NEC

User's Manual

μSAP77016-B05

MPEG-4 CELP Speech Codec Middleware

Target Devices

μPD77110
μPD77111
μPD77112
μPD77113
μPD77114
μPD77115

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[MEMO]

Patent for MPEG-4 CELP

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- Availability of related technical literature
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Major Revisions in This Edition

Page	Description
Throughout	Addition of μPD77111, 77112, and 77115.
p.11	Modification of description in **1.2 MPEG-4 CELP Speech Codec**
p.12	Modification of **1.3 Product Overview**
p.19	Modification of Return value, Function, and Hardware resources in **2.3.2 mpc_InitDec function**
p.20	Modification of Hardware resources in **2.3.3 mpc_Enc function**
pp.22, 23	Modification of Function and Hardware resources in **2.3.4 mpc_Dec function**
p.25	Addition of description to **2.4 Compressed Data Format**
p.34	Modification of **APPENDIX SAMPLE PROGRAM SOURCE**

The mark ★ shows major revised points.

PREFACE

Target Readers

This manual is intended for users who wish to design and develop application systems using the μPD77016 Family.

The μPD77016 Family includes the μPD77015, 77016, 77017, 77018, 77019, 77110, 77111, 77112, 77113, 77114, and 77115. This manual, however, only covers the μPD77110, 77111, 77112, 77113, 77114, and 77115.

Purpose

The purpose of this manual is for users to gain an understanding of the middleware used for support when designing and developing application systems using the μPD77016 Family.

Organization

This manual consists of the following.

CHAPTER 1 INTRODUCTION
CHAPTER 2 LIBRARY SPECIFICATIONS
CHAPTER 3 INSTALLATION
CHAPTER 4 SYSTEM EXAMPLE
APPENDIX SAMPLE PROGRAM SOURCE

How to Read This Manual

It is assumed that the reader of this manual has general knowledge in the fields of electrical engineering, logic circuits, and microcontrollers.

Conventions

Data significance:	Higher digits on the left and lower digits on the right
Note:	Footnote for item marked with **Note** in the text
Caution:	Information requiring particular attention
Remark:	Supplementary information
Number representation:	Binary ×××× or 0b××××
	Decimal ××××
	Hexadecimal 0x××××

Related Documents The related documents indicated in this publication may include preliminary versions. However, preliminary versions are not marked as such.

Documents Related to Devices

Document Name / Part Number	Pamphlet	Data Sheet	User's Manual		Application Note
			Architecture	Instructions	Basic Software
μPD77110	U12395E	U12801E	U14623E	U13116E	U11958E
μPD77111					
μPD77112					
μPD77113		U14373E			
μPD77114					
μPD77115	–	U14867E	–	–	–

Documents Related to Development Tools

Document Name		Document No.
IE-77016-98, IE-77016-PC User's Manual	Hardware	U13044E
IE-77016-CM-LC User's Manual		U14139E
RX77016 User's Manual	Function	U14397E
	Configuration Tool	U14404E
RX77016 Application Note	HOST API	U14371E

Caution The related documents listed above are subject to change without notice. Be sure to use the latest version of each document for designing.

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CHAPTER 1 INTRODUCTION

1.1 Middleware

Middleware is the name given to a group of software that has been tuned so that it draws out the maximum performance of the processor and enables processing that is conventionally performed by hardware to be performed by software. The concept of middleware was introduced with the development of a new high-speed processor, the DSP, in order to facilitate operation of the environments integrated in the system.

By providing appropriate speech codec and image data compression/decompression-type middleware, NEC is offering users the kind of technology essential in the realization of a multimedia system for the μPD77016 Family, and is continuing its promotion of system development.

The μSAP77016-B05 is middleware that supplies the functions of speech compression/decompression.

★ 1.2 MPEG-4 CELP Speech Codec

The MPEG-4 CELP[Note 1] speech codec is a CELP speech compression/decompression function standardized as ISO/IEC[Note 2] 14496-3 (MPEG-4 version 1) Audio Part. In addition, the error robustness and silence compression functions are expanded by ISO/IEC 14496-3/Amd1 (MPEG-4 version 2) Audio Part. This MPEG-4 CELP speech codec employs an algorithm proposed by NEC.

The speech input/output data processed by the MPEG-4 CELP speech codec is 16-bit linear PCM data resulting from sampling an analog input signal at 8 or 16 MHz. If the signal is sampled at 8 kHz (narrow band: NB), 28 types of bit rates, 3.85 to 12.2 Kbps, are supported. If the signal is sampled at 16 kHz (wide band: WB), 30 types of bit rates, 10.9 to 23.8 Kbps, are supported (refer to 2.5 Relationship Between Bit Rate and Number of Samples).

Notes 1. CELP: Code Excited Linear Prediction

2. ISO: International Organization for Standardization
IEC: International Electrotechnical Commission

★ 1.3 Product Overview

1.3.1 Features

(1) Speech input/output data: 16-bit linear PCM data
(2) Coding/decoding 80 to 320 samples/frame at sampling frequency of 8 or 16 kHz
(3) 28 types of bit rates (3.85 to 12.2 Kbps) at sampling frequency of 8 kHz or 30 types of bit rates (10.9 to 23.8 Kbps) at 16 kHz
(4) High-quality speech coding
- Wide band (16 kHz sampling)
- Quality equivalent to ITU-T G.729[Note] at 8 Kbps and sampling frequency of 8 kHz

Note International Telecommunication Union – Telecommunication Standardization Sector

Table 1-1 lists the supported functions.

Table 1-1. Supported Functions

	Function	Encoder	Decoder
Version 1	Basic coding function (base layer)	√	√
	Bit rate hierarchy function (Bit Rate Scalable)	×	×
	Band hierarchy function (Band Width Scalable)	×	×
	Multi-pulse sound source (Multi Pulse Excitation)	√	√
	Regular pulse sound source (Regular Pulse Excitation)	×	×
	Fine rate control	×	×
	Version 1 compressed data format	√	√
Version 2	Error concealment[Note]: Bit error	–	√
	Error concealment[Note]: Frame erasure	–	√
	Silence compression	×	√
	Version 2 compressed data format	×	√

Note Error concealment is a function of version 2, but this middleware allows it to be used with data of version 1.

Caution “Version” in the above figure indicates the version of MPEG-4, not the version of the middleware.

Remark √: Supported, ×: Not supported, –: Not subject to support

1.3.2 Operating environment

(1) Target DSP:

μPD77110, 77111[Note], 77112[Note], 77113, 77114, 77115[Note]

Note Applicable when these processors operate only as decoders.

(2) Required memory size:

This middleware can be used as a codec, or separately as an encoder or decoder. Table 1-2 shows the required memory size.

Table 1-2. Required Memory Size

Memory	Type	Size (Words)	Encoder [Words]	Decoder [Words]
Instruction memory	–	14.6 K	8.0 K	8.0 K
X memory	RAM (Work) (Static)	Encoder: 3 K / Decoder: 1.5 K 3.2 K	3.0 K 2.7 K	1.5 K 0.6 K
	ROM	5.5 K	2.4 K	5.0 K
Y memory	RAM (Work) (Static)	Encoder: 4.7 K / Decoder: 0.7 K 2.5 K	4.7 K 2.5 K	0.7 K 0.1 K
	ROM	13.1 K	10.1 K	9.3 K

(3) Software tools (Windows™ version):

DSP tools

- WB77016 (workbench assembler)
- HSM77016 (high-speed simulator)
- IE77016 (debugger)

1.3.3 Performance

[Condition] DSP: μPD77016 Family (33 MIPS @ 33 MHz operation)

