magnitudes for the maximum bound Table F.3/T.81 | ISO/IEC 10918-1 is extended to 18 magnitude bits. Table 4 shows these extended categories.

Table 4/T.851 – Extended categories for each maximum bound

Exclusive upper bound (M)	Sz range	Number of low order magnitude bits
65 536	32 768,…,65 535	15
131 072	65 536,…,131 071	16
262 144	131 072,…,262 143	17
524 288	262 144,…,524 287	18

The statistical models for DC coefficient coding and AC coefficient coding shall be extended with context-indices X16, X17, X18, and X19 in Table F.4/T.81 | ISO/IEC 10918-1 and the corresponding M16, M17, M18, and M19 magnitude coding bins in Table F.5/T.81 | ISO/IEC 10918-1.

The differential Start of Frames for arithmetic coding (SOF_{13}, SOF_{14}, and SOF_{15}) may appear without a preceding Define Hierarchical Progression (DHP) marker when the input samples are signed data.

8.3 Summary

Figure 8-2 shall replace the SOI marker in the flow of compressed data syntax for Figure B.16/T.81 | ISO/IEC 10918-1.

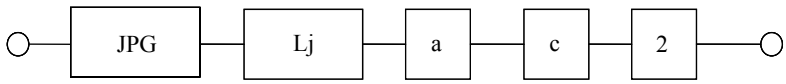

Figure 8-2/T.851 – JPG extension marker replaces SOI in Figure B.16/T.81 | ISO/IEC 10918-1

9 Huffman coding

The Huffman coding shall not be used with the JPG extension when its parameters start with 'ac2' although Define Huffman Table (DHT) markers may appear in data streams.

10 Arithmetic coders

Annex D/T.81 | ISO/IEC 10918-1 defines an adaptive binary arithmetic coding (QM-coding) procedure to be used for entropy coding in any of the coding processes except the baseline sequential process. This clause defines an alternative arithmetic coder (Q15-coder) that shall be used with the technologies specified in ITU-T Rec. T.81 | ISO/IEC 10918-1 when the compressed data starts with the JPG extension instead of the SOI marker. This arithmetic coder is defined for the same conventions used in ITU-T Rec. T.81 | ISO/IEC 10918-1 for the order of the symbols, namely the MPS is closer to zero than the LPS. The compressed data shall be bit-stuffed rather than byte-stuffed.

NOTE – Bit stuffing allows the decoder to resolve the carry rather than waiting until the encoder has resolved the carry (potentially the entire rest of the entropy-coded segment).

There is no requirement in this Recommendation that any encoder or decoder shall implement the procedures in precisely the manner specified by the flow charts in this clause. It is necessary only that an encoder or decoder implement the function specified in this clause.

10.1 Encoder procedures

Figures D.1 (Code_1(S)) and D.2 (Code_0(S))/T.81 | ISO/IEC 10918-1 shall apply to this arithmetic coder.

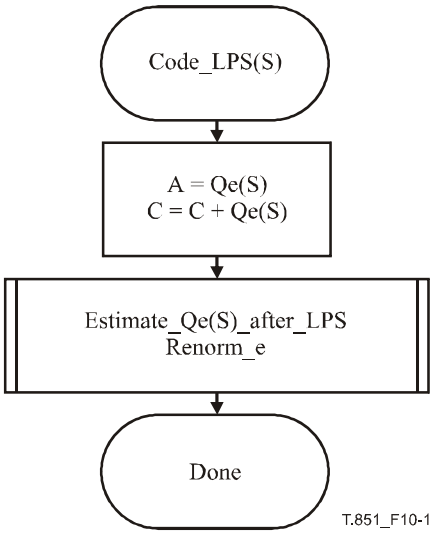

Figure 10-1/T.851 – Code_LPS(S) procedure for Q15-coder

Figure 10-1 shows the Code_LPS(S) procedure (Figure D.3/T.81 | ISO/IEC 10918-1 without the conditional exchange) for the Q15-coder.

