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AN204354

FM3 Microcontroller Simple AV System Solution (JPEG, I²S, MP3, AAC, USB)

Associated Part Family:	Series Name	Product Number
	MB9B500A	MB9BF504NA/505NA/506NA/504RA/505RA/506RA
	MB9B300A	MB9BF304NA/305NA/306NA/304RA/305RA/306RA

This application note is for those planning to design an image output processing system or process audio data using a microcontroller of the FM3 family.

Contents

1 Introduction

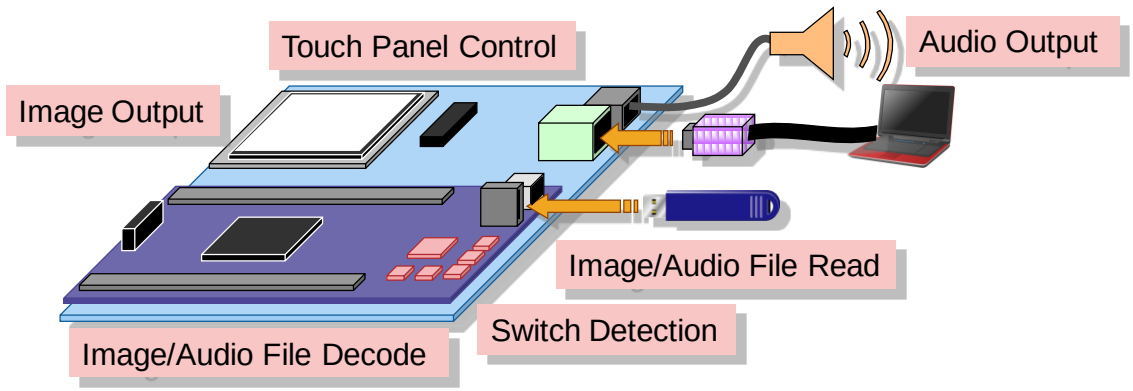
This application note is for those planning to design an image output processing system or process audio data using a microcontroller of the FM3 family made by Fujitsu Semiconductor. This document takes specific examples of a system or audio output control, LCD control and decoding of audio or image data contained in a USB memory, and gives the ROM and RAM size required by the FM3 family, and actual measurement results of CPU occupancy and system processing speed

2 Simple AV System Board

The simple AV system described in the application notes conducts the following operations. For details, see the User Manual for the simple AV system board.

1. Reads image/audio files in USB memory (JPEG, MP3, AAC)
2. Switch detection
3. Image/audio file decoding (JPEG, MP3, AAC)
4. Image output (LCD display)
5. Touch panel control
6. Audio output

Figure 1. Simple AV System Board Schematic View



2.1 System Operation

- Image data processing

1. Reads JPEG files in USB memory connected to the USB interface.
2. Decodes JPEG files.
3. Outputs decoded JPEG files on the LCD.

* JPEG file processing is not implemented if audio data is AAC.

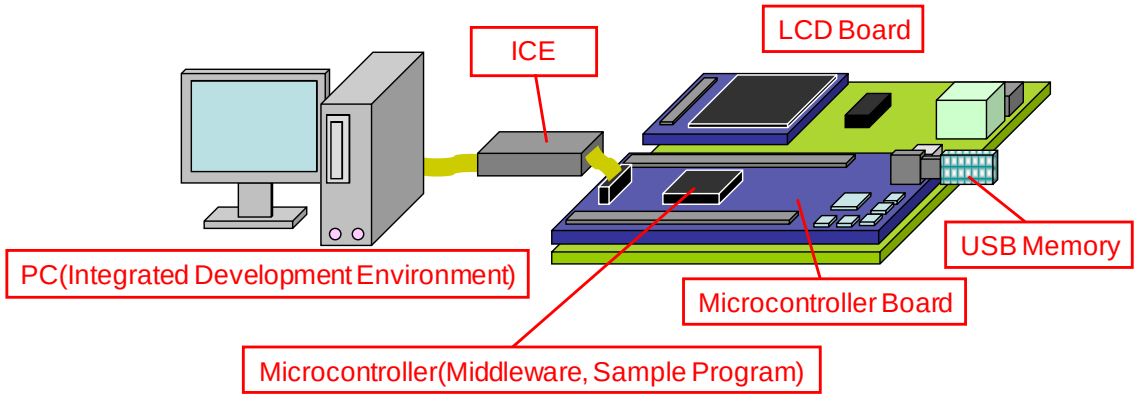
(See "3.3.1 Amount of ROM/RAM Used")

- Audio data processing

1. Reads audio data in USB memory connected to the USB interface.
2. Decodes read audio files.
3. Outputs decoded audio data to DA converter(DAC).

* Format of output audio data can be modified by middleware assembled. The application notes contain performance measurement results for MP3 and AAC file processing.

