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Cautions

Application Notes

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H8S/2215 USB Function Module Mass Storage Class (Bulk-Only Transport)

Application Notes

Renesas 16-Bit Single-Chip Microcomputer

HD64F2215

Renesas Electronics
www.renesas.com

Rev.1.0 2002.04

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Preface

These application notes describe the Mass Storage Class (Bulk-Only Transport) firmware that uses the USB Function Module in the H8S/2215. They are provided to be used as a reference when the user creates USB Function Module firmware.

These application notes describe a system configuration example based on the USB Function Module, and do not guarantee the contents of the configuration.

In addition to these application notes, the manuals listed below are also available for reference when developing applications.

[Related manuals]

- Universal Serial Bus Specification Revision 1.1
- Universal Serial Bus Mass Storage Class Specification Overview Revision 1.1
- Universal Serial Bus Mass Storage Class(Bulk-Only Transport) Revision 1.0
- H8S/2215 USB Function Module Mass Storage Class (Bulk-Only Transport) Application Notes
- H8S/2215 Hardware Manual
- H8S/2215 Solution Engine CPU Board (MS2215CP01-C/S) Instruction Manual
- H8S/2215 Series TFP120 User System Interface Cable (HS2215ECN61H) User's Manual
- E6000 (HS2214EPI61H) Emulator User’s Manual

[Caution] The sample programs described in these application notes do not include firmware related to interrupt transfer and isochronous transfer, which are USB transport types. When using these transfer types (see page 15-1 of the H8S/2215 Hardware Manual), the user needs to create the programs for them.

Also, the hardware specifications of the H8S/2215 and H8S/2215 Solution Engine, which will be necessary when developing the system described above, are described in these application notes, but more detailed information is available in the H8S/2215 Hardware Manual and the H8S/2215 Solution Engine Instruction Manual.

Contents

Section 1 Overview

These application notes describe how to use the USB Function Module that is built into the H8/2215, and contain examples of firmware programs.

The features of the USB Function Module contained in the H8/2215 are listed below.

- An internal UDC (USB Device Controller) conforming to USB 1.1
- Automatic processing of USB controls
- Automatic processing of USB standard commands for end point 0 (some commands need to be processed through the firmware)
- Full-speed (12 Mbps) transfer supported
- Various interrupt signals needed for USB transmission and reception are generated.
- Internal system clock (16 MHz) multiplied by three or external input clock (48 MHz) can be selected as the USB operating clock by the USB clock selector in the clock pulse generator.
- An internal bus transceiver
- Endpoint configuration selectable

End Point Configurations

End Point Name	Name	Transfer Type	Max. Packet Size	FIFO Buffer Capacity	DMA Transfer
End point 0	EP0s	Setup	8 bytes	8 bytes	-
	EP0i	Control In	64 bytes	64 bytes	-
	EP0o	Control Out	64 bytes	64 bytes	-
End point (optional)	EPn	Interrupt (in)	64 bytes	64 bytes (variable)	-
End point (optional)	EPn	Bulk-in	64 bytes	64 x 2 (128 bytes)	Possible
End point (optional)	EPn	Bulk-out	64 bytes	64 x 2 (128 bytes)	Possible
End point (optional)	EPn	Isochronous (in)	128 bytes	128 x 2 (variable)	-
End point (optional)	EPn	Isochronous (out)	128 bytes	128 x 2 (variable)	-
End point (optional)	EPn	Bulk-in	64 bytes	64 x 2 (128 bytes)	Possible
End point (optional)	EPn	Bulk-out	64 bytes	64 x 2 (128 bytes)	Possible
End point (optional)	EPn	Interrupt (in)	64 bytes	64 bytes (variable)	-

Figure 1.1 shows an example of a system configuration.

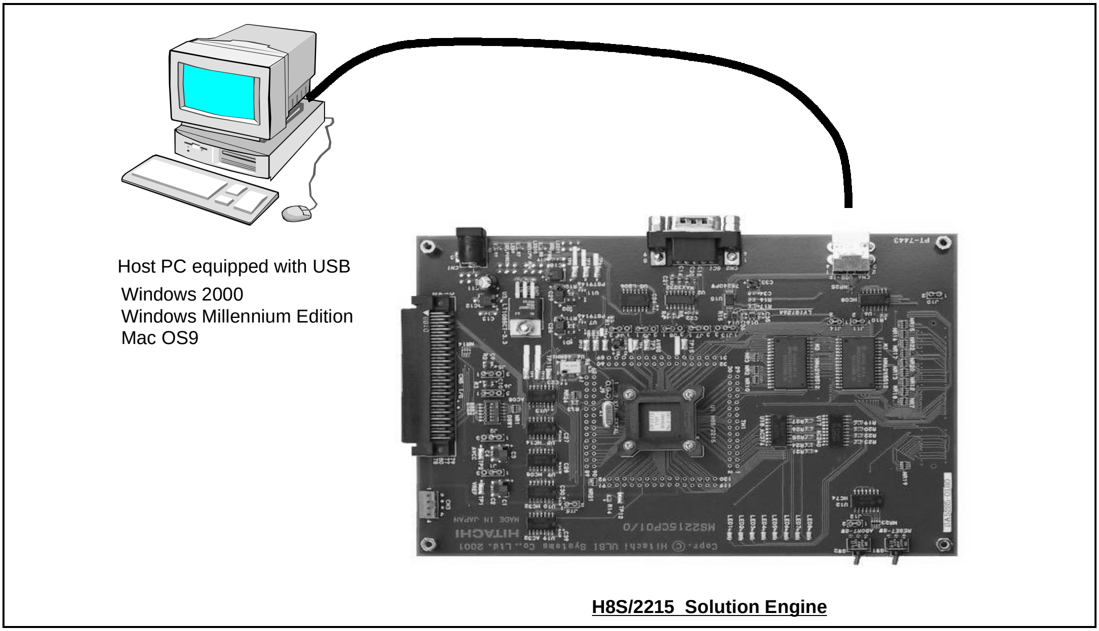


Figure 1.1 System Configuration Example

This system is configured of the H8/2215 Solution Engine made by Hitachi ULSI Systems Co., Ltd. (hereafter referred to as the MS2215CP) and a PC containing Windows 2000/Windows Millennium Edition or Mac OS9 operating system.

By connecting the host PC and the MS2215CP through USB, the SRAM in the MS2215CP can be accessed as a RAM disk, enabling data in the SRAM of the MS2215CP to be stored in and loaded from the host PC.

