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User's Manual

RENESAS

μSAP77016-B01

Acoustic Echo Canceller Middleware

Target Devices

μPD77015
μPD77016
μPD77017
μPD77018A
μPD77019
μPD77110
μPD77111
μPD77112
μPD77113
μPD77113A
μPD77114
μPD77115

Document No. U13130EJ4V0UM00 (4th edition)
Date Published June 2001 N CP(K)

[MEMO]

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J01.2

Major Revisions in This Edition

Page	Description
p. 12	Addition of μPD77113A and deletion of μPD77118, 77116 to/from **1.3.2 (1) Target DSP**
p. 13	Change of description in **1.3.4 Directory structure**

The mark ★ shows major revised points.

PREFACE

Target Readers

This manual is intended for users who understand the functions of the μPD77016 Family and who will design application programs using this family of microcontrollers.

The μPD7701X Family is the generic name for the μPD7701X Family (μPD77015, 77016, 77017, 77018A, and 77019) and μPD77111 Family (μPD77110, 77111, 77112, 77113, 77113A, 77114, and 77115).

Purpose

The aim of this manual is to introduce readers to the basic functions of the μPD77016 Family by using application programs. Note that programs and hardware configurations shown in this document are for educational purposes only, and are not intended for mass production.

Organization

This manual provides explanations of basic numerical operation programs.

CHAPTER 1 INTRODUCTION
CHAPTER 2 LIBRARY SPECIFICATIONS
CHAPTER 3 INSTALLATION
APPENDIX SAMPLE SOURCE (sample.asm)

How to Read This Manual

It is assumed that readers of this manual have general knowledge in the fields of logic circuits and microcontrollers.

To learn about the hardware functions of the μPD7701X Family,
→ Read ***μ*PD7701X Family Architecture User's Manual**.

To learn about the hardware functions of the μPD77111 Family,
→ Read ***μ*PD77111 Family Architecture User's Manual**.

To learn about the instruction functions of the μPD77016 Family,
→ Read ***μ*PD77016 Family Instruction User's Manual**.

Conventions

Data significance:	Higher digits on the left and lower digits on the right
Active low:	$\overline{\times\times\times}$ (overscore over pin or signal name)
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 μPD77016 Family

Document Name / Part Number	Pamphlet	Data Sheet	User's Manual		Application Note
			Architecture	Instructions	Basic Software
μPD77016	U12395E	U10891E	U10503E	U13116E	U11958E
μPD77015		U10902E			
μPD77017					
μPD77018					
μPD77018A		U11849E			
μPD77019					
μPD77019-013		U13053E			
μPD77110		U12801E	U14623E		
μPD77111					
μPD77112					
μPD77113A		U14373E			
μPD77114					
μPD77115		U14867E			

Documents Related to Development Tools

Document Name		Document No.
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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LIST OF TABLES

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 voice 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.

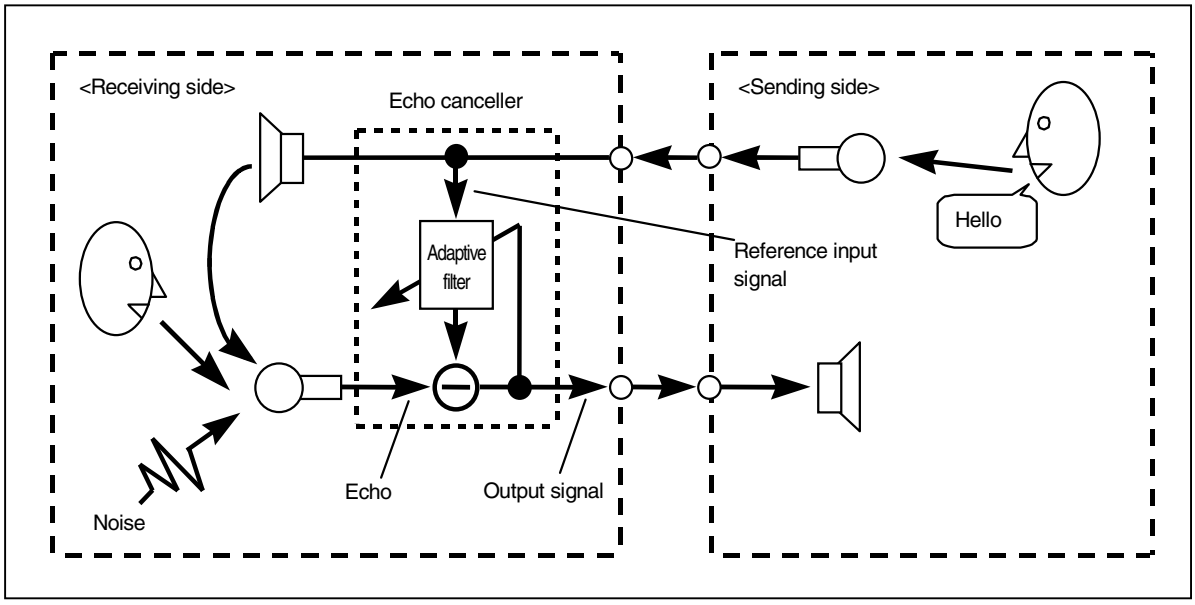
The product introduced here is middleware that supplies the functions of an acoustic echo canceller.