Figure 2. System Configuration Diagram

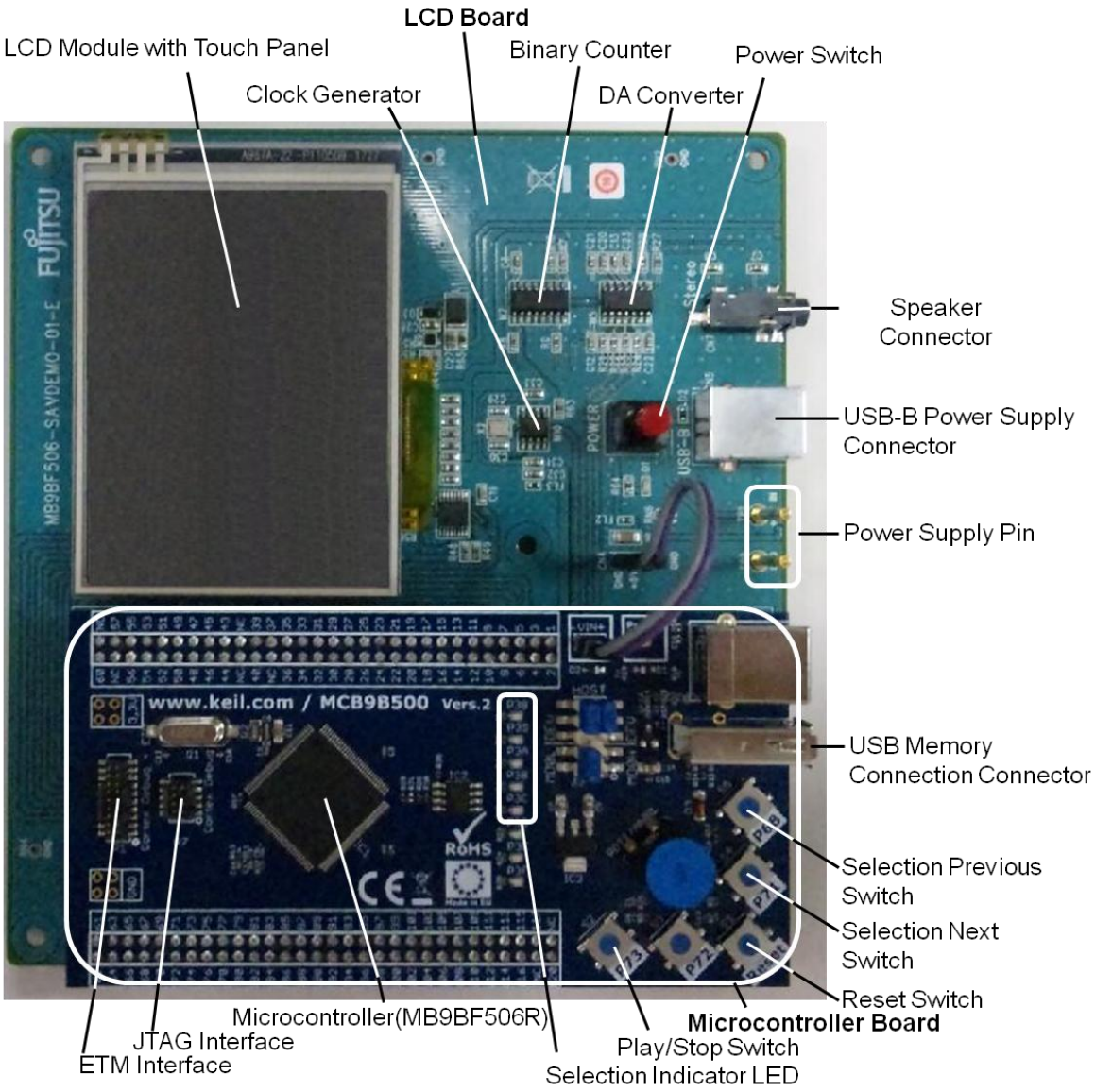


2.2 Hardware

2.2.1 External Appearance of Simple AV System Board

A photograph of the outer external appearance of the simple AV system board is shown in Figure 3.

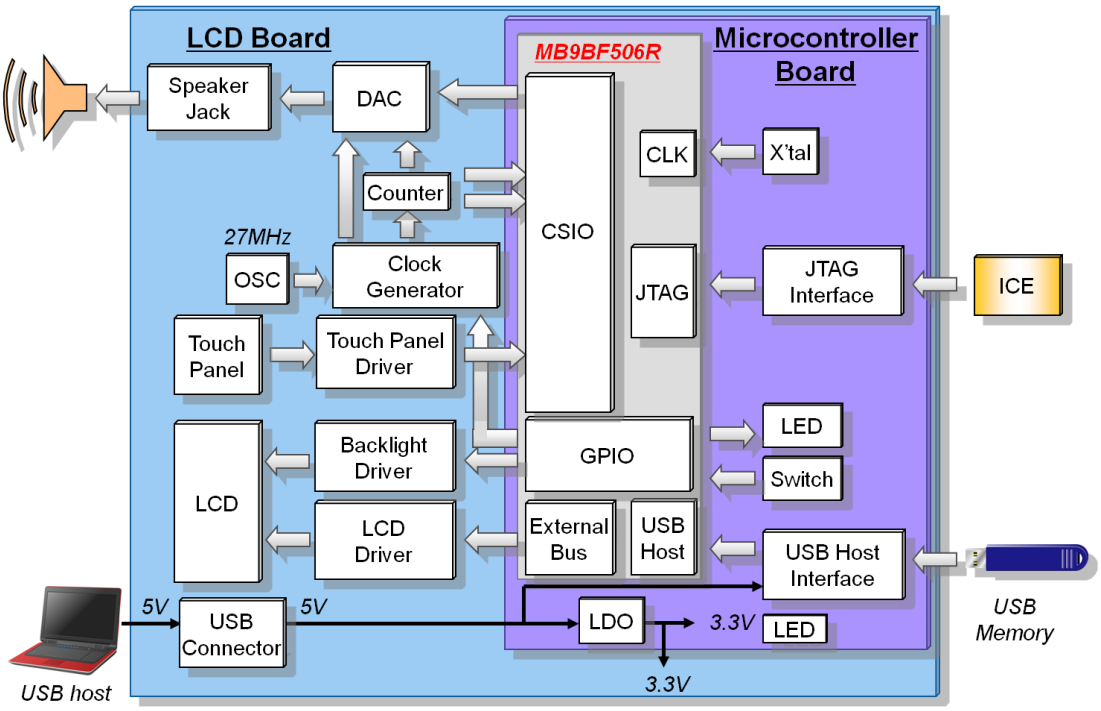
Figure 3. Photograph of External Appearance of Simple AV System Board



2.2.2 Hardware Block Diagram

The hardware block diagram of the system is shown in Figure 4.