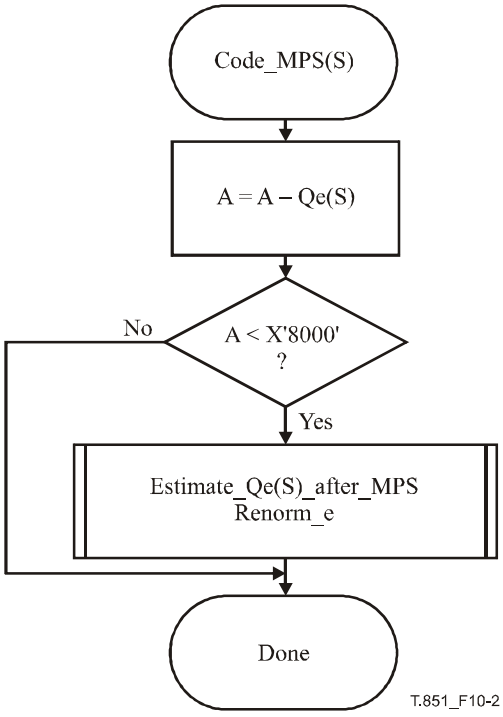

Figure 10-2/T.851 – Code_MPS(S) procedure for Q15-coder

Figure 10-2 shows the Code_MPS(S) procedure (Figure D.4/T.81 | ISO/IEC 10918-1 without the conditional exchange) for the Q15-coder.

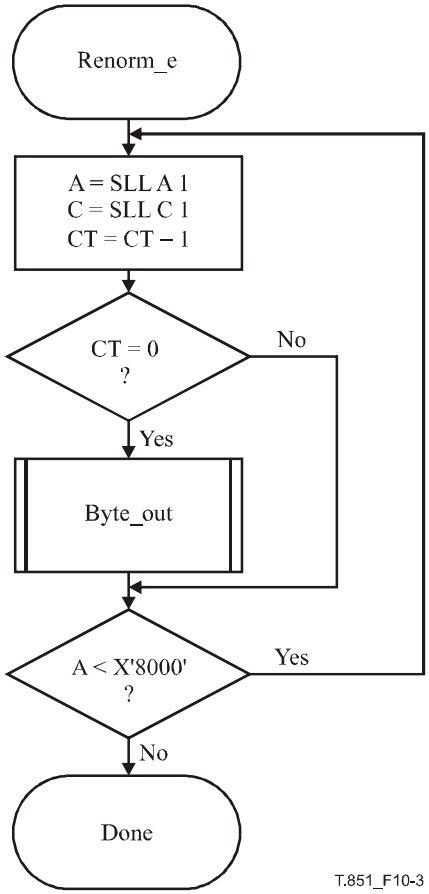

Figure 10-3/T.851 – Encoder renormalization procedure for Q15-coder

The rest of the changes relate to introducing bit-stuffing instead of byte-stuffing. Figure 10-3 shall replace Figure D.7/T.81 | ISO/IEC 10918-1.

NOTE 1 – The modified renormalization procedure has moved the CT = 8 statement inside of Byte_out since the count of output bits allowed in the next compressed byte is no longer a constant, but will be a 7 or an 8 with bit stuffing.