1.2 Echo Canceller

The echo canceller contains functions to calculate the acoustic echo generated during hands-free telephoning (the echo generated by the environment in which the hands-free telephone system is being used), and eliminate just the echo element from the voice signal (which is made up of echo + voice + noise) on the receiving side.

The applications where the echo canceller is thought to be most effective include hands-free systems such as in-car telephoning and video conferencing.

Figure 1-1. Concept of Echo Canceller



1.3 Product Overview

1.3.1 Features

- Employment of strong echo cancel algorithms for noise level fluctuation using an NEC original technique
- All voice I/O data (reference input signal, echo, output signal) is 16-bit linear data
- Full-duplex system echo canceller
- Appropriate-learning-type environment adaptability
- Echo elimination time freely settable
- Supports Windows™ based workbench for μPD77016 starter kit (WB77016 Ver2.21)

1.3.2 Operating environment

★ **(1) Target DSP**

μPD77015, 77016, 77017, 77018A, 77019, 77110, 77111, 77112, 77113, 77113A, 77114, 77115

(2) Required memory size

Usage	Size (words)			
	Instruction ROM	X Data RAM	Y Data RAM	Total
Program code	249	–	–	249
Coefficient table buffer	–	1 [word/tap]	1 [word/tap]	2 [word/tap]
Delay buffer	–	1 [word/tap]	–	1 [word/tap]
Work memory	–	–	19	19

Remarks 1. In addition, YRAM or YROM requires 24 words to store a copy write.

2. The memory size of the coefficient table buffer and delay buffer indicates size per tap.

Example: When the number of taps is 512

Coefficient table size: 1[word/tap] × 512 taps × 2 = 1024 [words]

Delay buffer size: 1[word/tap] × 512 taps = 512 [words]

(3) Supported A/D, D/A specs

A/D 2 channels

D/A 1 channel

16-bit resolution

(4) Software tools

DSP tools: WB77016 Ver2.21 (Windows based)

WB77016 for μPD77016 Starter Kit Ver2.21sk (Windows based)

1.3.3 Performance

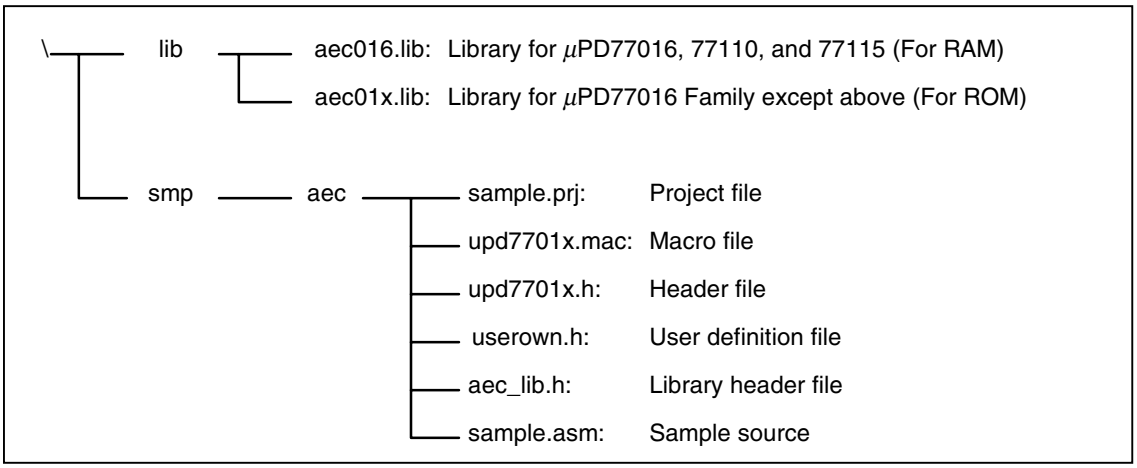
The performance of the μSAP77016-B01 is shown below.