Figure 4. Hardware Block Diagram

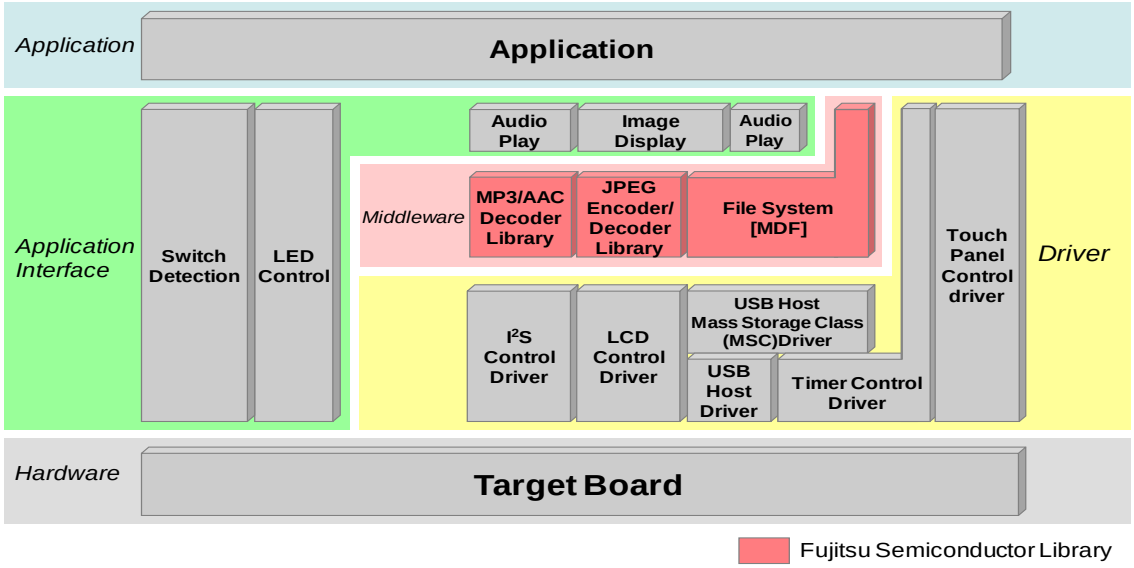


2.3 Software

2.3.1 Software Block Diagram

The software block diagram of the system is shown in Figure 5

Figure 5. Software Block Diagram



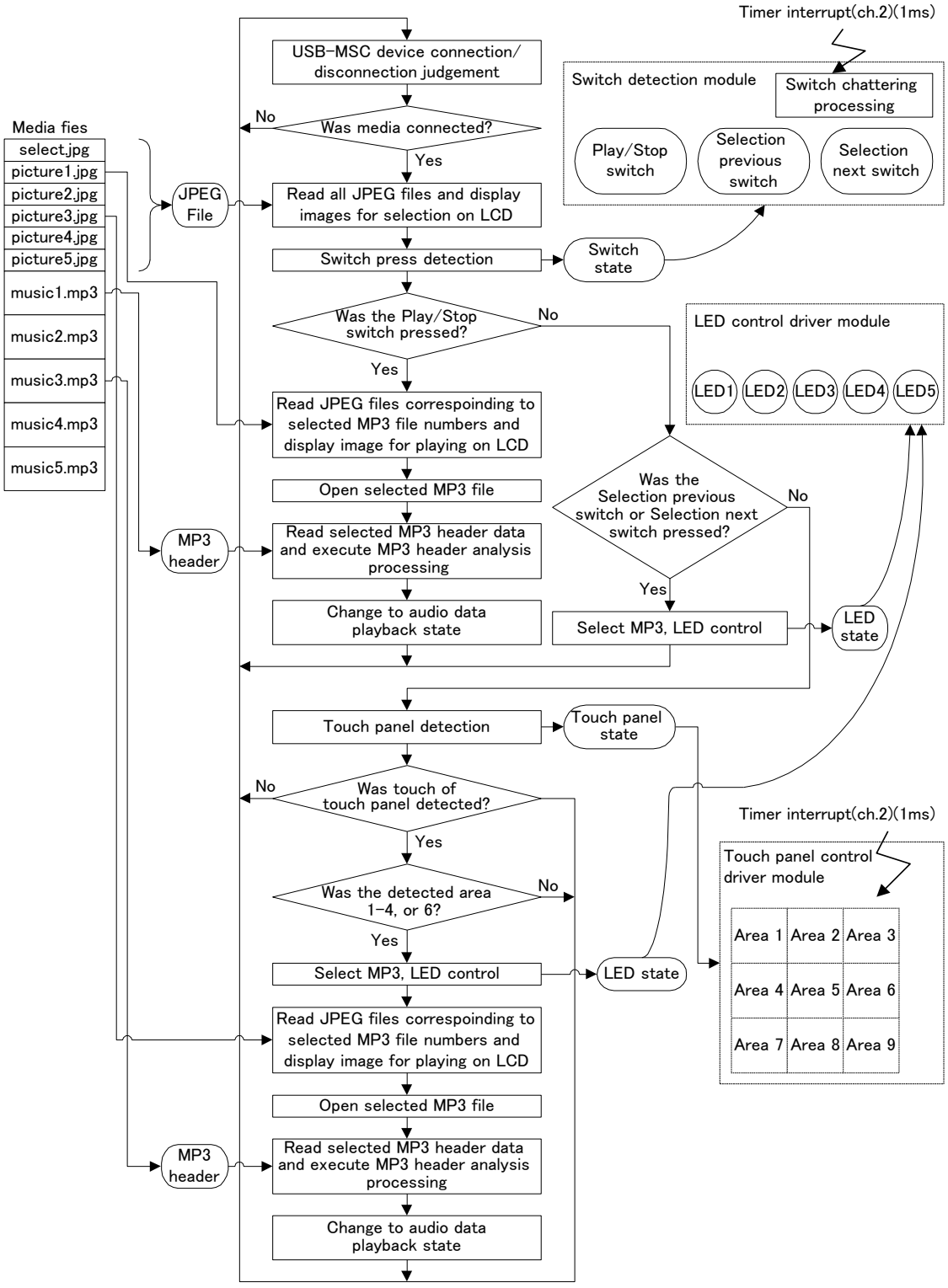
2.3.2 Operation Flow of Entire Application

MP3

1. The application operation flow with audio data playback stopped is as follows.
    1. USB MSC device connection/disconnection judgment is executed in the main loop.
    2. If a USB memory is connected, after reading the JPEG files from the USB memory and displaying the images for selection, switch pressing detection and touch panel detection are conducted.
    3. If the play/stop switch is detected to be pressed down, or if not detected, but an area of the touch panel is detected to have been touched, the JPEG files corresponding to the selected MP3 file are read from the USB memory and displayed for playback. If the selection previous switch or selection next switch are detected to have been pressed down, MP3 file selection is shifted and LED control is executed.
    4. The MP3 selected from the USB memory is then opened.
    5. The MP3 file header is read, MP3 file header analysis processing is conducted and operation shifts to audio data playback in progress status.

This operation is shown in Figure 6.

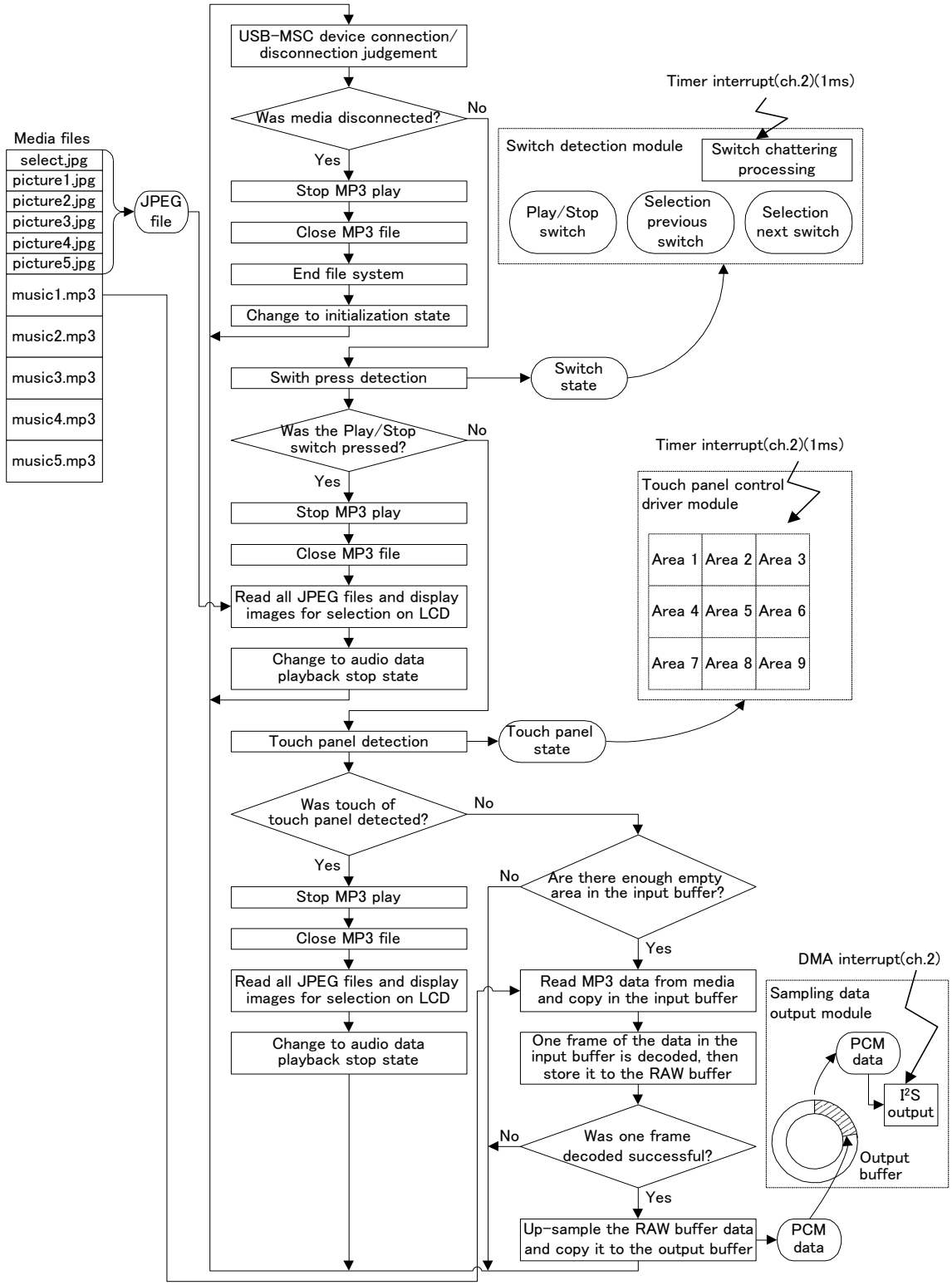
Figure 6. Application Operation Flow (Audio Playback Stopped Status, Case of MP3)