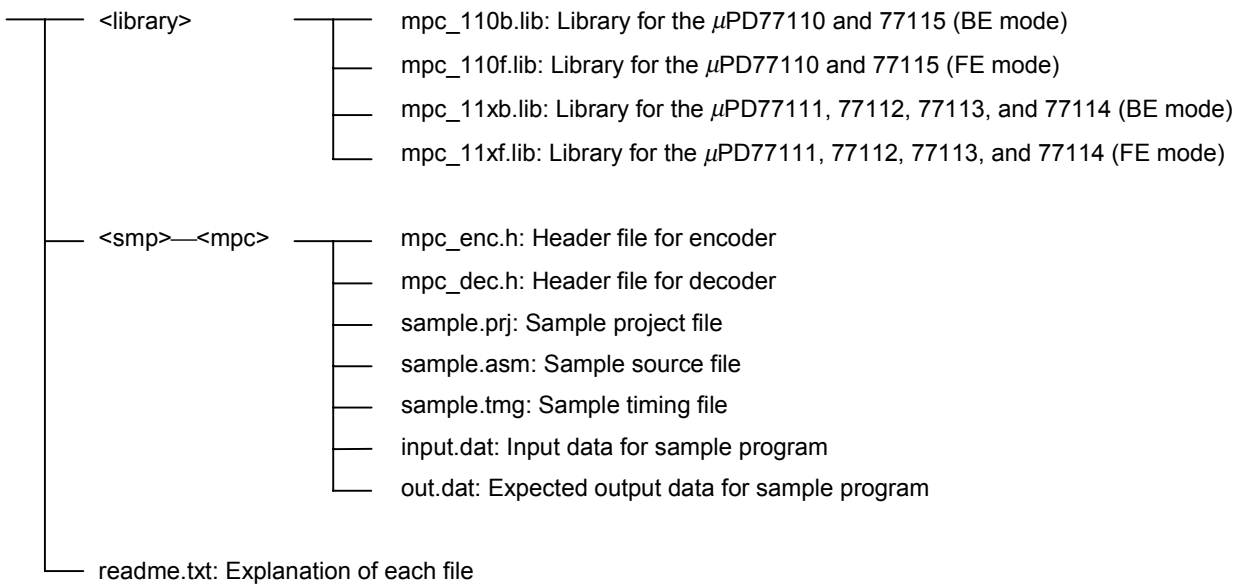
[The MIPS values required to execute the processing of 1 frame in real time]

Table 1-3. MIPS Values Required for Compression/Decompression Processing

Bit Rate [bps]	Compression Time [MIPS]	Decompression Time (Postprocessing Filter On) [MIPS]	Total (Postprocessing Filter On) [MIPS]
4650 (NB)	16.5	2.5	19.0
5500 (NB)	17.5	2.6	20.1
7300 (NB)	19.5	2.6	22.1
10700 (NB)	20.8	3.3	24.1
12200 (NB)	22.3	3.5	25.8
14300 (NB)	52.5	9.1	61.6
17000 (NB)	55.3	9.3	64.6
21100 (NB)	58.2	12.3	70.5
23800 (NB)	60.8	12.5	73.3

1.3.4 Directory structure

The contents of the packages are shown below.



Each directory is outlined below.

(1) library

Stores the library files.

Two types of libraries, for BE (Bit Error) mode and FE (Frame Erasure) mode, are available depending on the differences in the concealment processing of the decoder, and either of them is selected when the middleware is embedded into a system. They cannot be selected during reception.

- BE (Bit Error) mode

This mode is used if the system can receive error frame information.

The past frame data and part of the current frame data are used for decoding processing in this mode.

- FE (Frame Erasure) mode

This mode is used if the system can receive no error frame information.

In this mode, decoding processing is performed by using only the past frame data.

(2) <smp>--<mpc>

Stores the source files of the sample program, and the header files. A timing file, to be described later, is also available.

CHAPTER 2 LIBRARY SPECIFICATIONS

MPEG-4 CELP provides the following 5 functions.

Function Name	Function
mpc_InitEnc	Encode processing initialization
mpc_InitDec	Decode processing initialization
mpc_Enc	Encode processing
mpc_Dec	Decode processing
mpc_GetVersion	Version information acquisition

2.1 Application Processing Flow

Examples of application processing using the MPEG-4 CELP speech codec are shown in Figures 2-1 and 2-2 below.

Figure 2-1. Application Processing Flow (Encoder)

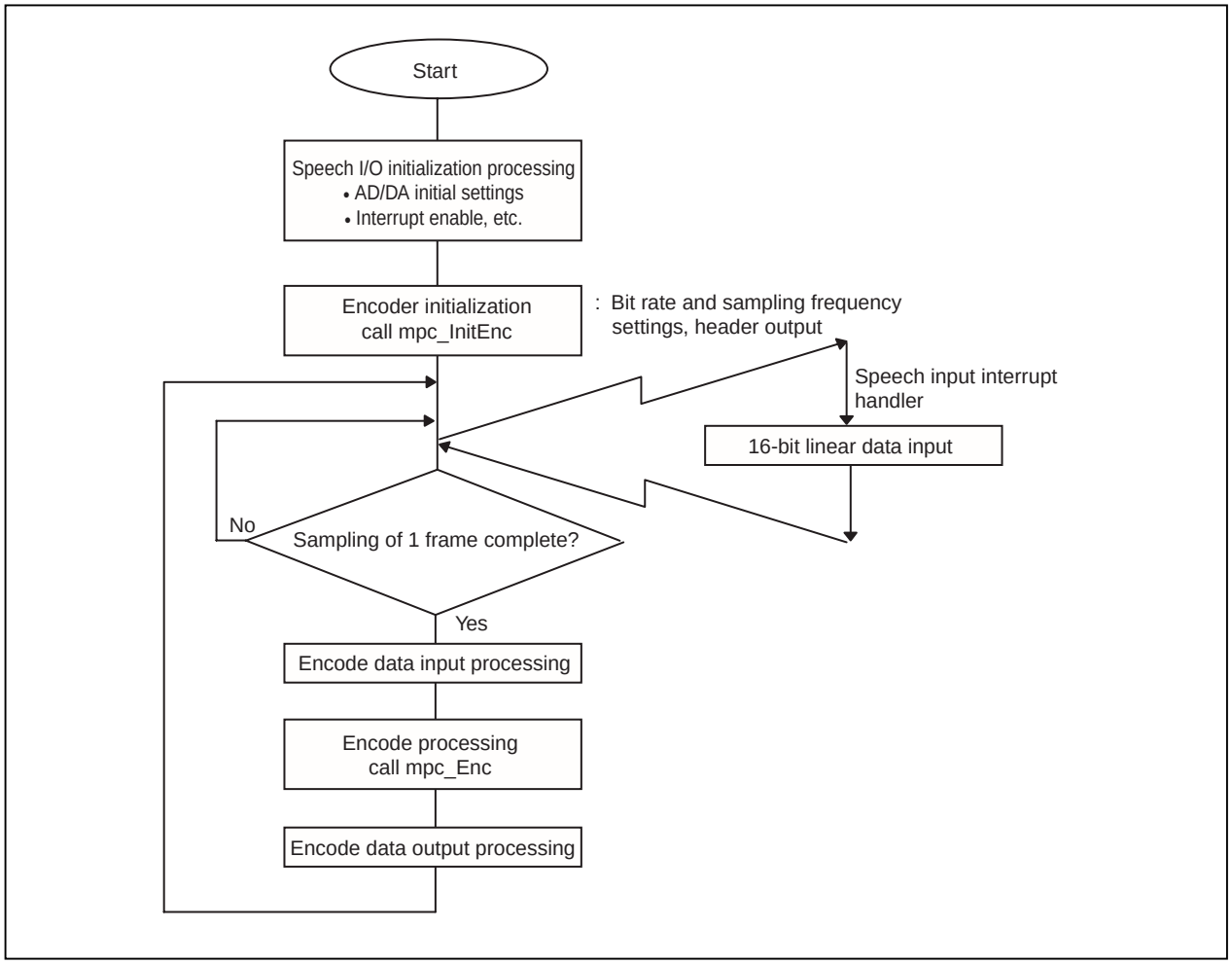
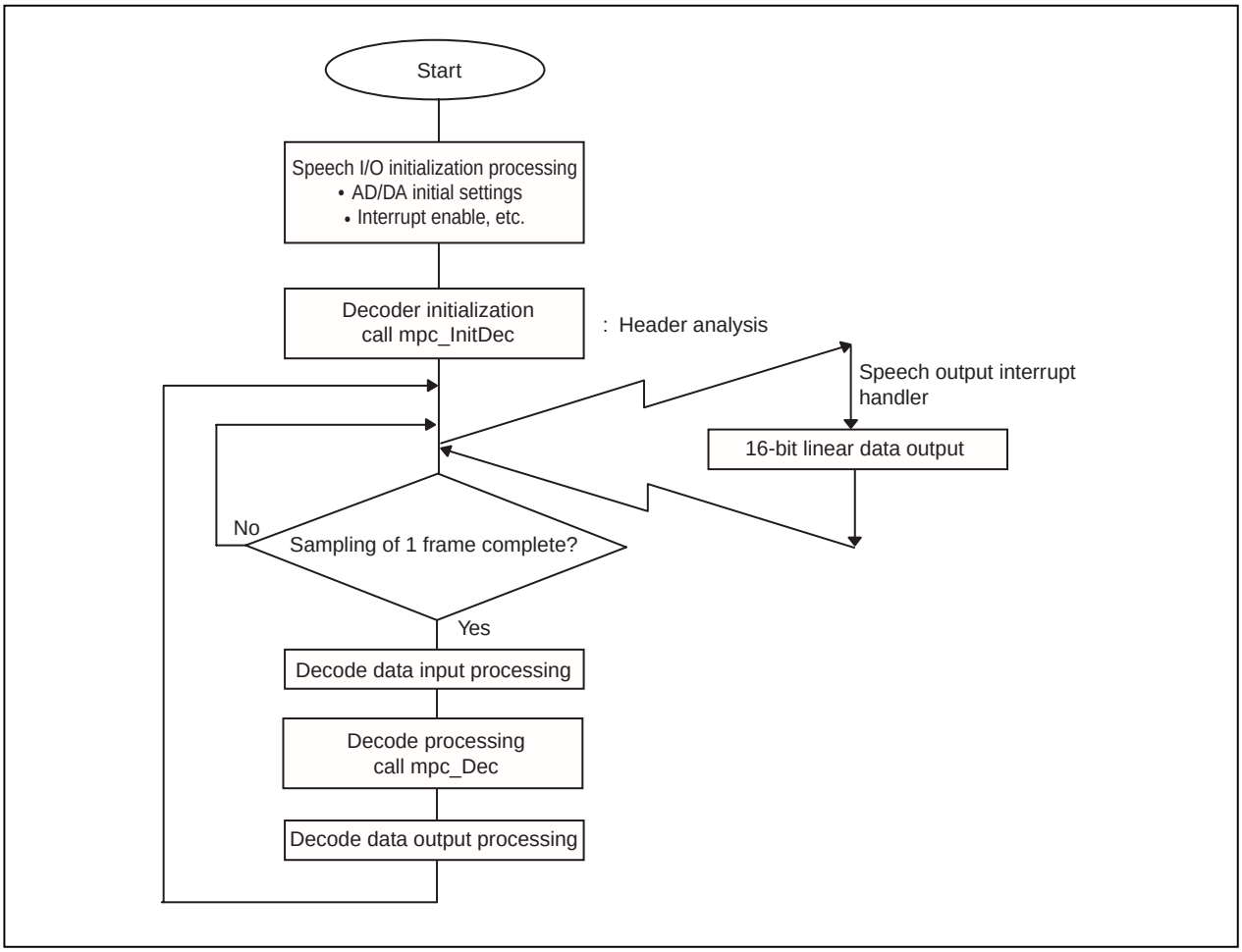