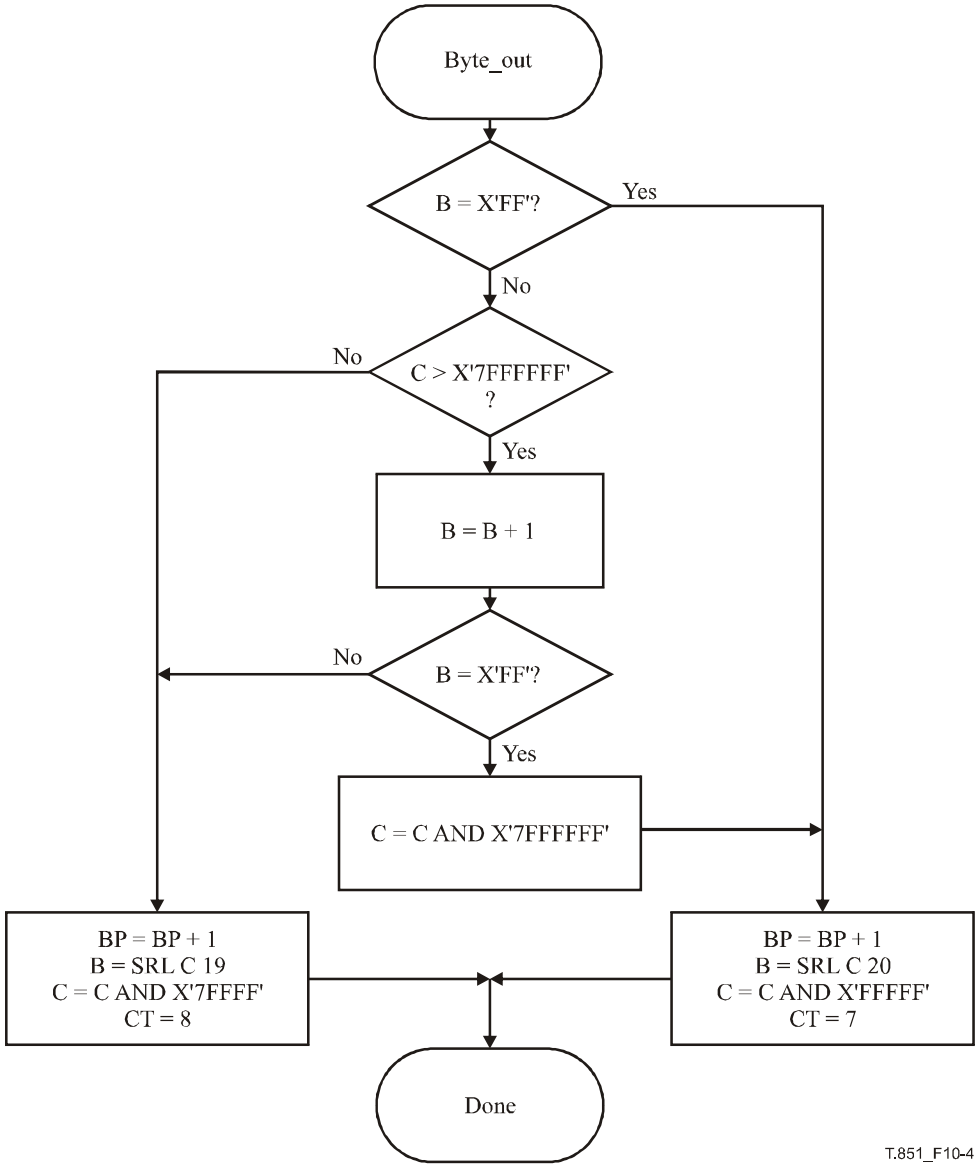

Figure 10-4/T.851 – Byte_out procedure for Q15-coder

Figure 10-4 shall replace Figures D.8 through D.11/T.81 | ISO/IEC 10918-1. This Byte_out procedure implements bit stuffing instead of byte stuffing.

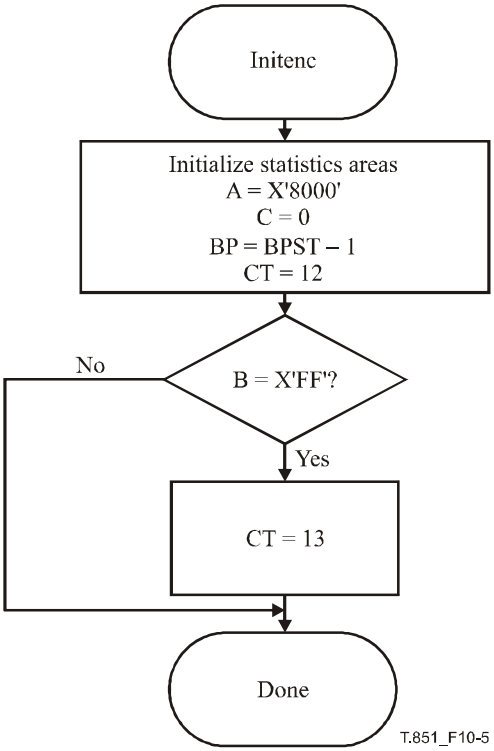

Figure 10-5/T.851 – Initialization of the encoder for Q15-coder

Figure 10-5 shall replace Figure D.12/T.81 | ISO/IEC 10918-1 for the initialization of the encoder.

NOTE 2 – The stack count (SC) is no longer needed. The initialization of the A-register is no longer defined with a 17-bit constant. CT is adjusted by 1. This initialization guarantees that the first byte will never be an X'FF'. This simplifies the initialization of the decoder.