2. The application operation flow with audio data playback in progress is as follows.
    1. USB MSC device connection/disconnection judgment is executed in the main loop.
    2. If the USB memory has been removed, stop playback, close the opened MP3 file, quit the file system and operation shifts to initialization status.
    3. If the USB memory is connected, play/stop switch press down detection and touch panel touch detection are executed.
    4. If the play/stop switch is detected to have been pressed down, or if not detected, but an area of the touch panel is detected to have been touched, playback is stopped, the MPA file is closed, all JPEF filed are read from the USB memory, that images for selection are displayed and operation shifts to audio data playback stopped status.
    5. It is confirmed whether there is enough empty area in an input buffer.
    6. If there is enough empty area, the MP3 file is read from the USB memory and copied in the input buffer.
    7. One frame of the input buffer is decoded and stored in the RAW buffer.
    8. When 1 frame had been decoded, the RAW buffer is up-sampled and buried in the output buffer.
    9. With DMA ch2 interrupt, data is sent from the output buffer to I^2S in sequence.

This operation is shown in Figure 7

Figure 7. Application Operation Flow (Audio Playback Status, Case of MP3)

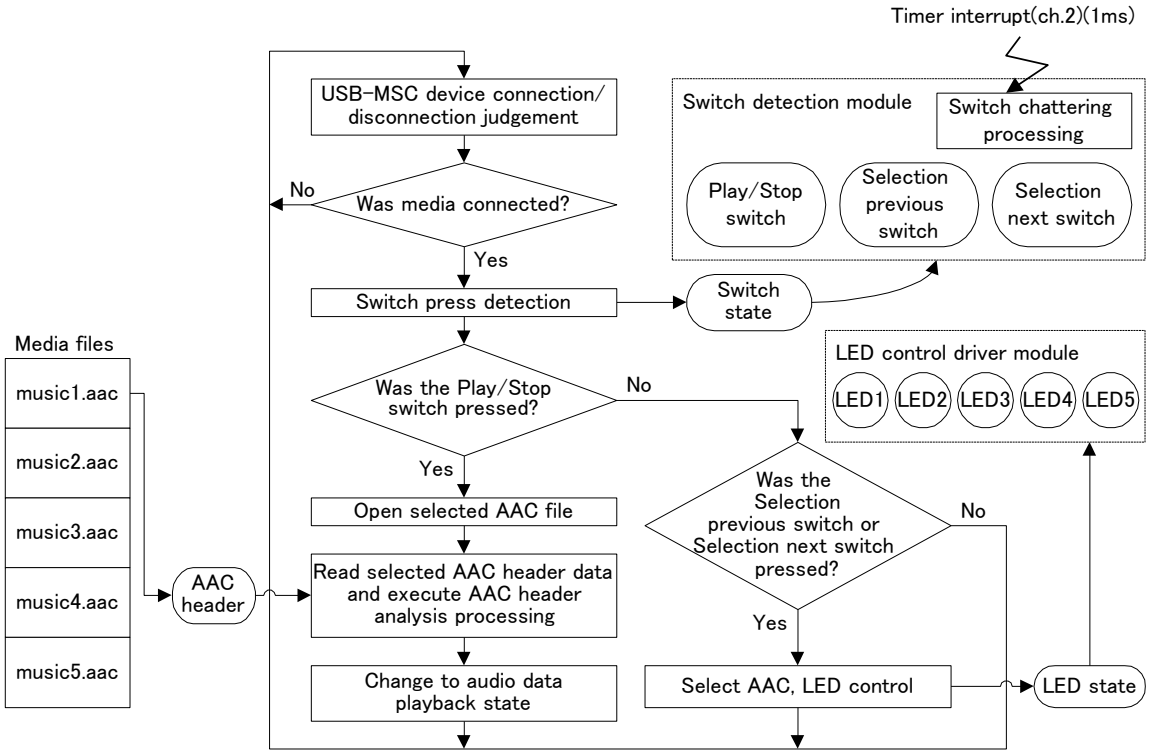


AAC

1. The application operation flow with audio data playback stopped is as follows.
    1. USB MSC device connection/disconnection judgment is executed in the main loop.
    2. If the USB memory is connected, switch press-down detection is executed.
    3. If the play/stop switch is detected to have been pressed down, the AAC file selected from the USB memory is opened. If the selection previous switch or selection next switch are detected to have been pressed down, AAC selection is shifted and LED control is executed.
    4. The AAC file header is read, AAC file header analysis processing is conducted and operation shifts to audio data playback status.

This operation is shown in Figure 8.