Table 1-1. Performance of μSAP77016-B01

Operating Environment	DSP: μPD77016 (operation frequency: 33 MHz) Number of taps: 512 Sampling frequency fs = 8 kHz
Performance	• When used in a real-world setting (for example, in a car) Echo cancel processing time = about 68.88 [μs] Number of taps × 4 [cycles] × (number of memory waits + 1) + (170 to 259) [cycles] Echo elimination amount 30 [dB] (TYP.) Echo elimination time 64 [ms]

★ **1.3.4 Directory structure**

The contents of the packages are shown below.

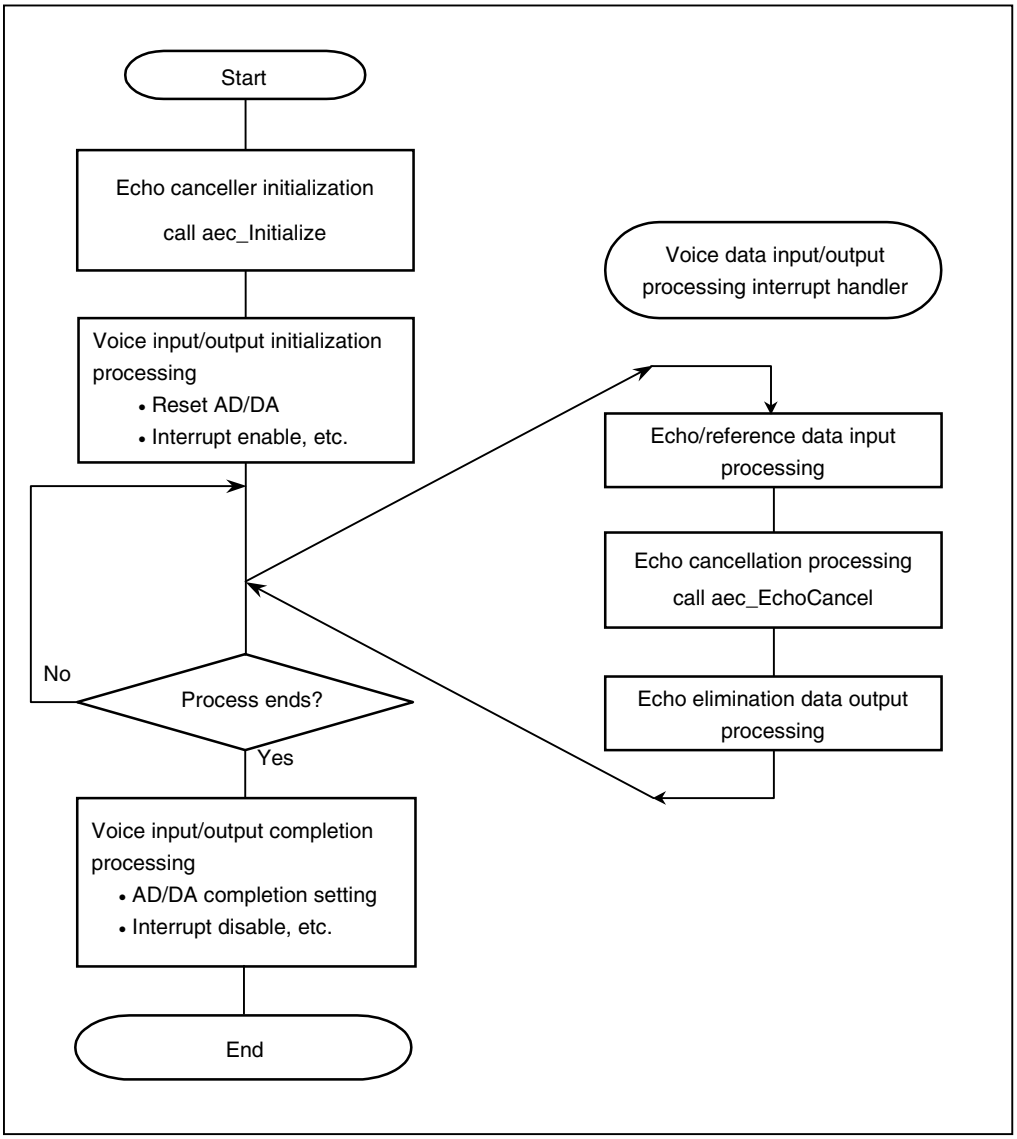


CHAPTER 2 LIBRARY SPECIFICATIONS

2.1 Echo Cancellation Processing Flow

The processing flow when the reference signals and the echo signal are input to the μPD77016 Family serial interfaces (SIO1, SIO2) is shown below.