It is also possible to use the USB Mass Storage Class (Bulk-Only Transport) device driver that comes as an accessory with the operating systems listed above.

This system offers the following features.

1. The sample program can be used to evaluate the USB module of the H8/2215 quickly.
2. The sample program supports USB control transfer and bulk transport.
3. An E6000 can be used, enabling efficient debugging.
4. Additional programs can be created to support interrupt transfer and isochronous transfer. *

Note: * Interrupt transfer and isochronous transfer programs are not provided, and will need to be created by the user.

Section 2 Overview of the USB Mass Storage Class (Bulk-Only Transport)

This section describes the USB Mass Storage Class (Bulk-Only Transport).

We hope that it will provide a convenient reference for use when developing USB storage-related systems. For more detailed information on standards, please see the following:

- Universal Serial Bus Mass Storage Class Specification Overview Revision 1.1
- Universal Serial Bus Mass Storage Class Bulk-Only Transport Revision 1.0

2.1 USB Mass Storage Class

USB Mass Storage Class is a class of standards that apply to large-scale memory (storage) devices that are connected to a host PC and handle reading and writing of data.

<u>In order to let the PC know that a function is in this class, a value of 0x08 must be entered in the bInterfaceClass field of the Interface Descriptor.</u>

When transferring data between the host PC and the function, four transport methods defined by the USB are used (control transfer, bulk transport, interrupt transfer, and isochronous transfer). Protocol codes determine the transport method and how it is used.

There are two types of data transport protocols:

- USB Mass Storage Class Bulk-Only Transport
- USB Mass Storage Class Control/Bulk/Interrupt (CBI) Transport

As its name indicates, USB Mass Storage Class Bulk-Only Transport is a data transport protocol that only uses bulk transport.

USB Mass Storage Class Control/Bulk/Interrupt (CBI) Transport is a data transport protocol that uses control transfer, bulk transport, and interrupt transfer. CBI Transport is further subdivided into a data transport protocol that uses interrupt transfer, and one that does not use interrupt transfer.

<u>The sample programs provided here use USB Mass Storage Class Bulk-Only Transport as the data transport protocol.</u>

When the host PC uses a device in order to load and save data, instructions (commands) are provided by the host PC to the function. The function then executes those commands to load and save data. The commands sent by the host PC to the function are defined in the form of sub-class code.

2.2 Sub-Class Code

Sub-class codes are values that indicate the command format sent from the host PC to a function by means of command transport. There are seven types of command formats, described in table 2.1.

Table 2.1

Sub-Class Code	Command Standards
0x01	Reduced Block Commands (RBC), T10/1240-D
0x02	Attachment Packet Interface (ATAPI) for CD-ROMs. SFF-8020i, Multi-Media Command Set 2 (MMC-2)
0x03	Attachment Packet Interface (ATAPI) for Tape. QIC-157
0x04	USB Mass Storage Class UFI Command Specification
0x05	Attachment Packet Interface (ATAPI) for Floppies. SFF-8070i
0x06	SCSI Primary Commands –2 (SPC-2), Revision 3 or later

In order to tell the host PC the command format supported by the device, a sub-class code value must be entered in the bINterfaceSubClass field of the Interface Descriptor.

The sample programs used here use a sub-class code value of 0x06, which indicates the SCSI Primary Commands.

2.3 Bulk-Only Transport

With Bulk-Only Transport, data is transferred between the host PC and a function using bulk data transport only.

Bulk transport can be divided into two types, depending on the direction in which the data is sent. If data is sent from the host controller to the function, bulk-out transport is used. If data is being sent to the host controller from the function, bulk-in transport is used.

With Bulk-Only Transport, a combination of bulk-out transport and bulk-in transport determined in advance is used to transfer data between the host and the function. Bulk-Only Transport always uses the combination of bulk transports shown in figure 2.1. These bulk transports have different meanings, but they are handled as stages (transports).

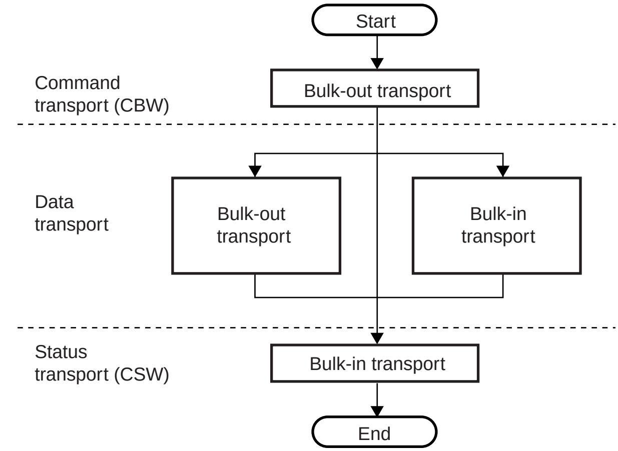


Figure 2.1 Relationship between Transfer Methods and Transports

In order to tell the host PC that the Bulk-Only Transport protocol is being used, a value of 0x50 must be entered in the bInterfaceProtocol field of the Interface Descriptor.

2.3.1 Command Transport

In command transport, commands are sent from the host PC to the function using bulk-out transport. This command packet is defined as the Command Block Wrapper (CBW), and Bulk-Only Transport must always begin with the CBW.

The CBW is sent from the host PC as a 31-byte packet, using bulk-out transport.

It is sent using the format shown in table 2.2.

Table 2.2

	7	6	5	4	3	2	1	0
00-03	dCBWSignature							
04-07	dCBWTag							
08-0B	dCBWDataTransferLength							
0C	bmCBWFlags							
0D	Reserved (0)				bCBWLUN			
0E	Reserved (0)			bCBWCBLength				
0F-1E	CBWCB							

The fields are explained below.

dCBWSignature:	This field identifies the data packet as a CBW. The value is 43425355h (Little Endian).
dCBWTag:	This is the command block tag. It is used to connect the CSW with its corresponding CBW, and is specified by the host PC.
dCBWDataTransferLength:	This is the length of the data planned for transport. If this is 0, no data transport exists.
bmCBWFlags:	If bit 7 of this field is 0, data is transported using bulk-out transport, and if it is 1, bulk-in transport is used. Bits 0 to 6 are fixed at 0.
bCBWLUN:	This is the Logical Unit Number of the device sending the command block.
bCBWCBLength:	This indicates the number of valid bytes for the next CBWCB field.
CBWCB:	This field stores the command block to be executed by the function. The command that the host PC wants to execute (the SCSI command in this sample program) is entered in this field.