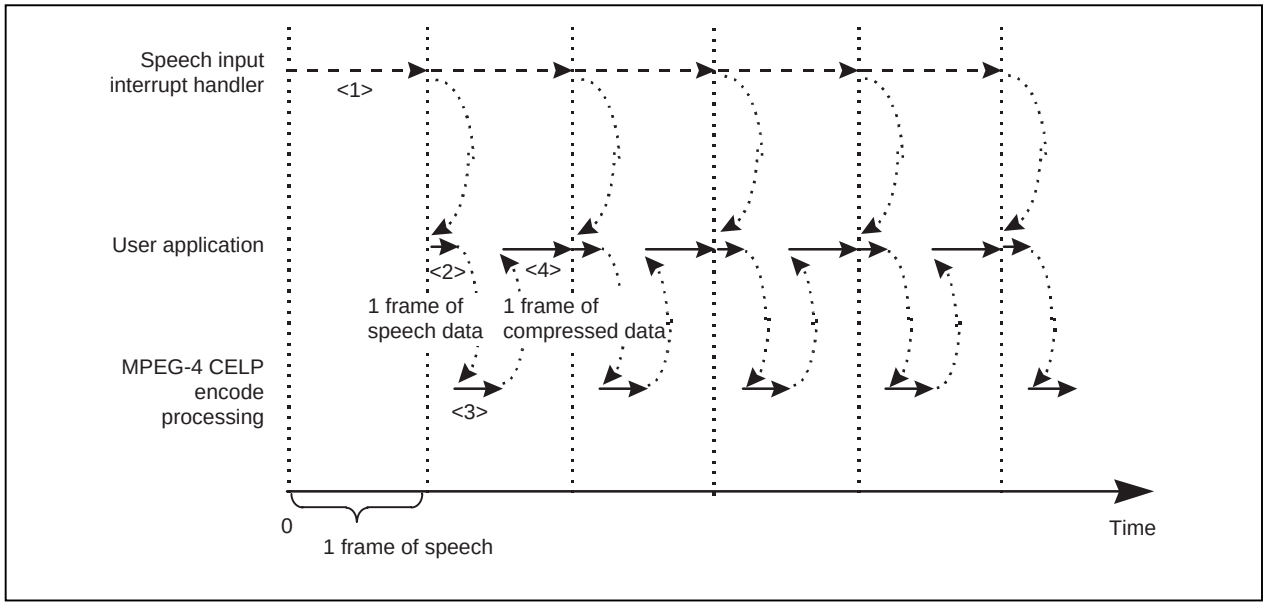
Figure 2-2. Application Processing Flow (Decoder)



The speech data I/O processing is dependent on the target system's hardware, so make sure the design accords with the target system.

2.2 Timing Diagrams

Figure 2-3. Encoder Timing Diagram



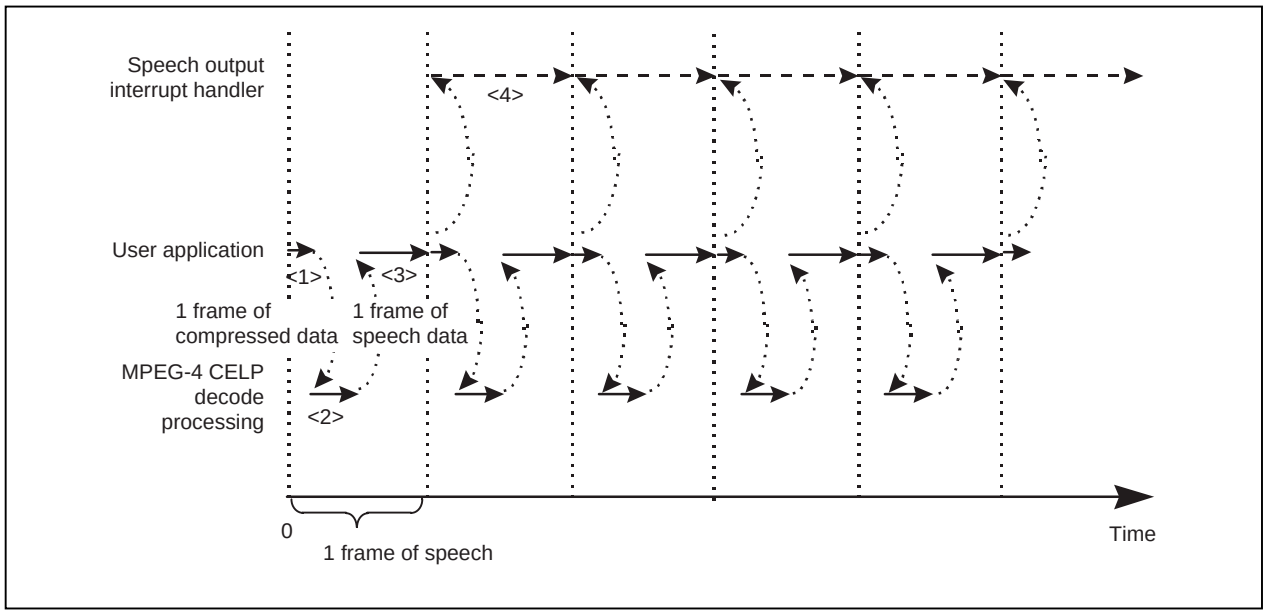
<1> Sampling frequency: 8 or 16 kHz, Precision: 16 bits; A/D converted to 1 frame of PCM data

<2> Buffering via the user application

<3> 1 frame of sample data is compressed

<4> 1 frame of compressed data is saved. The user can use the rest of the time for processing another application.