Figure 2-1. Application Process



2.2 Function Specifications

2.2.1 Memory structure

The following is an explanation of the structure of the memory required by this library.

- Coefficient table buffer
  The area to which the learned coefficients are saved. Each coefficient is 32 bits long, and the higher and lower 16 bits are divided and saved to the X and Y memory areas, respectively. The size of the coefficient table depends on the number of taps.

  Example __AEC_WORK_X XRAMSEG
  ch1_al_buff: ds tapnum ; 32bit coefficient of low word
  __AEC_WORK_Y YRAMSEG
  ch1_ah_buff: ds tapnum ; 32bit coefficient of high word

- Delay buffer
  The area to which the reference signals input to the echo canceller are saved. Secure X memory space for the delay buffer and align the first address of the secured area with the number of taps[Note]. The size of the delay buffer depends on the number of taps.

  Note When the number of taps is 2^n (512, 256, 128, …) $\rightarrow$ Align with 2^n
  When the number of taps is $2^n+\alpha$ (500, 300, 200, etc.) $\rightarrow$ Align with 2^{n+1}

  Example __AEC_WORK_X XRAMSEG align at tapnum
  ch1_z_buff: ds tapnum ; z buffer

- Work memory
  The area to which the statuses of the echo canceller are saved. Secure 19 words of the Y memory space for the work memory.

  Example __AEC_WORK_Y YRAMSEG
  ch1: ds 19 ; work memory

Cautions 1. Take care to avoid destroying the coefficient table buffer, delay buffer, and work memory areas while operating the echo canceller after calling the aec_initialize function. Normal operation of this library cannot be guaranteed if these areas are destroyed.

2. Neither of the coefficient table areas (higher 16 bits, lower 16 bits) can be allocated to external memory.

2.2.2 Macro

The macro used by this library is defined by aec_lib.h. To use this macro, aec_lib.h must be Included.

- AEC_CreateBuffer macro
  The AEC_CreateBuffer macro secures and declares the 1 channel of memory area required for echo cancellation processing. Accordingly, when configuring multiple channels, declare this macro for the required number of channels only.

[Classification] Securing memory
[Function name] AEC_CreateBuffer
[Summary of function] Secures 1 channel of memory area.
[Format] %AEC_CreateBuffer(name,tapnum)

[Arguments]

Type	Argument	Description
WORD	name	Symbol name
WORD	tapnum	Number of taps

[Return value] None
[Function] Allocates the delay buffer, coefficient table, and work memory from the memory.

Example When the AEC_CreateBuffer macro is declared with a setting whereby the symbol name = ch1 and the tap number is 256:
%AEC_CreateBuffer(ch1, 256)

The symbol names and memory sizes when the AEC_CreateBuffer macro is used are as follows.

Table 2-1. Symbol Name and Memory Size When Using AEC_CreateBuffer Macro

Symbol Name	Size[words]	X/Y	Description
ch1_z_buff	256	X	Delay buffer area
ch1_al_buff	256	X	Coefficient table area (lower 16 bits)
ch1_ah_buff	256	Y	Coefficient table area (higher 16 bits)
ch1	19	Y	Work memory first address

2.2.3 aec_Initialize function

The aec_Initialize function initializes the coefficient settings, coefficient table, and delay buffer. The aec_Initialize function performs initialization processing on 1 channel. To initialize multiple channels, call the aec_Initialize function for each channel individually.

[Classification] Echo canceller initialization processing
[Function name] aec_Initialize
[Summary of function] Initializes the RAM area used for the echo canceller and sets parameters.
[Format] call aec_Initialize

[Arguments]

Type	Argument	Description
register	R0L	Number of taps (elimination time × sampling frequency)
register	R1L	Step size (learning amount)
register	R2L	α coefficient (0 to 8)
register	R3L	β coefficient (0.99 to 0.999)
register	DP0	Coefficient table first address (low word)
register	DP1	Delay buffer first address
register	DP4	Coefficient table first address (high word)
register	DP5	Work memory first address

[Return value] None
[Function] Initializes this library, makes parameter settings, etc.
[Registers used] R0, R1, R2, R3, DP0, DP1, DP4, DP5
[Loop stack levels] 1 level used
[Stack levels] 0 levels used

Caution The echo canceller may not be able to perform normal processing if values outside the allowable range are set for the α and β coefficients.

Remark If the voice after processing is distorted due to excessive noise, either make the step size smaller, or the α coefficient larger. If convergence is slow, either make the step size larger, or the α coefficient smaller. If the variation in the power of the noise is extreme, make the β coefficient smaller (but within the range of 0.990 to 0.999). The recommended values for the step size, and α and β coefficients are as follows.