2.3.2 Status Transport

Status transport is used to send the results of command execution from the function to the host PC, using bulk-in transport.

This status packet is defined by the Command Status Wrapper (CSW). Bulk-Only Transport must always end with the CSW.

The CSW is sent to the host as a 13-byte packet, using bulk-in transport.

It is sent in the format shown in table 2.3.

Table 2.3

	7	6	5	4	3	2	1	0
0-3	dCSWSignature							
4-7	dCSWTag							
8-B	dCSWDataResidue							
C	bCSWStatus							

The fields are explained below.

dCSWSignature: This field identifies the data packet as the CSW. The value is 53425355h (Little Endian).

dCSWTag: This is the command block tag. It ties the CBW to the CSW, and the same value is entered here as that of the dCBWTag field of the CBW.

dCSWDataResidue: This reports any differences in the value of the CBW dCBWDataTransferLength and the actual amount of data processed by the function.

bCSWStatus: This indicates whether or not a command has been successfully executed. If the command was executed successfully, the function sets 0x00 in this field. Any value other than 0 indicates that the command was not executed successfully. Error values are as follows: 0x01 indicates a failed command, and 0x02 indicates a phase error.

2.3.3 Data Transport

Data transport is used to transfer data between the host PC and the function. For example, with the Read/Write command (see section 4.6), the actual data of the various storage sectors is sent using data transport.

Data transport is configured of multiple bus transactions.

Data transfers carried out using data transport use either bulk-out or bulk-in transport. The bmCBWFlags field of the CBW data determines which type of transport is used.

Data transport (bulk-out transport)

This section explains how data is transferred when bulk-out data transport is used.

This status is set if bit 7 of the bmCBWFlags field of the CBW data is 0, and the dCBWDataTransferLength field of the CBW data is not 0.

Here, the function receives the anticipated length of the data indicated by the dCBWDataTransferLength field of the CBW data. The data transferred at this point is needed when the SCSI command specified by the CBWCB field of the CBW data is executed.

Data transport (bulk-in transport)

This section explains how data is transferred when bulk-in data transport is used.

This status is set if bit 7 of the bmCBWFlags field of the CBW data is 1, and the dCBWDataTransferLength field of the CBW data is not 0.

Here, the anticipated length of the data indicated by the dCBWDataTransferLength field of the CBW data is sent to the host PC. The data transferred at this point is the result produced when the SCSI command specified by the CBWCB field of the CBW data was executed.

2.3.4 Class Commands

Class commands are commands that are defined by the various USB classes. They use control transfer.

When USB Mass Storage Class Bulk-Only Transport is used as the data transport protocol, there are two types of commands that must be supported. The class commands are indicated in table 2.4.

Table 2.4 Class Commands

bRequest Field Value	Command	Meaning of Command
255 (0xFF)	Bulk-Only Mass Storage Reset	Resets the interface
254 (0xFE)	Get Max LUN	Checks the number of LUNs supported

When the Bulk-Only Mass Storage Reset command is received, the function resets all of the interfaces used in USB Mass Storage Class Bulk-Only Transport.

When the Get Max LUN command is received, the function returns the largest logical unit number that can be used. In the sample system used here, there is one logic unit, so a value of 0 will be returned to the host.

2.4 SCSI Transparent Command Set Sub-Class Code

The various commands must be processed in response to the sub-class commands in the CBW sent to the function by the host PC.

In this sample program, the nine SCSI commands shown in table 2.5 are supported. If a command is not supported, the CSW will be used to inform the host PC that the command failed.

Table 2.5 Supported Commands

Operation Code	Command Name	Command Operation
12	INQUIRY	Tells the host the drive information.
25	READ CAPACITY	Tells the host the media sector information.
28	READ(10)	Reads the specified sector volume data from a specified sector.
2A	WRITE(10)	Writes the specified sector volume data to a specified sector.
03	REQUEST SENSE	If an error occurred for the previous command, this tells the host what kind of error occurred.
1A	MODE SENSE(10)	Tells the host the drive status.
1E	PREVENT ALLOW MEDIUM REMOVAL	Inhibits/enables installing and removing media.
00	TEST UNIT READY	Checks whether or not a medium can be used.
2F	VERIFY(10)	Confirms whether or not the data in a medium can be accessed.

Section 3 Development Environment

This chapter looks at the development environment used to develop this system. The devices (tools) listed below were used when developing the system.

- H8S/2215 Solution Engine (hereafter called the MS2215CP; type number: MS2215CP01-C/S) manufactured by Hitachi ULSI Systems Co., Ltd.
- E6000 (HS2214EPI61H) Emulator manufactured by Hitachi, Ltd.
- H8S/2215 Series TFP120 User System Interface Cable (hereafter called the H8S/2215 user cable; type number: HS2215ECN61H) manufactured by Hitachi, Ltd.
- PC (Windows 95/98) equipped with an ISA, PCI, or PCMCIA slot
- PC (Windows 2000/Windows Millennium Edition or Mac OS9) to serve as the USB host
- USB cable
- Hitachi Debugging Interface (hereafter called the HDI) manufactured by Hitachi, Ltd.
- Hitachi Embedded Workshop (hereafter called the HEW) manufactured by Hitachi, Ltd.

3.1 Hardware Environment

Figure 3.1 shows device connections.