Figure 2-4. Decoder Timing Diagram



<1> 1 frame of compressed data is read and passed to decompression processing

<2> 1 frame of compressed data is decompressed into 1 frame of sample data

<3> The decompressed speech data is buffered. The user can use the rest of the time for processing another application.
<4> Sampling frequency: 8 or 16 kHz, Precision: 16 bits; 1 frame of PCM data is D/A converted

2.3 Function Specifications

2.3.1 mpc_InitEnc function

- **Classification** MPEG-4 CELP encoder initialization processing

- **Function name** mpc_InitEnc

- **Summary of function** Makes the parameter settings and initializes the RAM area used by the MPEG-4 CELP encoder.

- **Format** call mpc_InitEnc

- **Arguments**

*mpc_E_ANA_BUFF_SADR:x	Output data buffer start address (X memory)	
*mpc_E_RATE_NUM:x	Bit rate setting. Sets the 28 types/30 types of bit rates in the No. column in the tables in **2.5 Relationship Between Bit Rate and Number of Samples**. Sets the MPE configuration of the header.	
*mpc_E_WB:x	Sets the sampling frequency. 0: NB/1: WB set in the sample rate mode of the header.	
R6	Start address of the X memory work area	
R5	Start address of the Y memory work area	

- **Return value**

*mpc_E_PCM_NUM:x	Number of samples per frame
*mpc_E_ANA_BITS:x	Number of compressed data bits in 1 frame

- **Function** Makes the parameter settings necessary for the MPEG-4 CELP encoder, initializes the calculation area, and outputs the header to the top of the buffer specified by mpc_E_ANA_BUFF_SADR. (11 bits with MSB first).
The bit rate cannot be changed after the initialization processing.
For details of the memory size required for the work area, refer to the value of the RAM (Work) in **1.3.2 (2) Required memory size**.
★ The encoded data can be output in version 1 only. It cannot be output in version 2.

- **Registers used** R0, R1, R2, R3, R4, R5, R6, R7, DP0, DP1, DP2, DP3, DP4, DP5, DN0, DN1

- **Hardware resources**

The hardware resources for this function are as follows.

Maximum stack level:	3
Maximum loop stack level:	1
Maximum number of repeats:	800
Maximum number of cycles:	2700

Caution Between when the mpc_InitEnc function was called and the end of compression processing, the RAM area must not be destroyed. If the RAM area is destroyed, operation is not guaranteed.

2.3.2 mpc_InitDec function

- **Classification** MPEG-4 CELP decoder initialization processing
- **Function name** mpc_InitDec
- **Summary of function** Makes the parameter settings and initializes the RAM area used by the MPEG-4 CELP decoder.
- **Format** call mpc_InitDec
- **Arguments**

*mpc_D_ANA_BUFF_SADR:x	Input data buffer start address (X memory)
*mpc_D_PF_FLAG:x	Post-processing filter flag. 0: OFF/1: ON
R6	Work area X memory start address
R5	Work area Y memory start address

- **Return value**

*mpc_D_PCM_NUM:x	Number of samples per frame
★ *mpc_D_ANA_BITS:x	Number of CelpBaseFrame bits among compressed data in 1 frame (this is the same as the number of compressed bits in 1 frame if silence compression is not used.)

- **Function** Analyses the compressed data by the header, sets the parameters required for the MPEG-4 CELP decoder, and initializes the calculation area. The header is input to ★ the top of the buffer specified by mpc_D_ANA_BUFF_SADR. (11 bits with MSB first in version 1, and 12 bits with MSB first in version 2). Whether the speech data output is passed through a post-processing filter is determined by mpc_D_PF_FLAG. The post-processing filter is a filter configured on the output side of the decoder to improve the sound quality of the decoded speech signals.
  Refer to **2.4.1 Header** for the format of the header.
  For details of the memory size required for the work area, refer to the value of the RAM (Work) in **1.3.2 Operating environment**.
- **Registers used** R0, R1, R2, R3, R4, R5, R6, R7, DP0, DP1, DP2, DP4, DP5, DN0
- **Hardware resources**
  The hardware resources for this function are as follows.

Maximum stack level:	3
Maximum loop stack level:	1
Maximum number of repeats:	50
★ Maximum number of cycles:	800

Caution Between when the mpc_InitDec function was called and the end of decompression processing, the RAM area must not be destroyed. If the RAM area is destroyed, operation is not guaranteed.

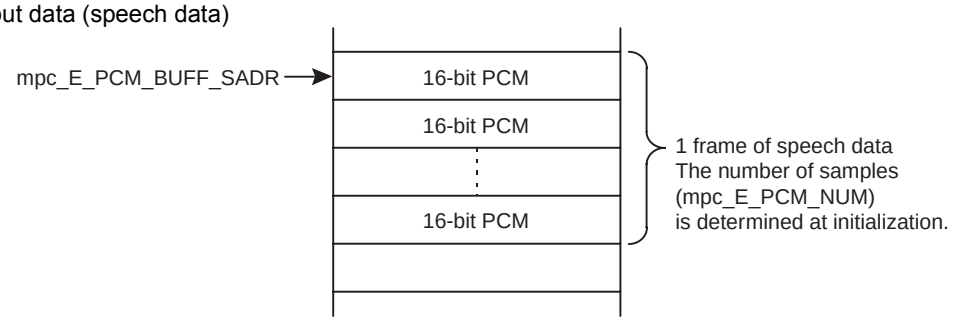
2.3.3 mpc_Enc function

- **Classification** MPEG-4 CELP encoder processing
- **Function name** mpc_Enc
- **Summary of function** Compresses 1 frame of specified speech data.
- **Format** call mpc_Enc
- **Arguments**

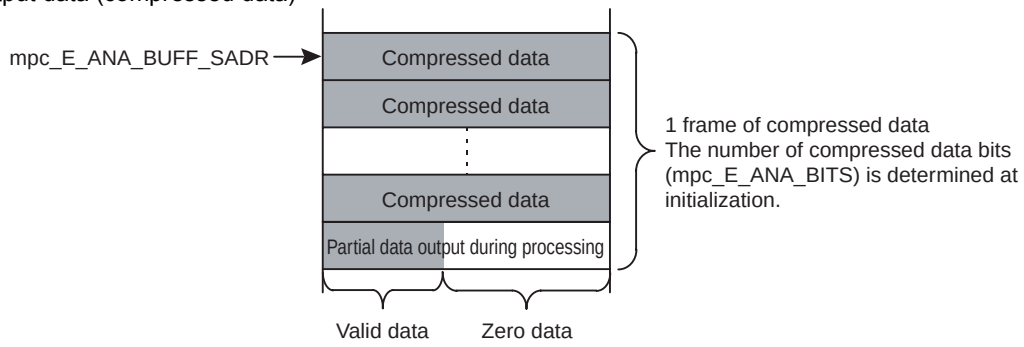
*mpc_E_PCM_BUFF_SADR:x	Input data buffer start address (X memory)
*mpc_E_ANA_BUFF_SADR:x	Output data buffer start address (X memory)

- **Return value** None
- **Function** Performs compression processing for speech data specified by mpc_E_PCM_BUFF_SADR and writes and returns this data to the compressed data buffer specified by mpc_E_ANA_BUFF_SADR. If the final word of the compressed data frame is less than 1 word, this data is word-aligned by outputting it after filling the remainder with 0s.
  The number of samples input in 1 frame is determined by the bit rate, and is assigned by mpc_E_PCM_NUM, which is the return value of the encoder initialization processing, mpc_InitEnc.
  The size of the compressed data output is also determined by the bit rate.
  Neither the bit rate nor NB/WB can be changed.
  The compressed data is a stream of bit units.