Step size = 0.1
α coefficient = 5
β coefficient = 0.995

2.2.4 aec_EchoCancel function

The aec_EchoCancel function creates an echo-free signal by eliminating the echo from the echo and reference signals.

[Classification] Echo cancellation processing section
[Function name] aec_EchoCancel
[Summary of function] Performs echo cancellation processing on signals that include echo.
[Format] call aec_EchoCancel

[Arguments]

Type	Argument	Description
register	R0H	Echo signal (16-bit linear PCM)
register	R1H	Reference signal (16-bit linear PCM)
register	DP0	Coefficient table first address (low word)
register	DP1	Delay buffer first address
register	DP4	Coefficient table first address (high word)
register	DP5	Work memory address

[Return value]

Type	Argument	Description
register	R0H	Signal after eliminating echo (16-bit linear PCM)

[Function] Creates a signal from which the echo has been eliminated by creating a replica echo from the reference signal and removing the replica echo signal from the echo signal.
[Registers used] R0, R1, R2, R3, R4, R5, DP0, DP1, DP4, DP5, DN1, DMX
[Loop stack levels] 1 level used
[Stack levels] 0 levels used

2.2.5 aec_GetVersion function

The aec_GetVersion function returns the version information of this library.

[Classification] Echo canceller version information acquisition function
[Function name] aec_GetVersion
[Summary of function] Returns the version information.
[Format] call aec_GetVersion
[Arguments] None

[Return Value]

Type	Return value	Description
register	R0H	Major version number
register	R0L	Minor version number

[Function] Returns the version number of this library as a 32-bit value.
Example When R0 = 0x00'0x0001'0x0100:
Version: V1.01

[Registers used] R0
[Loop stack levels] 0 levels used
[Stack levels] 0 levels used

2.3 Characteristics

The characteristics of the amount of echo eliminated (ERLE) from this library's reference signal and echo signal levels are shown below.

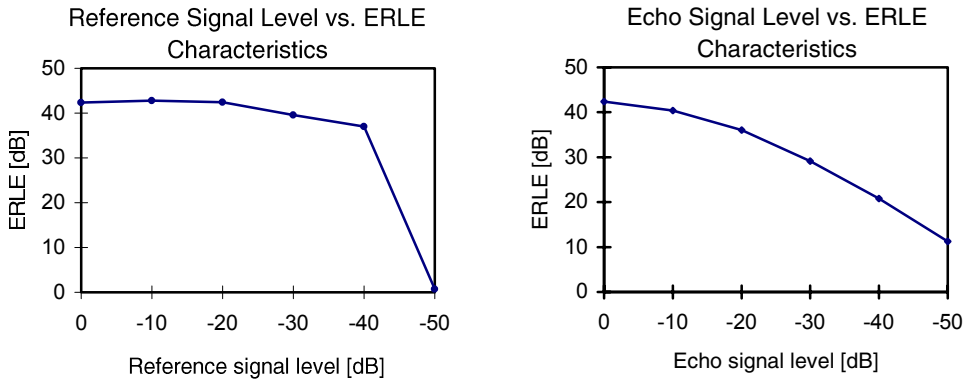
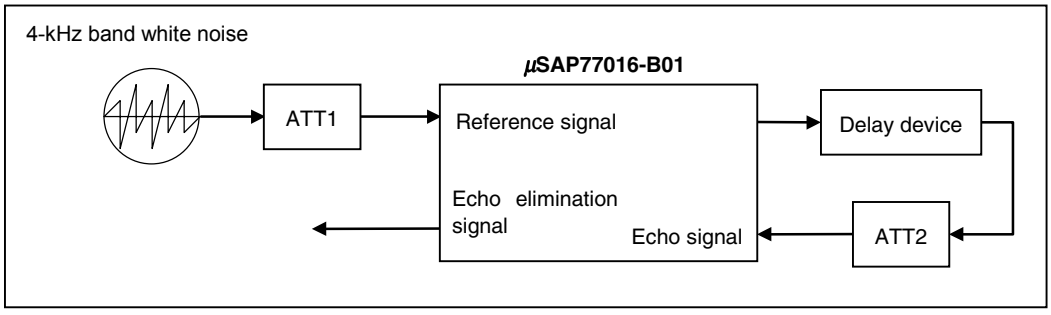


Table 2-2. Measuring Conditions of Characteristics

	Reference Signal Level vs ERLE	Echo Signal Level vs ERLE
Reference signal	4-kHz band white noise The average power of white noise is 5.87×10^7 (average value: 7660) with a 16-bit quantized value (–32768 to 32767).	
Delay time [ms]	2	
ATT1 [dB]	0 to –50	0
ATT2 [dB]	0	0 to –50