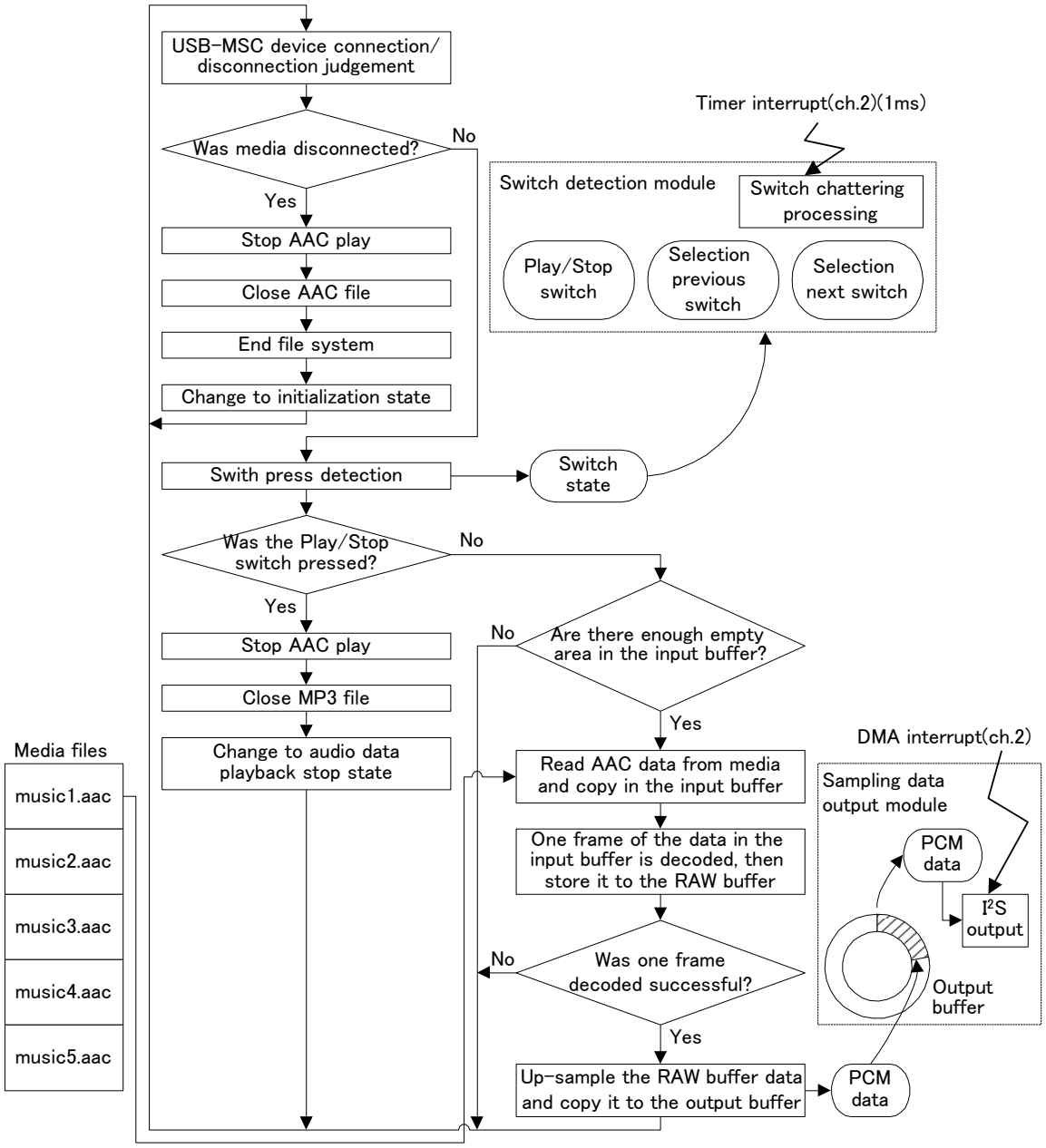
Figure 8. Application Operation Flow (Audio Playback Stopped Status, Case of AAC)



2. The application operation flow with audio data playback in progress is as follows.
    1. USB MSC device connection/disconnection judgment is executed in the main loop.
    2. If the USB memory has been removed, stop playback, close the opened AAC file, quit the file system and operation shifts to initialization status.
    3. If the USB memory is connected, play/stop button press-down detection is executed.
    4. If the play/stop button is detected to have been pressed down, playback stops, the AAC file is closed, and operation shifts to audio data playback stop status.
    5. It is confirmed whether there is enough empty area in an input buffer.
    6. If there is enough empty area, the AAC file is read from the USB memory and copied in the input buffer.
    7. One elementary stream of the input buffer is decoded and stored in the RAW buffer.
    8. When 1 elementary stream had been decoded, the RAW buffer is up-sampled and buried in the output buffer.
    9. With DMA ch2 interrupt, data is sent from the output buffer to I^2S in sequence.

This operation is shown in Figure 9.

Figure 9. Application Operation Flow (Audio Playback Status, Case of AAC)



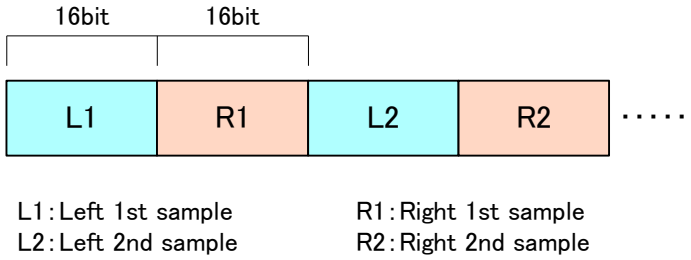
2.3.3 I²S Operation

With the simple AV solution, in order to transmit data by 44.1kHz or 48kHz sampling to DAC, MFS channels 4 and 5 are used as CSIO in the slave mode and the clock inputs 8 divisions of 11.2896MHz or 12.288MHz.

As for data, PCM data for which results of decoded MP3 or AAC file are output by up-sampling to 44.1kHz or 48kHz. (For up-sampling, see "3.2 Performance Measurement Items")

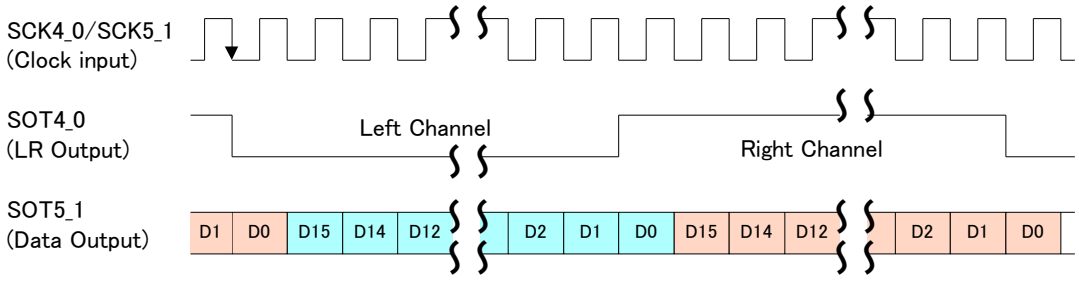
PCM data output to I²S is shown in Figure 10.

Figure 10. PCM Data Output to I2S



PCM data is synchronized and output to DAC from MFS channel 5, and left/right data is synchronized and output to DAC from channel 4. PCM data is transmitted to MFS using DMAC channel 2 and left/right data using DMAC channel 3.And left/right data is set 1bit earlier than PCM data.I/O format of I²S is shown in Figure 11

Figure 11. I2S I/O Format



Because PCM data of 1 sample output to DAC is 16-bit Stereos (2ch), it is

(11.2896[MHz]/8) / 16[bit] / 2[ch] = 44100[Hz]

(12.288 [MHz] /8) / 16 [bit] / 2 [ch] = 48000 [Hz],

and is therefore played at the sampling rate of 44.1kHz or 48kHz.

For details concerning the MFS and DMAC usage method, see the "FM3 32 bit Microcontroller MB9Axxx/MB9Bxxx Series Peripheral Manual".