Input data (speech data)



Output data (compressed data)



- **Registers used** R0, R1, R2, R3, R4, R5, R6, R7, DP0, DP1, DP2, DP3, DP4, DP5, DP6, DP7, DN0, DN1, DN2, DN3, DN4, DN5, DN6, DN7, DMX, DMY

- **Hardware resources**

  The hardware resources for this function are as follows.

Maximum stack level:	6
Maximum loop stack level:	4
Maximum number of repeats:	340
Maximum MIPS value:	60.8

★

2.3.4 mpc_Dec function

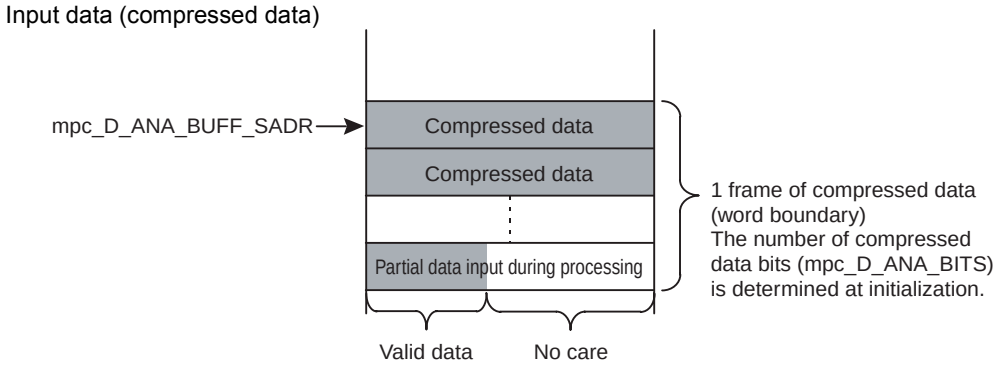
- **Classification** MPEG-4 CELP decoder processing
- **Function name** mpc_Dec
- **Summary of function** Decompresses 1 frame of the specified compressed speech data.
- **Format** call mpc_Dec
- **Arguments**

*mpc_D_ANA_BUFF_SADR:x	Input data buffer start address (X memory)
*mpc_D_PCM_BUFF_SADR:x	Output data buffer start address (X memory)
*mpc_D_ERR_FLAG:x	Recover processing flag. 0: OFF/1: ON

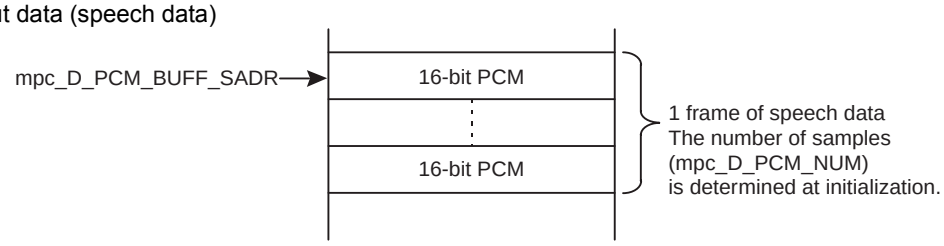
- **Return value** None

s

★ • **Function** Performs decompression processing for compressed data specified by mpc_D_ANA_BUFF_SADR and writes and returns this data to the speech data buffer specified by mpc_D_PCM_BUFF_SADR. When the mpc_D_ERR_FLAG is on, that frame is regarded to have an error, and recovery is performed by error concealment processing using the data of the previous frame.
A frame error must be detected by the calling system.
Recovery processing is performed in two modes, BE (Bit Error) mode and FE (Frame Erasure) mode, and is determined depending on the library to be embedded (refer to **1.2 MPEG-4 CELP Speech Codec** and **1.3.4 Directory structure**).
If the final word of the compressed data frame is less than 1 word, the valid data is input starting from the MSB.
The size of the compressed data input and the number of samples output in 1 frame is determined by the bit rate. The bit rate cannot be changed.
If silence compression is used, the size of the compressed data input varies depending upon the frame.
The compressed data is a stream of bit units.



Output data (speech data)



- **Registers used** R0, R1, R2, R3, R4, R5, R6, R7, DP0, DP1, DP2, DP3 DP4, DP5, DP6, DP7 DN0, DN1, DN2, DN3, DN4, DN5, DN6, DN7, DMX, DMY
- **Hardware resources**

  The hardware resources for this function are as follows.

Maximum stack level:	7
Maximum loop stack level:	3
Maximum number of repeats:	400
Maximum MIPS value:	12.5 (with no error code)

★

2.3.5 mpc_GetVersion function

- **Classification** Version information acquisition
- **Function name** mpc_GetVersion
- **Summary of function** Returns the version of the library.
- **Format** call mpc_GetVersion
- **Arguments** None
- **Return Value**

R0H	Major version number
R0L	Minor version number

- **Function** Returns the version number of the MPEG-4 CELP speech codec library as a 32-bit value.
  When R0 = 0x00’0x0001’0x0100:
  Version: V1.01
- **Registers used** R0
- **Hardware resources**
  The hardware resources for this function are as follows.

Maximum stack level:	1
Maximum loop stack level:	0
Maximum number of repeats:	0
Maximum number of cycles:	6

★ 2.4 Compressed Data Format

The MPEG-4 CELP speech codec has two types of compressed data formats: version 1 and version 2.

With this middleware, the encoder outputs compressed data of version 1. The decoder can read compressed data of both versions 1 and 2.

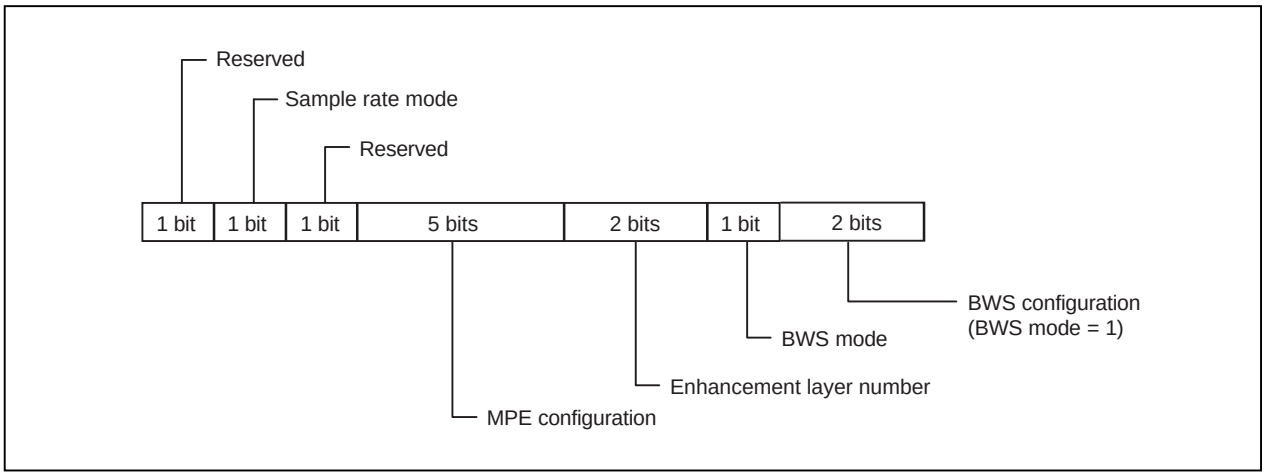
Version 1: Conforms to MPEG-4 CELP object
Version 2: Conforms to MPEG-4 ER-CELP object