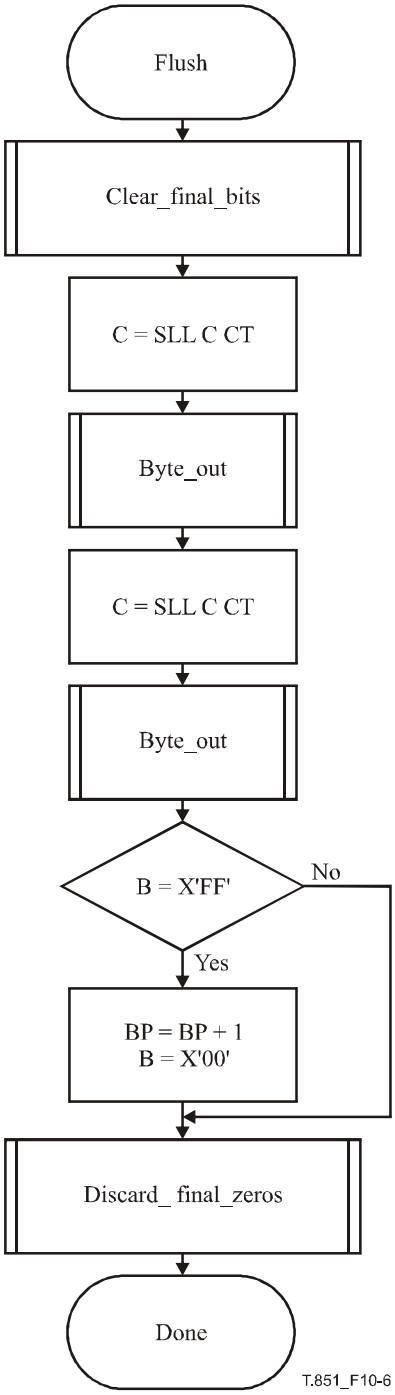

Figure 10-6/T.851 – Flush procedure for Q15-coder

Figure 10-6 shall replace the Flush procedure shown in Figure D.13/T.81 | ISO/IEC 10918-1. The Clear_final_bits procedure found in Figure D.14/T.81 | ISO/IEC 10918-1 shall be used. The Discard_final_zeros procedure found in Figure D.15/T.81 | ISO/IEC 10918-1 shall also be used.

10.2 Decoder procedures

The decoding procedures are defined in this clause.