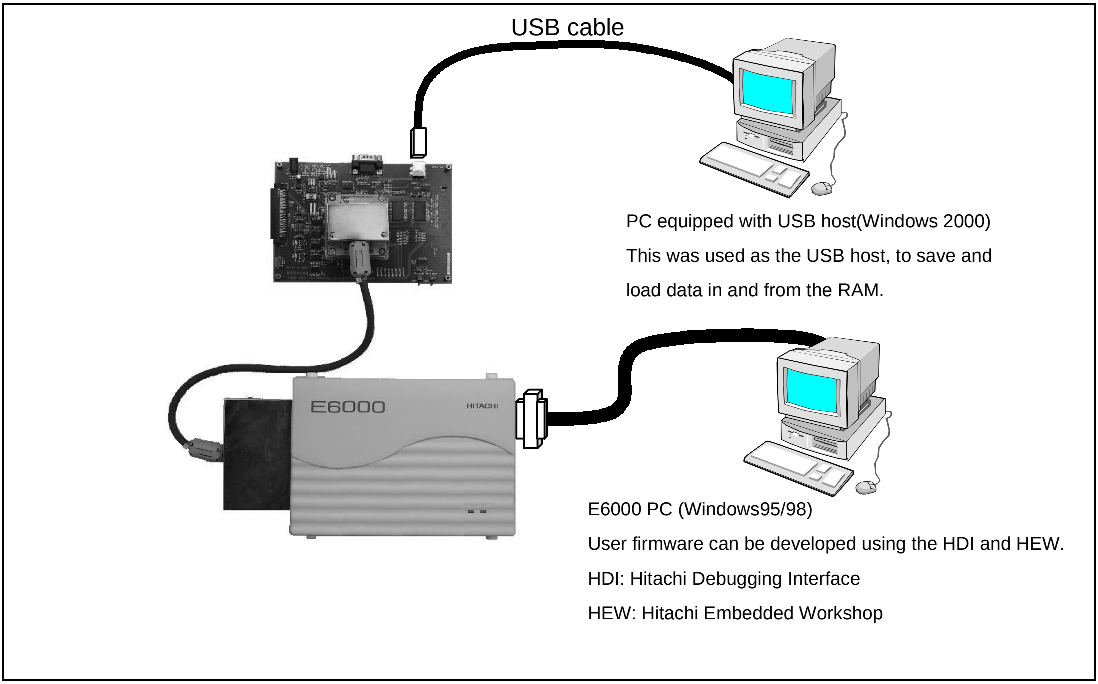


Figure 3.1 Device Connections

1. MS2215CP

   Some jumper settings on the MS2215CP board must be changed from those at shipment. Before turning on the power, ensure that the jumpers are set as follows. There is no need to change any other jumpers.

Table 3.1 Jumper Settings

At Shipment	After Change	Jumper Function
J9 1-2: Closed	J9 2-3: Closed	Switches the EXTAL48 pin level

2. USB host PC

   A PC with Windows 2000/Windows Millennium Edition or Mac OS9 installed, and with a USB port, is used as the USB host. This system uses USB Mass Storage Class (Bulk-Only Transport) device drivers installed as a standard part of the Windows 2000 system, and so there is no need to install new drivers.

3. E6000

   The ISA is used for the communication interface between the E6000 PC and the E6000 emulator.

   The E6000 I/F board should be inserted into an ISA slot and connected to the E6000 via an interface cable. Then, the E6000 should be connected to the MS2215CP via an H8S/2215 user cable. After connection, start the HDI and perform emulation.

3.2 Software Environment

A sample program, as well as the compiler and linker used, are explained.

3.2.1 Sample Program

Files required for the sample program are all stored in the H8S2215 folder. When this entire folder with its contents is moved to a PC on which HEW and HDI have been installed, the sample program can be used immediately. Files included in the folder are indicated in figure 3.2 below.

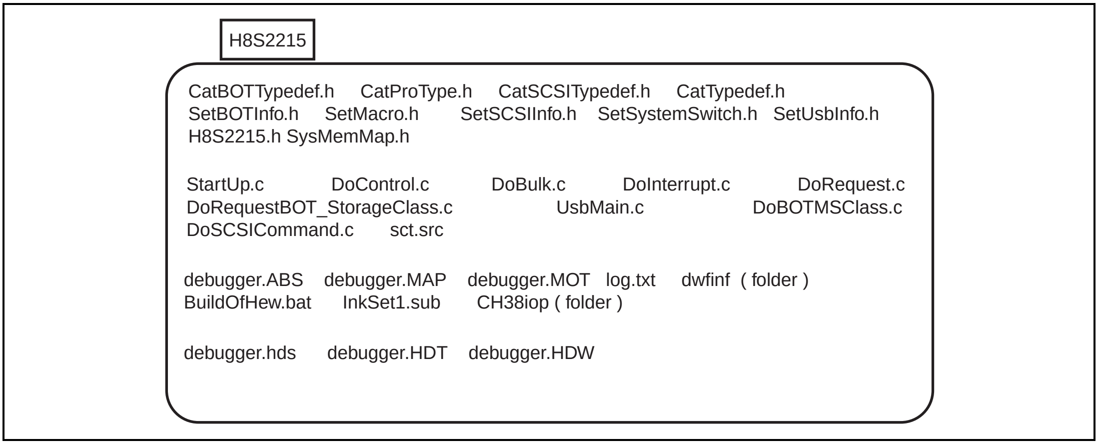


Figure 3.2 Files Included in the Folder

3.2.2 Compiling and Linking

The sample program is compiled and linked using the following software.

Hitachi Embedded Workshop Version 1.0 (release 9) (hereafter HEW)

When HEW is installed in C:\Hew, the procedure for compiling and linking the program is as follows.

First, a folder named Tmp should be created below the C:\Hew folder for use in compiling. (figure 3.3)

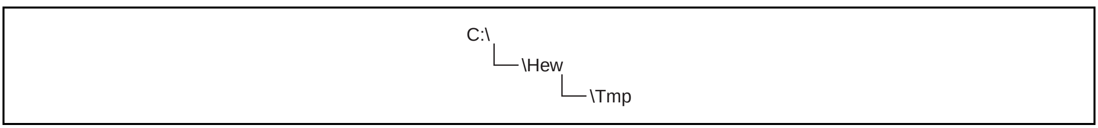


Figure 3.3 Creating a Working Folder

Next, the folder in which the sample program is stored (H8S/2215) should be copied to C:\Usr (or can be copied to any location, then "C:\Usr\h8s2215" written in the debugger.hds file should be modified to the path to the copied folder). In addition to the sample program, this folder contains a batch file named BildOfHew.bat. This batch file sets the path, specifies compile options, specifies a log file indicating the compile and linking results, and performs other operations. When BildOfHew.bat is executed, compiling and linking are performed. As a result, an executable file named debugger.ABS is created within the folder. At the same time, a map file named debugger.MAP and a log file named log.txt are created. The map file indicates the program size and variable addresses. The compile results (whether there are any errors etc.) are recorded in the log file. (figure 3.4)

Note: If HEW is installed in a folder other than C:\Hew, the compiler path setting and settings for environment variables used by the compiler in BildOfHew.bat, as well as the library settings in InkSet1.sub, must be changed. Here the compiler path setting should be changed to the path of ch38.exe, and the setting for the environment variable ch38 used by the compiler should be set to the folder of machine.h, and the setting of ch38tmp should specify the work folder for the compiler. The library setting should specify the path of c8s2ba.lib.