I²S Driver API

This section provides a brief description of the I²S driver's API.

Function	void I2S_Init (void)
Overview	Initializes I²S driver. Set MFS initial settings (CSIO settings) and DMAC initial settings.
Parameter	None
Return value	None

Function	STATUS I2S_Start (uint8_t audio_sample_rate)
Overview	Starts I²S operation. Set data for DMAC and activates CSIO. Be sure to initialize by I2S_Init function before function is invoked.
Parameter	audio sample_rate Sampling rate AUDIO_SAMPLE_44100 44.1kHz AUDIO_SAMPLE_48000 48kHz
Return value	I2S_RET_OK Successful I2S_RET_ILLEGAL_ERROR Not yet initialized, operating or stopped

Function	STATUS I2S_Stop (void)
Overview	Completes I²S operation. Stop CSIO.
Parameter	None
Return value	I2S_RET_OK Successful I2S_RET_ILLEGAL_ERROR Not yet initialized or stopped

Function	uint8_t I2S_Get_Status(void)
Overview	Gets I²S operating status.
Parameter	None
Return value	I2S_STATUS_INIT Initialization status (I²S can be started) I2S_STATUS_START Start (I²S operating) status I2S_STATUS_STOP Stop (I²S cannot be started) status

Usage Example I²S Driver API

The source codes for places using the I²S driver API are shown in Figure 12, Figure 13 and Figure 14. The figure gives the AUDIO_PlayTask for audio.c, AUDIO_DecodeStop function used in the AUDIO_PlayTask function and AUDIO_Init function used in AUDIO_DecodeStop. See the sample program for audio.c.

Figure 12. AUDIO_PlayTask Function Source Code (Excerpt)

```
void AUDIO_PlayTask(void)
{
        (An omission)
    i2s_status = I2S_Get_Status();          <-- Gets I²S operating status

    /* check I2S status,if I2S stoped,change audio task to stop */
    if (i2s_status == I2S_STATUS_STOP)
    {
        if (( s_AudioPlayStage != AUDIO_STAGE_STOP) &&
            (s_AudioPlayStage != AUDIO_STAGE_INIT))
        {
            AUDIO_SetAudioStage(AUDIO_STAGE_STOP);
        }
    }

    /* stop loop until decode one frame or stop(some error happened) */
    while (decode_loop == TRUE)
    {
        switch (s_AudioPlayStage)
        {
            (An omission)
            case AUDIO_STAGE_UPSAMPLE:
            (An omission)
                    /* the audio playing not been started */
                    if (s_AudioStartFlg == FALSE)
                    {
                        /* start I2S */
                        if ((s_AudioSampleRate == SAMPLING_RATE_8000HZ)  ||
                            (s_AudioSampleRate == SAMPLING_RATE_12000HZ) ||
                            (s_AudioSampleRate == SAMPLING_RATE_16000HZ) ||
                            (s_AudioSampleRate == SAMPLING_RATE_24000HZ) ||
                            (s_AudioSampleRate == SAMPLING_RATE_32000HZ) ||
                            (s_AudioSampleRate == SAMPLING_RATE_48000HZ)) {
                            I2S_Start(AUDIO_SAMPLE_48000);   <-- Starts I²S operation(48kHz)
                        } else {
                            I2S_Start(AUDIO_SAMPLE_44100);   <-- Starts I²S operation(44.1kHz)
                        }
                        s_AudioStartFlg = TRUE;
                    }
            (An omission)
                break;

            case AUDIO_STAGE_STOP:
                /* stop playing audio */
                AUDIO_DecodeStop();          <-- Please refer to AUDIO_DecodeStop function
            (An omission)
        }
    }

    return;
}
```

Figure 13. AUDIO_DecodeStop Function Source Code

```
void AUDIO_DecodeStop(void)
{
    /* stop I2S operation */
    (void)I2S_Stop();          // Stops I2S operation

    /* free the memory for library context */
    if (s_LibContext != NULL)
    {
        free(s_LibContext);
        s_LibContext = NULL;
    }

    /* close file */
    FS_close(s_AudioPlayFileNo);

    /* AUDIO module initialize */
    AUDIO_Init();              // Please refer to AUDIO_Init function

    return;
}
```

Figure 14. AUDIO_Init Function Source Code (Excerpt)

```
void AUDIO_Init(void)
{
  (An omission)
   /* initialize I2S */
   I2S_Init();                 // Initializes I2S driver

   /* up-sampling initialize */
   UPSAMPLE_Init();

   return;
}
```

3 Performance

3.1 Performance Measurement Environment

The performance measurement environment is given in Table 1.

Table 1. Performance Measurement Environment

No.	Part Number	Description	Manufacturer	marks (Ver. No., e
1	ICE	ULINK2	KEIL	
2	Integrated development environment	µVision V4.20.03.0	KEIL	
3	Microcontroller board	MCB9B500 Vers.2	KEIL	
4	LCD board	—	Fujitsu Semiconductor	
5	Middleware	Multi Device File Access Library V03L01(object for small MCU)	Fujitsu Semiconductor	V03L01 (*1)
6	Middleware	MP3 Decoder Library for FM3 V01 Evaluation	Fujitsu Semiconductor	V01L01 (*1)
7	Middleware	MPEG-4/2 AAC LC Decoder Library (2ch) for FM3 V01 Evaluation	Fujitsu Semiconductor	V01L01 (*1)
8	Middleware	JPEG Baseline Process Encoder/Decoder Library for FM3 V01 Evaluation	Fujitsu Semiconductor	V01L01 (*1)
9	Sample program	—	Fujitsu Semiconductor	
10	USB memory	— (equipment that supports USB Full Speed)	—	

1. Middleware is for evaluation.
   A separate contract is required for usage.

3.2 Performance Measurement Items

Performance measurement items are given in Table 2.

Table 2.Performance Measurement Items

No.	Performance Measurement Items	Condition 1	Condition 2	Remarks
1	Amount of ROM/RAM used	MP3 decoder assembly (*2)	JPEG decoder assembly, screen display assembly	Compile conditions: No optimization
2		AAC decoder assembly (*2)	No JPEG decoder assembly, no screen display assembly	Compile conditions: No optimization
3	Processing time (*1)	MP3 decoder assembly (*2)	MP3 Decode	1 frame decode time
4			Up-sampling (*3)	Set to 1 unit (*4) I^2S output buffer
5			JPEG decode	1 scan decode time
6			LCD display	1 JPEG data display time
7			USB data read	JPEG/MP3 file
8		AAC decoder assembly (*2)	AAC Decode	1ES (*5) decode time
9			Up-sampling (*3)	Set to 1 unit (*4) I^2S output buffer
10			USB data read	AAC file
11		Common	MSC (*6) connection detection	Time from USB connection to MSC (*6) connection detection
12	CPU occupancy	MP3 play in progress	Sampling rate: 24kHz Bit rate: 64kbps	Channel mode: Joint Stereo
13			Sampling rate: 32kHz Bit rate: 96kbps	Channel mode: Joint Stereo
14			Sampling rate: 48kHz Bit rate: 128kbps	Channel mode: Joint Stereo
15		AAC play in progress	Sampling rate: 24kHz Bit rate: 64kbps	Channel mode: Stereo
16			Sampling rate: 32kHz Bit rate: 96kbps	Channel mode: Stereo
17			Sampling rate: 48kHz Bit rate: 128kbps	Channel mode: Stereo

1. Main operating frequency conditions: 80MHz, APB1/APB2/APB3:40MHz
2. MP3 decoder and AAC decoder cannot be assembled simultaneously.
3. Because sampling frequency for audio data input to DAC is fixed at 44.1kHz or 48kHz, the following up-sampling processing is used.