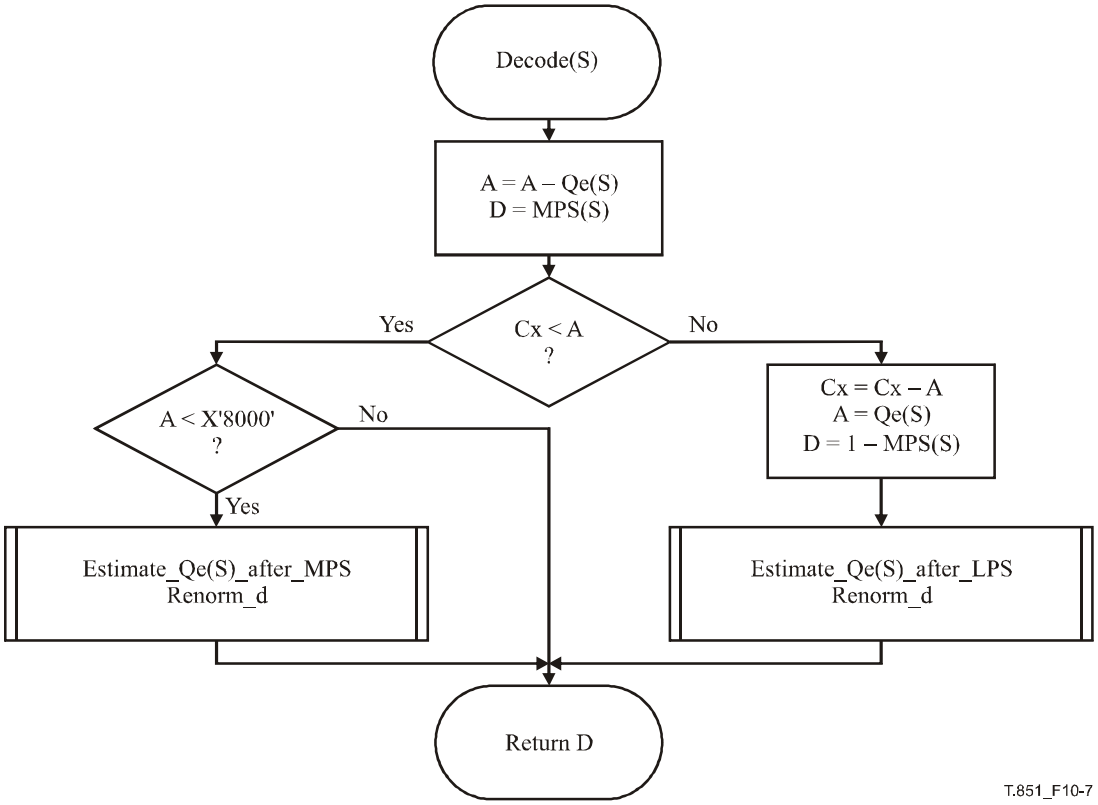

Figure 10-7/T.851 – Decode(S) procedure for Q15-coder

Figure 10-7 shall replace Figures D.16 through D.18/T.81 | ISO/IEC 10918-1.

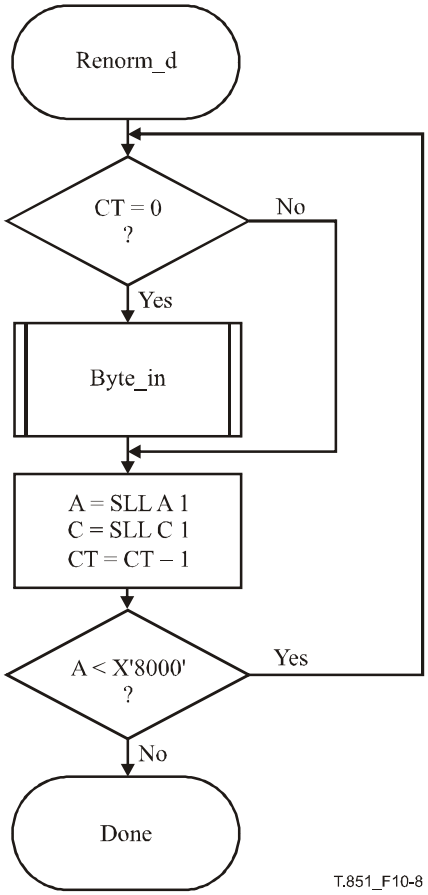

Figure 10-8/T.851 – Decoder renormalization procedure

Figure 10-8 shall replace Figure D.19/T.81 | ISO/IEC 10918-1.

NOTE – The number of valid bits (CT) is no longer a constant and is moved into the Byte_in procedure.