Figure 2-2. Characteristics Measuring Configuration Diagram



2.4 Cautions

- Set the return amount of the echo included in the echo signal so that it attenuates. If the return amount is amplified, it will be impossible to eliminate the echo.
- Set the level of the reference signal so that it does not overflow at CODEC.
- Do not input a tone signal (DTMF signal etc.) for the reference signal. If a tone signal is input, the amount of echo cancelled will be reduced.
- If the variation of the echo path[Note] is extreme, the echo canceller will have trouble converging the learning of the echo path.
- If the echo canceller is used in a noisy environment, converging the learning of the echo path may take longer than when the echo canceller is used in a noise-free environment.

Note Echo path: The path along which the voice is reflected and returns.

CHAPTER 3 INSTALLATION

3.1 Installation Procedure

The μSAP77016-B01 is supplied on a 3.5-inch floppy disk (1.44 MB). The procedure for installing the μSAP77016-B01 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 software tools 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.

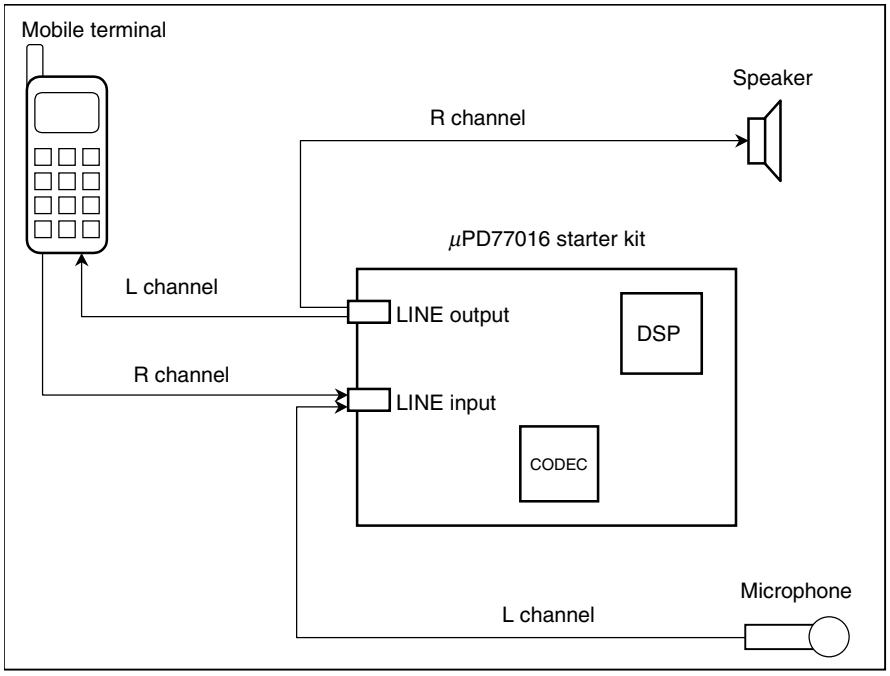
```
a:\>dir c:\DSPTools <CR>
```

3.2 Sample Creation Procedure

The sample program is stored in the smp directory. Refer to **APPENDIX SAMPLE SOURCE (sample.asm)** for details on the sample.asm source program.

With the sample program is it possible to connect a microphone, speakers, etc. and evaluate a hands-free system. Note that the sample program operates with the μPD77016 starter kit.

Figure 3-1. Sample Program Evaluation System



The following is an explanation of how to build the μSAP77016-B01 sample program.

(1) Start up the WB77016.

(2) Open the sample.prj project file.
Example Specify C:\DSPTools\smp\aec\sample.prj with the Open Project command on the Project menu.

(3) Execute Build and confirm that sample.lnk has been created.
Example The sample.lnk file can be created by selecting the Build All command from the Make menu.

(4) Execute the sample program by downloading it to the target system using the starter kit debugger (ie77016s.exe).

Cautions 1. Use the starter kit workbench to create the sample file.

2. Because the file structure of the project file (sample.prj) is specified via an absolute path, if the library has been installed in a directory other than "C:\DSPTools", it is necessary to reset the file structure.

3.3 Change of Location

The section names shown in Table 3-1 below have been attached in this library. The locations can be changed to accord with the user's target system.