   8/12/16/24/32KHz => 48kHz

   11.025/22.05kHz => 44.1kHz
4. 1 unit is as follows according to sampling rate.

   8,16,32(kHz)：3072byte

   11.25,12,22.05,24,44.1,48(kHz)：2048byte
5. ES: Elementary Stream
6. MSC: Mass Storage Class

3.3 Performance Measurement Results

3.3.1 Amount of ROM/RAM Used

The amount of ROM and RAM used when the decoding file is MP3 and when it is AAC are given in Table 3 and Table 4 respectively.

Table 3. Amount of ROM/RAM Used for MP3 Decoder Assembly

Unit: Bytes

	ROM	RAM		
		Variable	Stack	Heap
MP3 Decoder	34403	0	364	19148
JPEG Encoder/Decoder	7914	252	124	0
MDF (*1)	21362	6588	2344	204
USB host driver	11804	268	376	2048
USB host MSC driver	4070	92	920	0
Application	2191	29	6360	0
Audio playback	19660	16979	6360	0
Screen display	6904	8301	2368	2048
Others	7380	259	64	0
Total	**115688**	**32768**	**(Secured area) 8192**	**(Secured area) 24576**
		65536		

Amount of ROM used : 113.0 Kbytes (*2)

Amount of RAM used : 64.0 Kbytes (*2)

Stack : Area size secured on system given in total

Max. usage size given for each item

Heap : Area size secured on system given in total

1. Multi Device File Access Library
2. 1Kbyte = 1024byte

Table 4. Amount of ROM/RAM Used for AAC Decoder Assembly

Unit: Bytes

	ROM	RAM		
		Variable	Stack	Heap
AAC Decoder	90364	168	1104	29388
JPEG Encoder/Decoder (*1)	—	—	—	—
MDF (*2)	21362	6588	1536	204
USB host driver	11804	268	376	2048
USB host MSC driver	4070	92	920	0
Application	1603	21	6360	0
Audio playback	19652	17511	6360	0
Screen display (*1)	—	—	—	—
Others	7413	256	64	0
Total	**156268**	**24904**	**(Secured area) 8192**	**(Secured area) 32256**
		65360		

Amount of ROM used : 152.6 Kbytes (*3)

Amount of RAM used : 63.8 Kbytes (*3)

Stack : Area size secured on system given in total

Max. usage size given for each item

Heap : Area size secured on system given in total

1. Image display impossible because screen display requires 8K of RAM.
2. Multi Device File Access Library
3. 1Kbyte = 1024byte

3.3.2 Processing Time

Processing time measurement results are given in Table 5

Table 5. Processing time

No.	Condition 1	Condition 2	Condition 3	Processing time
1	MP3 decoder assembly	MP3 Decode	Sampling rate: 24kHz Bit rate: 64kbps Channel mode: Joint Stereo	8.7ms
2			Sampling rate: 32kHz Bit rate: 96kbps Channel mode: Joint Stereo	18.2ms
3			Sampling rate: 48kHz Bit rate: 128kbps Channel mode: Joint Stereo	16.5ms
4		Up-sampling	Sampling rate: 24kHz Bit rate: 64kbps Channel mode: Joint Stereo	3.10ms
5			Sampling rate: 32kHz Bit rate: 96kbps Channel mode: Joint Stereo	1.75ms
6			Sampling rate: 48kHz Bit rate: 128kbps Channel mode: Joint Stereo	1.90ms
7		JPEG decode	Capacity 26813 bytes, YUV 4:2:0	348ms
8			Capacity 93265 bytes, YUV 4:4:4	860ms
9		LCD display	Capacity 26813 bytes, YUV 4:2:0	396ms
10			Capacity 93265 bytes, YUV 4:4:4	920ms
11		USB data read	JPEG file (*1)	4.04ms
12			MP3 file (*2)	2.02ms
13	AAC decoder assembly	AAC Decode	Sampling rate: 24kHz Bit rate: 64kbps Channel mode: Stereo	17.2ms
14			Sampling rate: 32kHz Bit rate: 96kbps Channel mode: Stereo	16.4ms
15			Sampling rate: 48kHz Bit rate: 128kbps Channel mode: Stereo	14.5ms
16		Up-sampling	Sampling rate: 24kHz Bit rate: 64kbps Channel mode: Stereo	1.35ms
17			Sampling rate: 32kHz Bit rate: 96kbps Channel mode: Stereo	2.3ms

No.	Condition 1	Condition 2	Condition 3	Processing time
18			Sampling rate: 48kHz Bit rate: 128kbps Channel mode: Stereo	1.72ms
19		USB data read	AAC file (*2)	2.02ms
20	Common	MSC connection detection	–	526ms

1. 2048 bytes read
2. 1024 bytes read

Measurement location for processing time are as follows.

1. MP3 decode, AAC decode

   From before to after place where audio_decode_decoding called
2. Up-sampling

   From before to after place where audio_decode_upsample called
3. JPEG decode

   From before to after place where JPEGDecodeScan function and JPEGGetScanHeader in image_scan_decode function called
4. LCD display

   From before to after place where IMAGE_Show function called
5. USB data read

   JPEG file: From before to after place where image_code_input function called MP3/AAC file: From before to after place where audio_decode_read function called
6. MSC connection detection

   From place immediately preceding USB connection detection status is set in av_demoapp_usb_event_callback function to place following completion of internal processing in av_demoapp_msc_connect_callback function.

   See sample program for location of audio_decode_decoding function, audio_decode_upsample function, JPEGGetScanHeader function, JPEGDecodeScan function, IMAGE_Show function, image_code_input function, audio_decode_read function invocation, av_demoapp_usb_event_callback function, and av_demoapp_msc_connect_callback function.