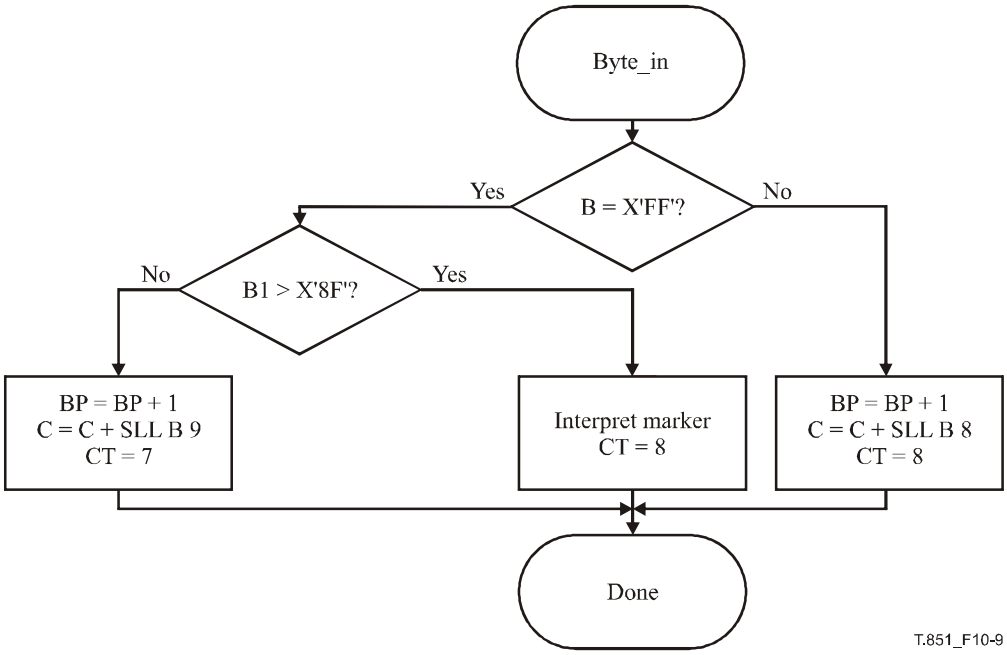

Figure 10-9/T.851 – Byte_in procedure for decoder

Figure 10-9 shall replace Figures D.20 and D.21/T.81 | ISO/IEC 10918-1. If no bit was stuffed (B not equal to X'FF'), then the BP shall be incremented to the next byte. Then byte B shall be shifted left 8 bits and then added into C. Otherwise, if B is the first byte of a marker, the marker shall be interpreted and CT shall be set to 8. The missing bits are all zeros so C shall be unchanged. If B is not a marker, BP shall be incremented to the next byte and the new byte B shall be shifted left 9 bits and added into C. CT shall be set to 7.

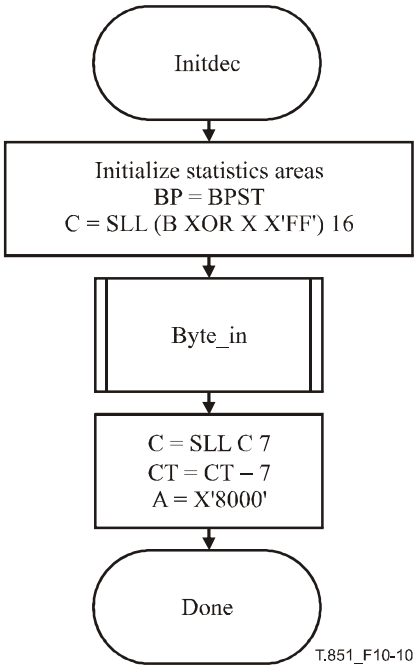

Figure 10-10/T.851 – Initialization of the decoder

Figure 10-10 shall replace Figure D.22/T.81 | ISO/IEC 10918-1.

10.3 Probability estimation

Table 5 shall replace the probability estimation state machine given in Table D.3/T.81 | ISO/IEC 10918-1. Every time a fixed probability estimate of 0.5 (Qe = X'5601', MPS = 0 is used instead of the T.81 value of Qe = X'5A1D') is required, index 46 in Table 5 may optionally be used instead.

Table 5/T.851 – Qe values and probability estimation state machine

Index	Qe_Value	Next_index		Switch _MPS
		_LPS	_MPS	
0	X'5601'	1	1	1
1	X'3401'	6	2	0
2	X'1801'	9	3	0
3	X'0AC1'	12	4	0
4	X'0521'	29	5	0
5	X'0221'	33	38	0
6	X'5601'	6	7	1
7	X'5401'	14	8	0

Table 5/T.851 – Qe values and probability estimation state machine

Index	Qe_Value	Next_index		Switch _MPS
		_LPS	_MPS	
8	X'4801'	14	9	0
9	X'3801'	14	10	0
10	X'3001'	17	11	0
11	X'2401'	18	12	0
12	X'1C01'	20	13	0
13	X'1601'	21	29	0
14	X'5601'	14	15	1
15	X'5401'	14	16	0
16	X'5101'	15	17	0
17	X'4801'	16	18	0
18	X'3801'	17	19	0
19	X'3401'	18	20	0
20	X'3001'	19	21	0
21	X'2801'	19	22	0
22	X'2401'	20	23	0
23	X'2201'	21	24	0
24	X'1C01'	22	25	0
25	X'1801'	23	26	0
26	X'1601'	24	27	0
27	X'1401'	25	28	0
28	X'1201'	26	29	0
29	X'1101'	27	30	0
30	X'0AC1'	28	31	0
31	X'09C1'	29	32	0
32	X'08A1'	30	33	0
33	X'0521'	31	34	0
34	X'0441'	32	35	0
35	X'02A1'	33	36	0
36	X'0221'	34	37	0
37	X'0141'	35	38	0
38	X'0111'	36	39	0
39	X'0085'	37	40	0
40	X'0049'	38	41	0
41	X'0025'	39	42	0
42	X'0015'	40	43	0
43	X'0009'	41	44	0
44	X'0005'	42	45	0
45	X'0001'	43	45	0
46	X'5601'	46	46	0

11 Encoder and decoder control procedures

In Figure E.1/T.81 | ISO/IEC 10918-1 the "Append SOI marker" shall be replaced by "Append JPG marker segment". In Figure E.6/T.81 | ISO/IEC 10918-1 the "SOI?" shall be replaced with "JPG?".

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