2.4.1 Header

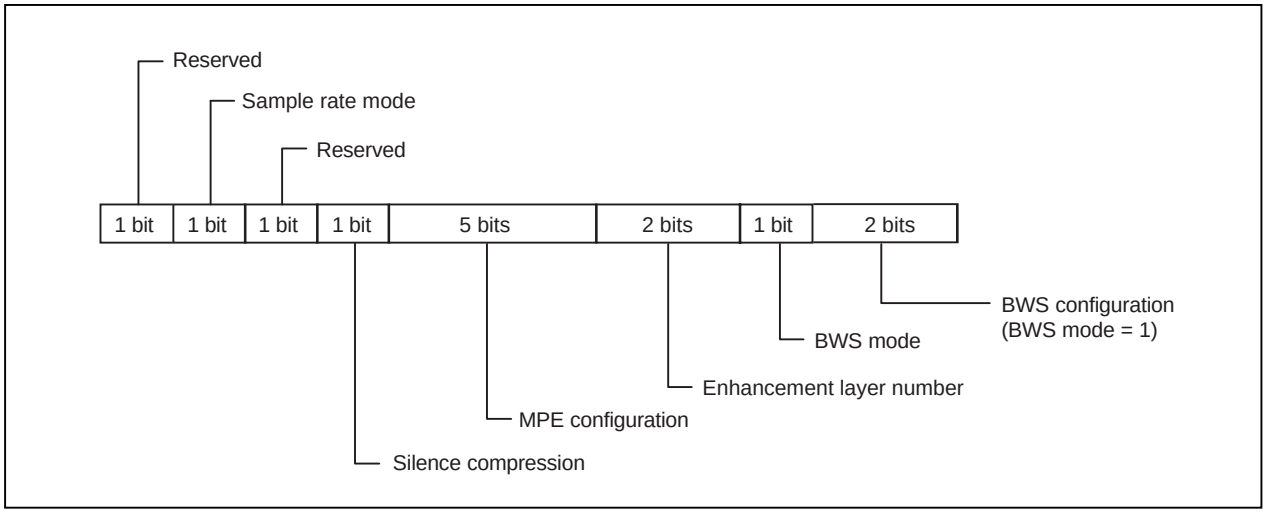
With version 1, the header size is 11 bits (BWS = OFF) or 13 bits (BWS = ON), and the header configuration is as shown in Figure 2-5 (a). With version 2, the header size is 12 bits (BWS = OFF) or 14 bits (BWS = ON), and the header configuration is as shown in Figure 2-5 (b).

Figure 2-5. Header Format

(a) Version 1



(b) Version 2



(1) Sample rate mode:
Determines the sampling frequency of MPEG-4 CELP. 8 kHz (narrow band): 0, 16 kHz (wide band): 1

(2) Silence compression (provided in version 2 only):
Specifies silence compression.
Off: 0, on: 1

(3) MPE configuration:
Determines the compression bit rate of MPEG-4 CELP. (28 types/30 types)

(4) Number of enhancement layers:
Not supported in this middleware (always 0).

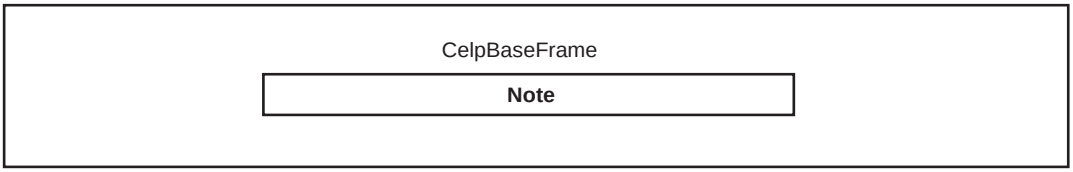
(5) BWS mode:
Not supported in this middleware (always 0).

(6) BWS configuration:
Not supported in this middleware (this bit does not exist).

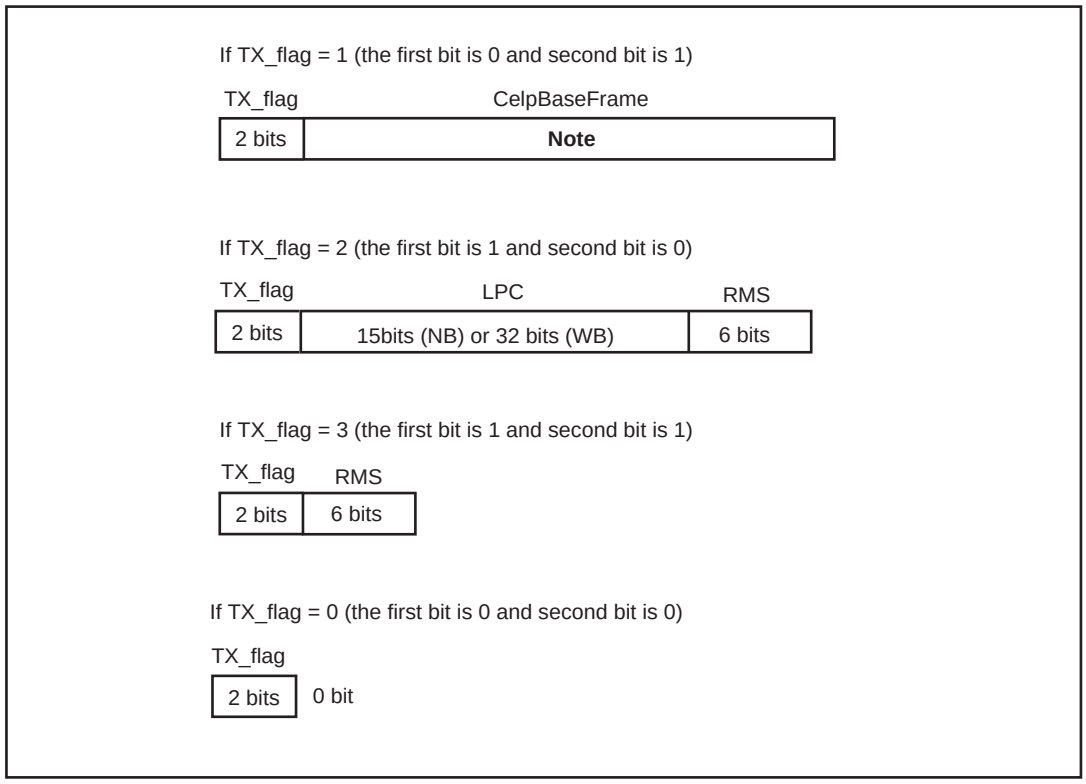
2.4.2 Frame

Figure 2-6. Frame Configuration

(a) With version 1 or version 2 when Silence Compression = OFF



(b) With version 2 when Silence Compression = ON



Note The bit length of the CelpBaseFrame differs depending upon the bit rate and can be calculated by the following expression (refer to **2.5 Relationship Between Bit Rate and Number of Samples**):

- For Narrow Band
  Compressed bit rate (X) × Number of samples per frame (L) ÷ 8000
- For Wide Band
  Compressed bit rate (X) × Number of samples per frame (L) ÷ 16000

The bit length can be obtained by the return value “mpc_E_ANA_BITS:x” of the mpc_InitEnc function or the return value “mpc_D_ANA_BITS:x” of the mpc_InitDec function.

2.5 Relationship Between Bit Rate and Number of Samples

The relationship between the number of samples and the 28 types of compression bit rates for the narrow band (8 kHz sampling) and 30 types of compression bit rates for the wide band (16 kHz sampling) is shown in the tables below.