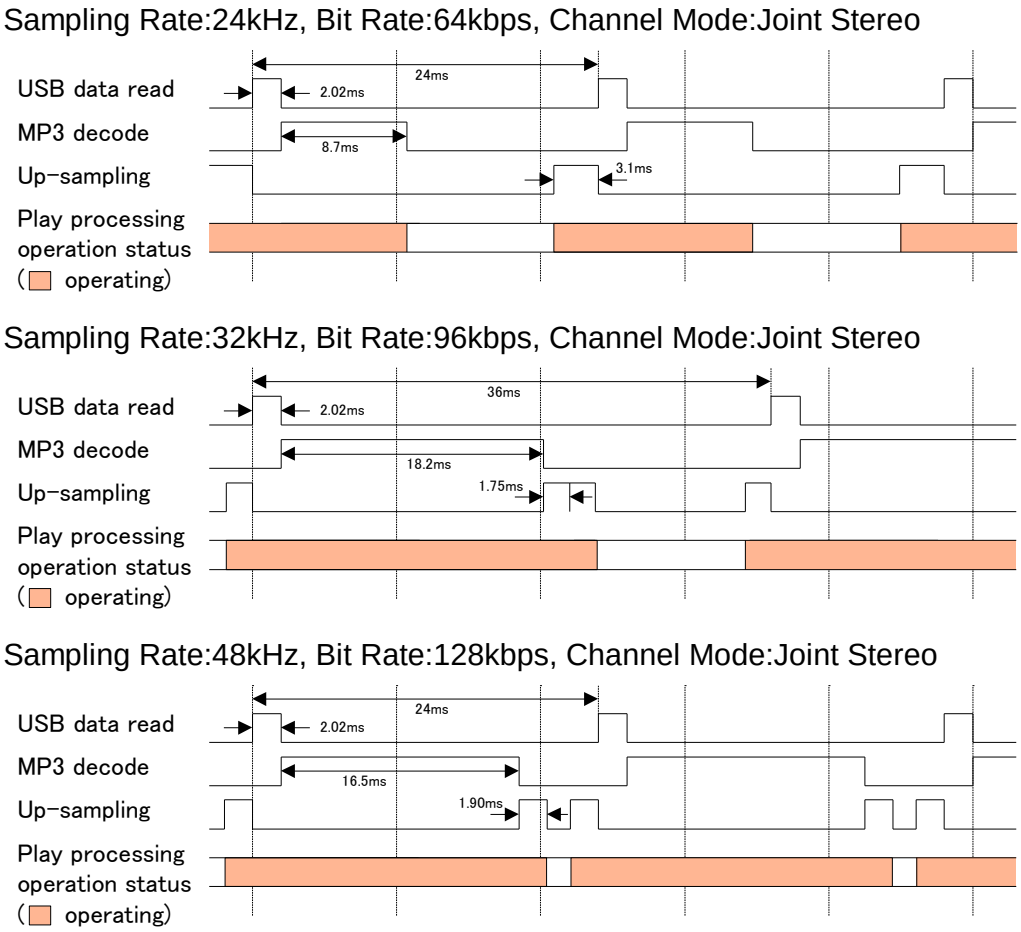
3.3.3 CPU Occupancy

MP3 Play in Progress

CPU processing status when MP3 is played is shown in Figure 15

(Vertical line is 10 ms unit.)

Figure 15. Processing Status While MP3 Plays



CPU occupancy is as given in Table 6 while MP3 plays

Table 6. CPU Occupancy While MP3 Plays.

Conditions			CPU occupancy (%)
Sampling Rate	**Bit Rate**	**Channel Mode**	
24kHz	64kbps	Joint Stereo	57.6
32kHz	96kbps	Joint Stereo	70.8
48kHz	128kbps	Joint Stereo	93.0

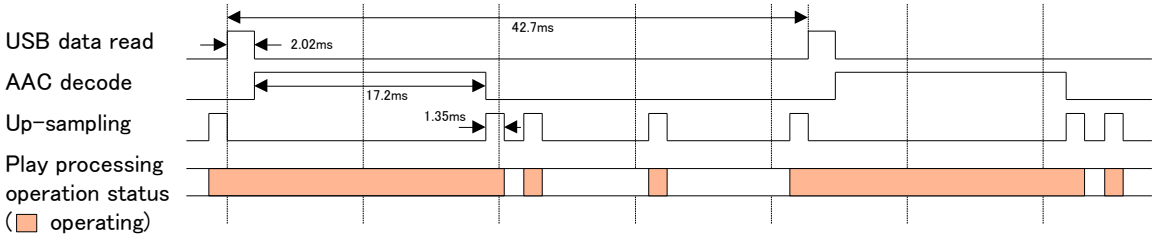
AAC Play in Progress

CPU processing status when AAC is played is shown in Figure 16.

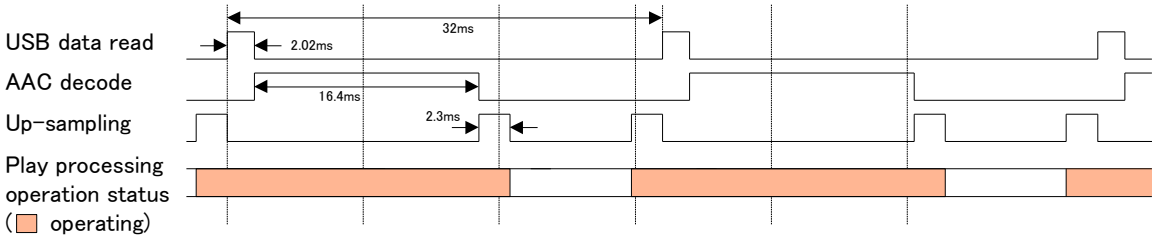
(Vertical line is 10 ms unit.)

Figure 16. Processing Status While AAC Plays

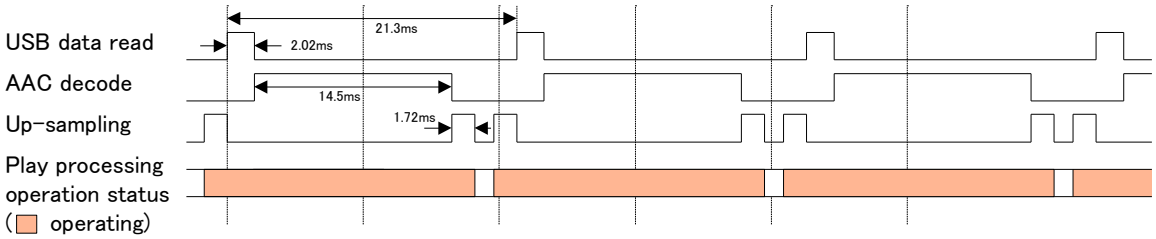
Sampling Rate:24kHz, Bit Rate:64kbps, Channel Mode:Stereo



Sampling Rate:32kHz, Bit Rate:96kbps, Channel Mode:Stereo



Sampling Rate:48kHz, Bit Rate:128kbps, Channel Mode:Stereo



CPU occupancy is as given in Table 7 while AAC plays.

Table 7. CPU Occupancy While AAC Plays

Conditions			CPU Occupancy (%)
Sampling Rate	Bit Rate	Channel Mode	
24kHz	64kbps	Stereo	58.4
32kHz	96kbps	Stereo	71.9
48kHz	128kbps	Stereo	93.6

Document History

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Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	-	YUIS	08/23/3011	Rev01.Initial Release
			02/06/2012	Rev02. Correction format Correction lineup of FM3 Correction by RoHS c compliant for board, parts change, and software change
*A	5032777	YUIS	12/02/2015	Migrated Spansion Application Note from AN706-00041-2v0-E to Cypress format
*B	5872329	AESATP12	09/06/2017	Updated logo and copyright.

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