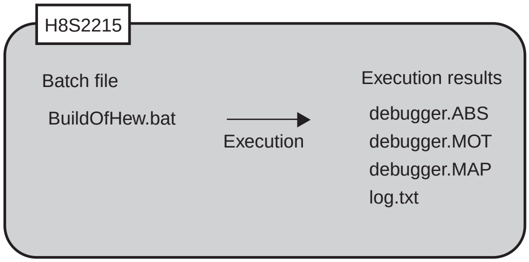
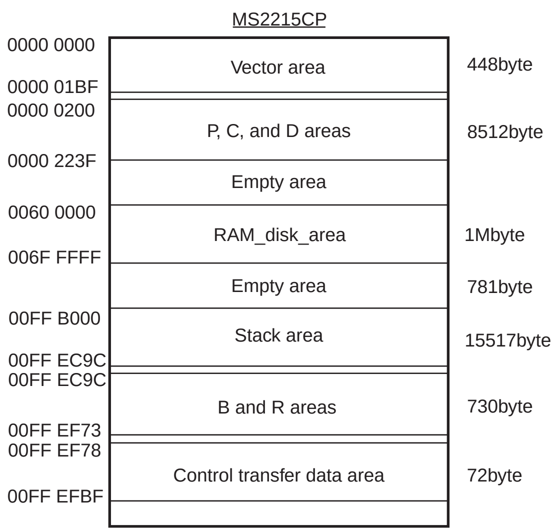


Figure 3.4 Compile Results

3.3 Loading and Executing the Program

Figure 3.5 shows the memory map for the sample program.



Note: The memory map differs according to the compiler version, compiling conditions, fimware upgrade, etc.

Figure 3.5 Memory Map

As shown in figure 3.5, this sample program allocates areas for vectors P, C, and D to the on-chip ROM area (E6000 emulation memory) in area 1, the stack, B, R, and control transfer areas to the on-chip RAM, and the RAM disk area to the SRAM. These memory allocations are specified by the InkSet1.sub file in the H8S2215 folder. When modifying the program allocation, this file must be modified.

3.3.1 Loading the Program

In order to load the sample program into the MS2215CP, the following procedure is used.

- Connect the E6000 PC in which the HDI has been installed to the E6000.
- Connect the E6000 to the MS2215CP through an H8S/2215 user cable.
- Turn on the power to the E6000 PC to start up the machine.
- Turn on the power to the MS2215CP.
- Execute debugger.hds in the H8S2215 folder.

Through the above procedure, the sample program can be loaded into the MS2215CP.

3.3.2 Executing the Program

In order to execute the program which was loaded in section 3.3.1 above, the program counter (PC) must be set appropriately.

Select Register Window from the View menu to open the Registers window. On double-clicking the numerical area of the register (PC) in the window, a dialog box appears, and the register value can be changed. Use this dialog box to set the PC to H'0000 0200.

After making the above settings, select Go from the Run menu to execute the program.

3.4 Using the RAM Disk

The following describes an example in which Windows 2000 is used.

After the program has been run, the Series B connector of the USB cable is inserted into the MS2215CP, and the Series A connector on the opposite side is connected to the USB host PC.

After the emulation used for control transfer and bulk transport has ended, USB Large-Size Storage Device is displayed under USB Controller in the Device Manager, and Hitachi EX RAM Disk USB Device is displayed under Disk Drive. As a result, the host PC recognizes the MS2215CP as the storage device, and the local disk is mounted in the microcomputer.

Next, the local disk needs to be formatted.

Select Local Disk and click with the right button of the mouse to display a floating menu. Select Format. A format selection window for the drive is displayed. Enter the necessary format settings. Check to make sure FAT has been selected for the file system, and click on the Start button.

A format confirmation window is displayed. Click on the OK button.

When the formatting has been completed, a message window is displayed. Click on the OK button.

The screen returns to the drive format selection window. Click on the Close button to exit the procedure.

The MS2215CP can now be used as the RAM disk for USB connection.

Section 4 Overview of the Sample Program

In this section, features of the sample program and its structure are explained. This sample program runs on the MS2215CP, which works as a RAM disk, and initiates USB transfers by means of interrupts from the USB function module. Of the interrupts from modules in the H8S/2215, there are three interrupts related to the USB function module: EXIRQ0, EXIRQ1, and IRQ6, but in this sample program, only EXIRQ0 is used.

Features of this program are as follows.

- Control transfer can be performed.
- Bulk-out transfer can be used to receive data from the host controller.
- Bulk-in transfer can be used to send data to the host controller.
- It operates as a RAM disk that supports SCSI commands.

4.1 State Transition Diagram

Figure 4.1 shows a state transition diagram for this sample program. In this sample program, as shown in figure 4.1, there are transitions between four states.

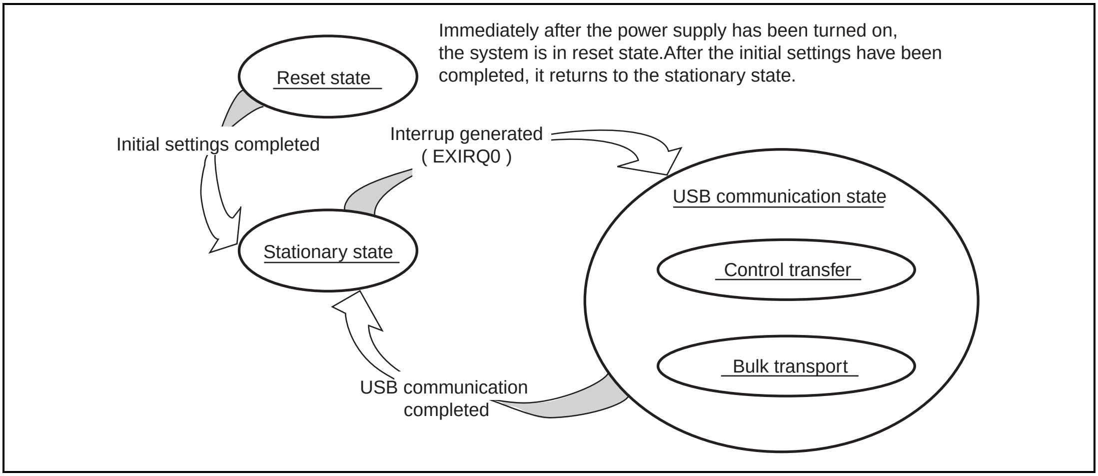


Figure 4.1 State Transition Diagram

- Reset State

  Upon power-on reset and manual reset, this state is entered. In the reset state, the H8S/2215 mainly performs initial settings.
- Stationary State

  When initial settings are completed, a stationary state is entered in the main loop.