Table 3-1. Section Names

Section Name	Type	Description
__AEC_WORK_X	XRAMSEG	X memory area data RAM
__AEC_WORK_Y	YRAMSEG	Y memory area data RAM
__AEC_COPYRIGHT_Y	YROMSEG/YRAMSEG	Copyright storage area
__AEC_LIB	IROMSEG/IRAMSEG	Echo canceller program

3.4 Symbol Naming Regulations

The symbols used in this library are named according to the following regulations. Take care not to duplicate these names when using the μSAP77016-B01 in combination with another application.

Table 3-2. Symbol Names

Classification	Regulation
Function	aec_XXXX
Macro, constant	AECXXXX

APPENDIX SAMPLE SOURCE (sample.asm)

```
/*---------------------------------------------------------------------*/
/*     File Information                                                */
/*---------------------------------------------------------------------*/
/*     Name         : sample.asm                                       */
/*     Type         : Assembler program module                         */
/*     Version      : 1.00a                                            */
/*     Date         : 1997 JAN 14                                      */
/*     CPU          : uPD7701x Family                                  */
/*     Assembler    : WB77016                                          */
/*     About        :NEC uPD7701x Family Middle-Ware                   */
/*                   Sample Program of Echo Canceller Library          */
/*---------------------------------------------------------------------*/
/*     Copyright (C) NEC Corporation 1996                              */
/*     NEC CONFIDENTIAL AND PROPRIETARY                                */
/*     All rights reserved by NEC Corporation.                         */
/*     Use of copyright notice does not evidence publication           */
/*---------------------------------------------------------------------*/

#include "aec_lib.h"
#include "userown.h"
#include "upd7701x.mac"

/* ====================================================================
 *     Define CODEC(uPD63310) control register
 * ================================================================== */
#define  CODEC_CTL   *0x4000:X
#define  CGAIN_ADR   *0x8000:X
#define  CGAIN_DAT   *0x8001:X

/* ====================================================================
 *     Define echo canceller status
 * ================================================================== */
#define TAPS  512
#define U0    0.1
#define ALFA  5
#define BETA  0.995

/* ====================================================================
 *     Allocate echo canceller buffer
 * ================================================================== */
%AEC_CreateBuffer(ch1, TAPS);

/* ====================================================================
 *     Allocate work buffer
 * ================================================================== */
WORK_Y YRAMSEG
R0TMP: ds     3
cnt:   ds     1
flag:  ds     1
echo:  ds     1
ref:   ds     1
err:   ds     1

#define CNT   *cnt:Y
#define FLAG  *flag:Y
```

```
#define ECHO  *echo:Y
#define REF   *ref:Y
#define ERR   *err:Y

/* ========================================================================
 *     Vector registration
 * ======================================================================== */
%BeginVector(StartUp)                                ;Regist start up routine
       %NotUseVector(VectorINT1)                     ;
       %NotUseVector(VectorINT2)                     ;
       %NotUseVector(VectorINT3)                     ;
       %NotUseVector(VectorINT4)                     ;
       %RegistVector(VectorSI1, SI1Handler)          ;Regist SI1 handler
       %NotUseVector(VectorSO1)                      ;
       %NotUseVector(VectorSI2)                      ;
       %NotUseVector(VectorSO2)                      ;
       %NotUseVector(VectorHI)                       ;
       %NotUseVector(VectorHO)                       ;
%EndVector

/* ========================================================================
 *     Sample programe code section
 * ======================================================================== */
SAMPLE_CODE   IMSEG at 0x240
StartUp:
       ;;=================================================================;;
       ;;     Initialize Register & Peripheral Units                      ;;
       ;;=================================================================;;
       %ClearAllRegister                 ;Clear all uPD7701x register
       %SetIWTR(0x0054)                  ;Set instruction ROM/RAM wait cycle
       %SetDWTR(0x3c3c)                  ;Set data ROM/RAM wait cycle
       %SetPort(P0_OUT_MODE|P0_L_LEVEL)  ;Set P0 output mode & low level
       %SetPort(P1_OUT_MODE|P1_L_LEVEL)  ;Set P1 output mode & low level
       %SetPort(P2_IN_MODE)              ;Set P2 output mode & low level
       %SetPort(P3_IN_MODE)              ;Set P3 input mode
       ;;=================================================================;;
       ;;     Initialize CODEC chip(uPD63310)                             ;;
       ;;=================================================================;;
       clr(R0)                           ;
       clr(R1)                           ;
       R1L = 0x0002                      ;
       CGAIN_ADR = R0L                   ;ch1-L
       nop                               ;
       CGAIN_DAT = R1L                   ;