Table 2-1. Relationship Between Narrow Band Bit Rate and Number of Samples

No.	Compression Bit Rate (bps): X	Number of Samples per Frame: L
0	3850	320
1	4250	320
2	4650	320
3	4900	240
4	5200	240
5	5500	240
6	5700	160
7	6000	160
8	6300	160
9	6600	160
10	6900	160
11	7100	160
12	7300	160
13	7700	160
14	8300	160
15	8700	160
16	9100	160
17	9500	160
18	9900	160
19	10300	160
20	10500	160
21	10700	160
22	11000	80
23	11400	80
24	11800	80
25	12000	80
26	12200	80
27	6200	240

Table 2-2. Relationship Between Wide Band Bit Rate and Number of Samples

No.	Compression Bit Rate (bps): X	Number of Samples per Frame: L
0	10900	320
1	11500	320
2	12100	320
3	12700	320
4	13300	320
5	13900	320
6	14300	320
7	Reserve	—
8	14700	320
9	15900	320
10	17100	320
11	17900	320
12	18700	320
13	19500	320
14	20300	320
15	21100	320
16	13600	160
17	14200	160
18	14800	160
19	15400	160
20	16000	160
21	16600	160
22	17000	160
23	Reserve	—
24	17400	160
25	18600	160
26	19800	160
27	20600	160
28	21400	160
29	22200	160
30	23000	160
31	23800	160

CHAPTER 3 INSTALLATION

3.1 Installation Procedure

The MPEG-4 CELP speech codec middleware is supplied on a 3.5-inch floppy disk (1.44 MB). The procedure for installing the μSAP77016-B05 in the host machine is outlined below.

(1) Set the floppy disk in the floppy disk drive and copy the files to the directory where tools from ATAIR are used (e.g. C:\DSPTools). The following is an example of when files are copied from the A drive to the C drive.

```
A:\>xcopy /s *.* c:\DSPTools <CR>
```

(2) Confirm that the files have been copied. Refer to **1.3.4 Directory structure** for details on the directories.

```
A:\>dir c:\DSPTools <CR>
```

3.2 Sample Creation Procedure

The sample program is stored in the sample directory of the supplied medium. With the sample program, it is possible to simulate the external I/O of speech and compressed data by using a timing file to be described later (in **CHAPTER 4 SYSTEM EXAMPLE**) on the SM77016 ATAIR simulator.

The following is an explanation of how to build the MPEG-4 CELP speech codec middleware sample program.

(1) Start up the WB77016 (workbench).
(2) Open the sample.prj project.
Example Specify sample.prj from Open Project on the Project menu.
(3) Execute Build and confirm that sample.lnk has been created.
Example The sample.lnk file is generated by selecting Build All from the Make menu.
(4) Start up the SM77016 (simulator)
(5) Open sample.lnk
Example Specify sample.lnk by clicking Open on the File menu.
(6) Open the timing file sample.tmg.
Example Specify sample.tmg by clicking Open on the File menu.

3.3 Symbol Naming Regulations

The section names used in this library are shown below.

Classification	Regulation
Function name, variable name	mpc_xxxx
Macro, constant name	MPC_XXXX
Section name	__MPC_XXXX (Two underscores at the start)

CHAPTER 4 SYSTEM EXAMPLE

4.1 Simulation Environment in Which Timing File Used

An example in which the speech codec compression/decompression processing simulator and a timing file are used is shown below. Speech data is input, and then output frame by frame after each frame has undergone compression/decompression processing.

Software environment:

- High-speed simulator: HSM77016
- Sample program: sample.lnk (created in **3.2 Sample Creation Procedure**)
- Timing file: sample.tmg

4.2 Operation

(1) Start up the HSM77016 (high-speed simulator)

(2) Open sample.lnk, which was created in **3.2 Sample Creation Procedure**.
Example Specify sample.lnk by clicking Open on the File menu.

(3) Open the timing file sample.tmg.
Example Specify sample.tmg by clicking Open on the File menu.

(4) Make the wait settings.
Example Set waits in the DWTR/IWTR registers in the setting windows opened by clicking Periphery Register on the Window menu.

(5) Execute with Run.
The timing file sample.tmg is described below.
The high-speed simulator (HSM77016) provides a function for simulating external I/O using a timing file.

(a) Data file input (16-bit data)
Data is input from a file via the host interface. An example of the description format is shown below.

- Preparation

```
open input “input.dat”          ; Input file specification (encode data)
input format hex                ; Input file format specification
```

- Input processing (16-bit data)

```
wait cond pin hwe == 0          ; Waiting until the host can write to HDT(in).
wait cond pin hcs == 1          ; Waiting until the chip select signal becomes inactive.

set pin hcs = 0                 ; Input starts when the chip select signal becomes active.
; (A)
set port ha = 0                 ; The lower 8 bits of the HDT register are selected.
set pin hwr = 0                 ; The host write strobe is activated.

input data                      ; Data values are input from the data file and are assigned as “data”.
set port hd = data&0xFF         ; The 8-bit “data” is input from the HD port.
wait 100ns                      ; Waiting until the data is transferred.
```

```
set pin hwr = 1                 ; Input ends when hwr becomes inactive.
wait 5ns                        ; delay
; (B)

;The processing from (A) to (B) is repeated for higher 8 bits.
set port ha = 1                 ; The higher 8 bits of the HDT register are selected.
wait 5ns                        ; delay
set pin hwr = 0                 ; start output
set port hd = (data>>8)&0xFF    ; input high byte to host port
wait 100ns                      ; access duration
set pin hwr = 1                 ; end input

set pin hcs = 1                 ; Input ends when the chip select signal becomes inactive.
```

- Termination

```
    close input                 ; The data file is closed.
```

(b) Data file output (16-bit data)

- Preparation

```
open output “out.dat”                   ; Output file specification (encode data)
output format HIDEBASE unsigned hex     ; Output file format specification
```

- Output processing (16-bit data)

```
wait cond pin hre == 0          ; Waiting until the host can read from HDT(out).
wait cond pin hcs == 1          ; Waiting until the chip select signal becomes inactive.

set pin hcs = 0                 ; Output starts when the chip select signal becomes active.
; (A)
set port ha = 0                 ; The lower 8 bits of the HDT register are selected.
set pin hrd = 0                 ; The host read strobe is activated.

wait 50ns                       ; access duration
set lowbyte = port hd&0xff      ; 8 bits are read out from the HD port and are assigned as “lowbyte”.
set pin hrd = 1                 ; Output ends when hrd becomes inactive.
wait 5ns                        ; delay
; (B)

;The processing from (A) to (B) is repeated for higher 8 bits.
set port ha = 1                 ; The higher 8 bits of the HDT register are selected.
wait 5ns                        ; delay
set pin hrd = 0                 ; start output
wait 50ns                       ; access duration
output ((port hd&0xFF)<<8)|lowbyte; output word data to file
set pin hrd = 1                 ; end output

set pin hcs = 1                 ; Output ends when the chip select signal becomes inactive.
```