- USB Communication State

  In the stationary state, when an interrupt from the USB module occurs, this state is entered. In the USB communication state, data transfer is performed by a transfer method according to the type of interrupt. The interrupts used in this sample program are indicated by interrupt flag registers 0 to 3 (UIFR0 to UIFR3), and there are nine interrupt types in all. When an interrupt factor occurs, the corresponding bits in UIFR0 to UIFR3 are set to 1.

4.2 USB Communication State

The USB communication state can be further divided into two states according to the transfer type (see figure 4.2). When an interrupt occurs, first there is a transition to the USB communication state, and then there is further branching to a transfer state according to the interrupt type. The branching method is explained in section 5, Sample Program Operation.

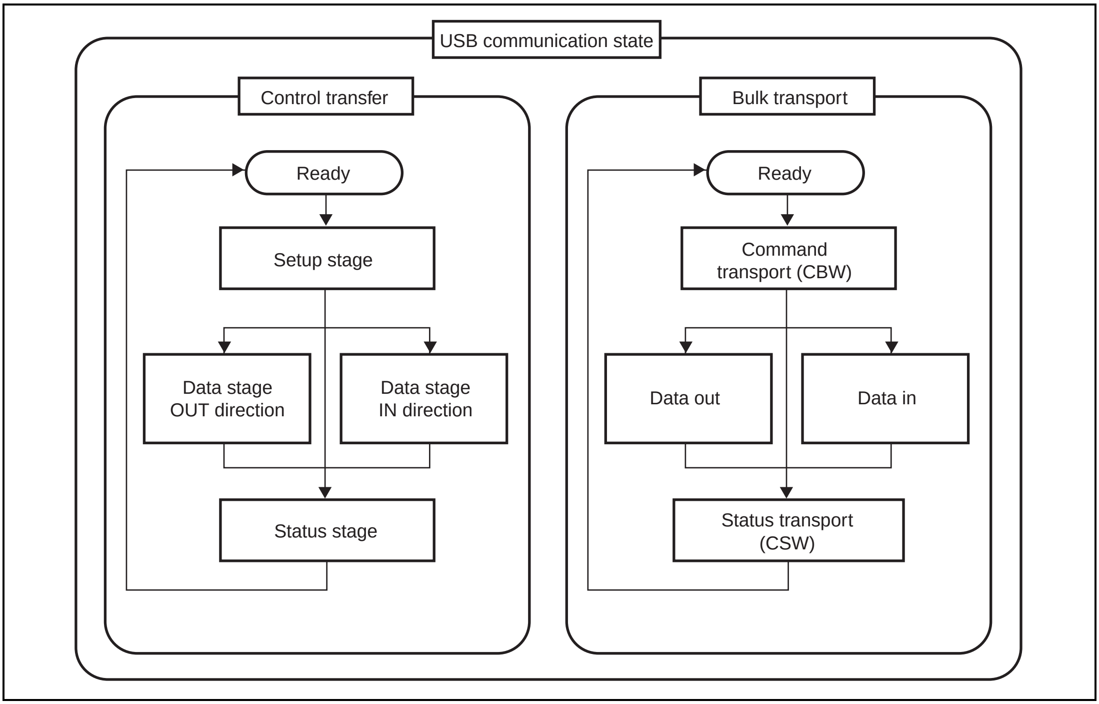


Figure 4.2 USB Communication State

4.2.1 Control Transfer

Control transfer is used mainly for functions such as obtaining device information and specifying device operating states. For this reason, when the function is connected to the host PC, control transfer is the first transport to be carried out.

Transport processing for control transfer is carried out in a series of two or three stages. These stages are a setup stage, a data stage, and a status stage.

4.2.2 Bulk Transport

Bulk transport has no time limitations, so it is used to send large volumes of data with no errors. The data transport speed is not guaranteed, but the data contents are guaranteed. With USB Mass Storage Class (Bulk-Only Transport), bulk transport is used to transfer storage data between the host PC and the function.

Transport processing for USB Mass Storage Class (Bulk-Only Transport) is carried out in a series of two or three stages. These stages are command transport (CBW), data transport, and status transport (CSW).

4.3 File Structure

This sample program consists of eight source files and eleven header files. The overall file structure is shown in table 4.1. Each function is arranged in one file by transfer method or function type. Figure 4.3 shows the layered configuration of these files.

Table 4.1 File Structure

File Name	Principle Role
StartUp.c	Microcomputer default settings
UsbMain.c	Judging the causes of interrupts Sending and receiving packets
DoRequest.c	Processing setup commands issued by the host
DoRequestBOT_StorageClass.c	Processing Mass Storage Class (Bulk-Only Transport) class commands
DoControl.c	Executing control transfer
DoBulk.c	Executing bulk transport
DoBOTMSClass.c	Executing Mass Storage Class (Bulk-Only Transport)
DoSCSICommand.c	Analyzing and processing SCSI commands
h8s2215.h	Defining H8S/2215 registers
SysMemMap.h	Defining MS2215CP memory map addresses
CatProType.h	Prototype declarations
CatTypedef.h	Defining the basic structures used in USB firmware
CatBOTTypedef.h	Defining structures used for Bulk-Only Transport
CatSCSITypedef.h	Defining structures used for SCSI
SetUsbInfo.h	Default settings of variables needed to support USB
SetBOTInfo.h	Default settings of variables needed to support Bulk-Only Transport
SetSCSIInfo.h	Default settings of variables needed to support SCSI commands
SetSystemSwitch.h	System operation settings
SetMacro.h	Defining macros