       R0L = 0x0001                      ;ch1-R
       CGAIN_ADR = R0L                   ;
       nop                               ;
       CGAIN_DAT = R1L                   ;
       R0L = 17                          ;out-L
       CGAIN_ADR = R0L                   ;
       R0L = 0x0001                      ;
       CGAIN_DAT = R0L                   ;
       R0L = 18                          ;out-R
       CGAIN_ADR = R0L                   ;
       R0L = 0x0001                      ;
       CGAIN_DAT = R0L                   ;
       R0L = 0x000f                      ;
       CODEC_CTL = R0L                   ;
```

```
        ;;=============================================================;;
        ;;     Initialize Echo cannceller module                       ;;
        ;;=============================================================;;
        R0L = TAPS                ;Initialize echo cancel module
        R1L = U0                  ;
        R2L = ALFA                ;
        R3L = BETA                ;
        DP0 = ch1_al_buff         ;
        DP4 = ch1_ah_buff         ;
        DP1 = ch1_z_buff          ;
        DP5 = ch1                 ;
        call aec_Initialize       ;
        ;;=============================================================;;
        ;;     Initialize work/flag memory                             ;;
        ;;=============================================================;;
        clr(R0)                   ;
        CNT = R0L                 ;
        FLAG = R0L                ;
        ECHO = R0L                ;
        REF = R0L                 ;
        ;;=============================================================;;
        ;;     Initialize Serial I/F                                   ;;
        ;;=============================================================;;
        R0L = 0x0200              ;Initialize Serial I/F 1
        *SST1:X = R0L             ;

        %DisableMask(SR_ALL)      ;Disable all interrupt mask
        %EnableMask(SR_SI1)       ;Enable SI1 interrupt mask
        %EnableInterrupt          ;Enable interrupt
        ;;=============================================================;;
        ;;     Main routine                                            ;;
        ;;=============================================================;;
loop1:
        nop                       ;Wait Echo canceller start flag
        R0 = FLAG                 ;
        if(R0 == 0) jmp loop1     ;
        R0 = ECHO                 ;Set echo signal to R0
        R1 = REF                  ;Set reference signal to R1
        DP0 = ch1_al_buff         ;Set coefficient table start address
        DP4 = ch1_ah_buff         ;
        DP5 = ch1                 ;Set AECINFO struck start address
        call aec_EchoCancel       ;Echo cancel process
        ERR = R0H                 ;Get echo removabled signal
        clr(R0)                   ;
        FLAG = R0H                ;
        jmp loop1                 ;

        ;;=============================================================;;
        ;;     SI1 handler                                             ;;
        ;;=============================================================;;
SI1Handler:
        *R0TMP+0:Y = R0L          ;Save work register of R0
        *R0TMP+1:Y = R0H          ;
        *R0TMP+2:Y = R0E          ;
        R0L = *PDT:X              ;if P3 is low level, no echo canceller.
        R0 = R0 & 0x0008          ;
        if(R0 == 0) jmp no_cancel ;
```

```
        clr(R0)                     ;Echo cancel process
        R0L = CNT                   ;
        R0 = R0 ^ 0x0001            ;
        CNT = R0L                   ;
        if(R0 == 0) jmp R_channel   ;
L_channel:
        R0 = *SDT1:X                ;Get L-channel signal
        ECHO = R0H                  ;Save echo signal
        R0 = ERR                    ;Load output signal
        jmp si1_end                 ;
R_channel:
        R0 = FLAG                   ;
        if(R0 == 0) jmp no_error    ;
        %SetPort(P0_H_LEVEL)        ;
no_error:
        R0 = *SDT1:X                ;Get R-channel signal
        REF = R0H                   ;Save reference signal
        R0L = *PDT:X                ;
        R0 = R0 & 0x0004            ;
        if(R0 != 0) jmp $+3         ;
        R0H = ERR                   ;
        jmp $+2                     ;
        R0H = REF                   ;
        R0L = 0x0001                ;Set echo canceller start flag
        FLAG = R0L                  ;
si1_end:
        *SDT1:X = R0H               ;Output signal
        R0E = *R0TMP+2:Y            ;Save work register of R0
        R0H = *R0TMP+1:Y            ;
        R0L = *R0TMP+0:Y            ;
        reti                        ;

no_cancel:                          ;No cancel process
        clr(R0)                     ;
        R0L = CNT                   ;
        R0 = R0 ^ 0x0001            ;
        CNT = R0L                   ;
        if(R0 == 0) jmp R_channel2  ;
        R0 = *SDT1:X                ;Get L-channel signal
        ECHO = R0H                  ;
        jmp si1_end                 ;
R_channel2:
        R0 = *SDT1:X                ;Get R-channel signal
        REF = R0H                   ;
        R0H = ECHO                  ;
        jmp si1_end                 ;

end
```

[MEMO]

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