- Termination

```
close input                    ; The data file is closed.
```

```
/*-------------------------------------------------------------------------*/
/*  File Information                                                       */
/*-------------------------------------------------------------------------*/
/*  Name    : sample.asm for Timing File                                   */
/*  Type    : SPX Assembler Code                                                */
/*  Version : 2.00a                                                        */
/*  Date    : 2000.06.21                                                       */
/*  CPU     : uPD7701x                                                     */
/*  Compiler: Atair uPD77016 Workbench                                     */
/*  About   : encoder function module                                      */
/*-------------------------------------------------------------------------*/
/*  Copyright (C) NEC Corporation 1998,1999                                */
/*  NEC CONFIDENTIAL AND PROPRIETARY                                       */
/*  All rights reserved by NEC Corporation.                                */
/*  Use of copyright notice does not evidence publication                  */
/*-------------------------------------------------------------------------*/

#include "mpc_enc.h"
#include "mpc_dec.h"


#define STACK_SIZE_E        0x1500
#define STACK_SIZE_D        0x700

#define HST 0x3807
#define HDT 0x3806
#define HDO 0x3806

#define START_ADDRESS   0x200
#define VECTR_ADDRESS   0x210
#define BEGIN_ADDRESS   0x240

#define WB_FLAG         1                   /* 0:NB / 1:WB */
#define RATE_NUMBER     6                   /* bit rate number */
#define FRAME_SIZE      320                 /* PCM frame size */
#define POSTFILTER_FLAG 1                   /* PostFilter 0:off/1:on */
#define VERSION         1                   /* Bitstream version */

%DEFINE(_read_host(reg))
(
    r0l=*HST:x;
    r0=r0 & 0x1;
    if(r0 != 0) jmp $-2;
    r@reg = *HDT:x;
)
%DEFINE(_write_host(reg))
(
    r0l=*HST:x;
    r0=r0 & 0x2;
    if(r0 != 0) jmp $-2;
    *HDT:x=r@reg;
)
%DEFINE(_VECTOR_DEF)
```

```
(
    nop;
    reti;
    nop;
    nop;
)


/*---------------------------------------------------------------------*/

USER_DATA XRAMSEG
  InputData:
    ds  320;
  CodeData:
    ds  30;
  OutputData:
    ds  320;

USER_FREE_X xramseg
  _USER_Free_X_Area_D:
    ds  STACK_SIZE_D;
  _USER_Free_X_Area_E:
    ds  STACK_SIZE_E;

USER_FREE_Y yramseg
  _USER_Free_Y_Area_D:
    ds  STACK_SIZE_D;
  _USER_Free_Y_Area_E:
    ds  STACK_SIZE_E;



/*---------------------------------------------------------------------*/
/* Function Name : main                                                */
/*---------------------------------------------------------------------*/
/*  others: r_      [*, , , , , , ,*]   dmx,dmy [ , ]                  */
/*          dp_     [*, , , , , , , ]   loops/stacks    [1/0]          */
/*          dn_     [ , , , , , , , ]   cycles      ???                */
/*---------------------------------------------------------------------*/
Startup imseg at START_ADDRESS
    jmp _main;
Vector imseg at VECTR_ADDRESS
;0x210  INT1
    %_VECTOR_DEF;
;0x214  INT2
    %_VECTOR_DEF;
;0x218  INT3
    %_VECTOR_DEF;
;0x21c  INT4
    %_VECTOR_DEF;
;0x220  Serial Input 1
    %_VECTOR_DEF;
;0x224  Serial Output 1
    %_VECTOR_DEF;
;0x228  Serial Input 2
    %_VECTOR_DEF;
```

```
;0x22c  Serial Output 2
    %_VECTOR_DEF;
;0x230  Host Input
    %_VECTOR_DEF;
;0x234  Host Output
    %_VECTOR_DEF;

main imseg at BEGIN_ADDRESS
  _main:
    clr(r0);
    call    _Init_Int;      /* Initialize interrupt */

    /* ------------- */
    /* clear memory  */
    /* ------------- */
    clr(r0);
    clr(r1);
    clr(r2);
    r0l=_USER_Free_X_Area_E;
    r1l=_USER_Free_Y_Area_E;
    r2l=STACK_SIZE_E;
    call    _Zero_Mem;
    clr(r0);
    clr(r1);
    clr(r2);
    r0l=_USER_Free_X_Area_D;
    r1l=_USER_Free_Y_Area_D;
    r2l=STACK_SIZE_D;
    call    _Zero_Mem;
    /* -------------------- */
    /* -------------------- */


    /* -------------------- */
    /*  Setting for Encoder */
    /* -------------------- */
    r7l = CodeData;
    *mpc_E_ANA_BUFF_SADR:x = r7l;
    r7l = RATE_NUMBER;
    *mpc_E_RATE_NUM:x = r7l;
    r7l=WB_FLAG;
    *mpc_E_WB:x=r7l;
    clr(r6);
    clr(r5);
    r6l=_USER_Free_X_Area_E;
    r5l=_USER_Free_Y_Area_E;
    call    mpc_InitEnc;           /* For Encoder Function */

    /* -------------------- */
    /*  Setting for Decoder */
    /* -------------------- */
    r7l= CodeData;
    *mpc_D_ANA_BUFF_SADR:x = r7l;
    r7l = POSTFILTER_FLAG;
    *mpc_D_PF_FLAG:x=r7l;
    r7l = VERSION;
```

```
    *mpc_D_VER:x=r7l;
    clr(r6);
    clr(r5);
    r6l=_USER_Free_X_Area_D;
    r5l=_USER_Free_Y_Area_D;
    call    mpc_InitDec;

    /* -------------------- */
    /*  Begin Main Loop     */
    /* -------------------- */
_main_loop:
        /* -------------------- */
        /*  Read Input Data     */
        /* -------------------- */
        r0l=InputData;
        call    _Read_Code_Data;

        /* -------------------- */
        /*  Encode one Frame    */
        /* -------------------- */
        r7l = InputData;
        *mpc_E_PCM_BUFF_SADR:x = r7l;
        call    mpc_Enc;

        /* -------------------- */
        /*  Decode one Frame    */
        /* -------------------- */
        r7l = OutputData;
        *mpc_D_PCM_BUFF_SADR:x = r7l;
        clr(r0);
        *mpc_D_ERR_FLAG:x = r0l;
        call    mpc_Dec;

        /* -------------------- */
        /*  Write Output Data   */
        /* -------------------- */
        r0l=OutputData;
        r1l=*mpc_D_PCM_NUM:x;
        call    _Write_Code_Data;

        jmp _main_loop;

/*-----------------------------------------------------------------------*/
/* Function Name : _Init_Int                                             */
/*  disable internal interrupt HO,HI                                     */
/*-----------------------------------------------------------------------*/
/*  others: r_      [*, , , , , , , ]   dmx,dmy [ , ]                    */
/*          dp_     [ , , , , , , , ]   loops/stacks    [0/0]            */
/*          dn_     [ , , , , , , , ]   cycles      ???                          */
/*-----------------------------------------------------------------------*/
  _Init_Int:
    r0l=sr;
    r0=r0 | 0x0300;
    sr=r0l;
    r0l=0x0001;
    *HST:x=r0l;
```

```
    ret;

/*-------------------------------------------------------------------------*/
/* Function Name : _Write_Code_Data                                        */
/*  [argv]                                                                 */
/*      r0l:Write Data Ponter : Xmem                                       */
/*      r1l:Number of Write Data                                                */
/*-------------------------------------------------------------------------*/
/*  others: r_      [*,*, , , , , ,*]   dmx,dmy [ , ]                     */
/*          dp_     [*, , , , , , , ]   loops/stacks    [1/0]              */
/*          dn_     [ , , , , , , , ]   cycles      ???                         */
/*-------------------------------------------------------------------------*/
  _Write_Code_Data:
    dp0=r0l;
    if(r1 == 0) jmp _end_Write_Code_Data;
    r7l=*dp0++;
    loop r1l{
        %_write_host(7l);
        r7l=*dp0++;
        nop;
    };
  _end_Write_Code_Data:
    r0l=*HST:x;
    r0=r0 & 0x2;
    if(r0 != 0) jmp $-2;
    ret;

/*-------------------------------------------------------------------------*/
/* Function Name : _Read_Code_Data                                         */
/*  [argv]                                                                 */
/*      r0l:Read Data Ponter : Xmem                                        */
/*  [ret]                                                                  */
/*-------------------------------------------------------------------------*/
/*  others: r_      [*, , , , , , , ]   dmx,dmy [ , ]                     */
/*          dp_     [*, , , , , , , ]   loops/stacks    [1/0]              */
/*          dn_     [ , , , , , , , ]   cycles      ???                         */
/*-------------------------------------------------------------------------*/
  _Read_Code_Data:
    dp0=r0l;
    r0l=FRAME_SIZE;
    loop r0l{
        %_read_host(0);
        *dp0++=r0h;
        nop;
    };
    ret;

/*-------------------------------------------------------------------------*/
/* Function Name : _Zero_Mem                                               */
/*  clear memory                                                                */
/*  [argv]                                                                 */
/*      r0l:Start Address : Xmem                                                */
/*      r1l:Start Address : Ymem                                                */
/*      r2l:Size                                                                */
/*  [ret]                                                                  */
/*      r0:0 :Error  !=0:OK                                                */
```

```
/*-------------------------------------------------------------------------*/
/*  others: r_      [*,*, , , , , , ]   dmx,dmy [ , ]                      */
/*          dp_     [*, , , ,*, , , ]   loops/stacks    [1/0]              */
/*          dn_     [ , , , , , , , ]   cycles      ???                        */
/*-------------------------------------------------------------------------*/
  _Zero_Mem:
    dp0=r0l;
    dp4=r1l;
    clr(r1);
    clr(r0);
    rep r2l;
        *dp0++=r0l  *dp4++=r1l;
    ret;

END
```

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