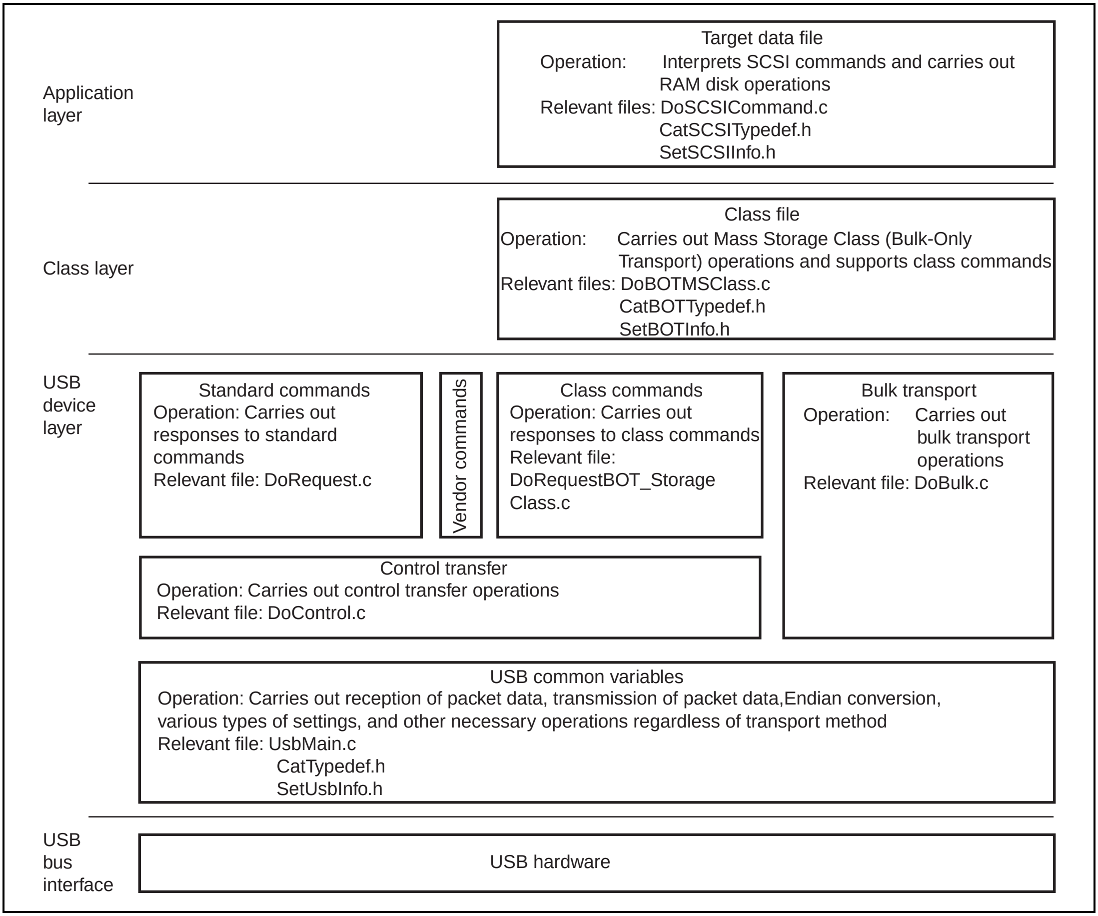


Figure 4.3 Layered Configuration of the Storage Class (BOT) Firmware

4.4 Purposes of Functions

Table 4.2 shows functions contained in each file and their purposes.

Table 4.2-1 StartUp.c

File in Which Stored	Function Name	Purpose
StartUp.c	SetPowerOnSection	Sets BSC, terminals, and interrupt controller, calls initialization routines, and shifts to the main loop
	_INITSCT	Copies variables that have default settings to the RAM work area
	InitMemory	Clears the RAM area used in bulk communication
	InitSystem	Specifies the USB clock, system interrupts, and masks

When a power-on reset or manual reset is carried out, the SetPowerOnSection of the StartUp.c file is called. At this point, the H8S/2215 default settings are entered and the RAM area used for bulk transport is cleared.

Table 4.2-2 UsbMain.c

File in Which Stored	Function Name	Purpose
UsbMain.c	BranchOfInt	Discriminates interrupt factors, and calls function according to interrupt
	GetPacket	Writes data transferred from the host controller to RAM
	GetPacket4	Writes data transferred from the host controller to RAM in longwords. Ring buffer support version (not used by this sample program).
	GetPacket4S	Writes data transferred from the host controller to ROM in longwords
	PutPacket	Writes data for transfer to the host controller to the USB module
	PutPacket4	Writes data for transfer to the host controller to the USB module in longwords. Ring buffer support version (not used by this sample program).

File in Which Stored	Function Name	Purpose
UsbMain.c	PutPacket4S	Writes data for transfer to the host controller to the USB module in longwords. High-speed version.
	SetControlOutContents	Overwrites data with that sent from the host
	SetUsbModule	Sets USB module initial settings
	ActBusReset	Clears FIFO on receiving bus reset
	ActBusVcc	Pulls up D+ and controls USB module when the USB cable is connected or disconnected
	ConvRealn	Reads data of a specified byte length from a specified address
	ConvReflexn	Reads data of a specified byte length from specified addresses, in reverse order

In UsbMain.c, interrupt factors are discriminated by the USB interrupt flag register, and functions are called according to the interrupt type. Also, packets are sent and received between the host controller and function modules.

Table 4.2-3 DoRequest.c

File in Which Stored	Function Name	Purpose
DoRequest.c	DecStandardCommands	Decodes command issued by host controller, and processes standard commands
	DecVenderCommands	Processes vendor commands

During control transfer, commands sent from the host controller are decoded and processed. In this sample program, a vendor ID of 045B (vendor: Hitachi) is used. When the customer develops a product, the customer should obtain a vendor ID at the USB Implementers' Forum. Because vendor commands are not used, DecVenderCommands does not perform any action. In order to use a vendor command, the customer should develop a program.

Table 4.2-4 DoRequestBOT_StorageClass.c

File in Which Stored	Function Name	Purpose
DoRequestBOT_ StorageClass.c	DecBOTClass Commands	Processes USB Mass Storage Class (Bulk-Only Transport) commands

This function carries out processing according to the Mass Storage Class (Bulk-Only Transport) commands (Bulk-Only Mass Storage Reset and Get Max LUN).

The Bulk-Only Mass Storage Reset command resets all of the interfaces used in Bulk-Only Transport.

The Get Max LUN command returns the largest logical unit number used by peripheral devices. In this sample program, there is one logical unit, so a value of 0 is returned to the host.

Table 4.2-5 DoControl.c

File in Which Stored	Function Name	Purpose
DoControl.c	ActControl	Controls the setup stage of control transfer
	ActControlIn	Controls the data stage and status stage of control IN transport (transport in which the data stage is in the IN direction)
	ActControlOut	Controls the data stage and status stage of control OUT transport (transport in which the data stage is in the OUT direction)

When a control transfer interrupt (EP0oTS) is generated, ActControl obtains the command, and decoding is carried out by DecStandardCommands. Next, the data stage and status stage are carried out using either ActControlIn or ActControlOut, depending on the type of command.

Table 4.2-6 DoBulk.c

File in Which Stored	Function Name	Purpose
DoBulk.c	ActBulkOut	Performs bulk-out transfer
	ActBulkIn	Performs bulk-in transfer
	ActBulkInReady	Performs preparations for bulk-in transfer

These functions carry out processing involving bulk transport. ActBulkInReady is not used in Mass Storage Class (Bulk-Only Transport).

Table 4.2-7 DoBOTMSClass.c

File in Which Stored	Function Name	Purpose
DoBOTMS Class.c	ActBulkOnly	Divides Bulk-Only Transport into separate stages
	ActBulkOnlyCommand	Controls CBW for Bulk-Only Transport
	ActBulkOnlyIn	Controls data transport and status transport (when the data stage is in the IN direction)
	ActBulkOnlyOut	Controls data transport and status transport (when the data stage is in the OUT direction)

With DoBOTMSClass.c, control of the two or three stages of the Mass Storage Class (Bulk-Only Transport) is carried out, and operation is carried out in accordance with the specifications.

Table 4.2-8 DoSCSICommand.c

File in Which Stored	Function Name	Purpose
DoSCSI Command.c	DecBotCmd	Processes SCSI commands sent from the host using Bulk-Only Transport

The DoSCSICommand.c function is used to analyze SCSI commands sent from the host PC and prepare for the next data transport or status transport.

Figure 4.4 shows the interrelationship between the functions explained in table 4.2. The upper-side functions can call the lower-side functions. Also, multiple functions can call the same function. In the stationary state, SetPowerOnSection calls other functions, and in the case of a transition to the USB communication state which occurs on an interrupt, BranchOfInt calls other functions. Figure 4.4 shows the hierarchical relation of functions; there is no order for function calling. For information on the order in which functions are called, please refer to the flow charts of section 5, Sample Program Operation.

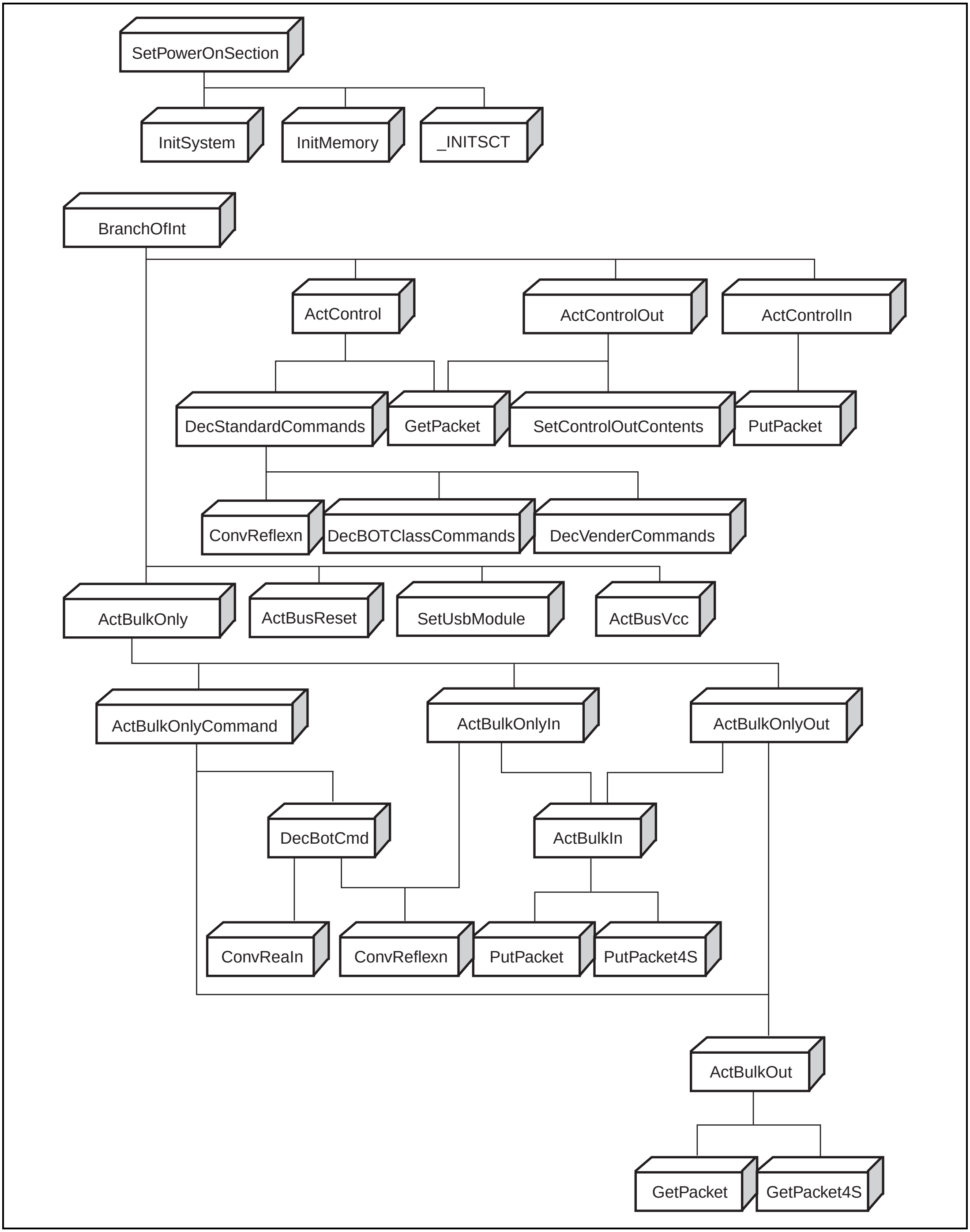


Figure 4.4 Interrelationship between Functions

4.5 RAM Disk

In the sample program provided here, the SRAM in the MS2215CP is selected as the disk device, and the host PC is notified that the MS2215CP (function) is a disk.

As shown in figure 4.5, the disk device of the function has a master boot block and a partition boot block. When the system is booted, an initialization routine is used to write the master boot block and the partition boot block to the RAM disk area on the SRAM.

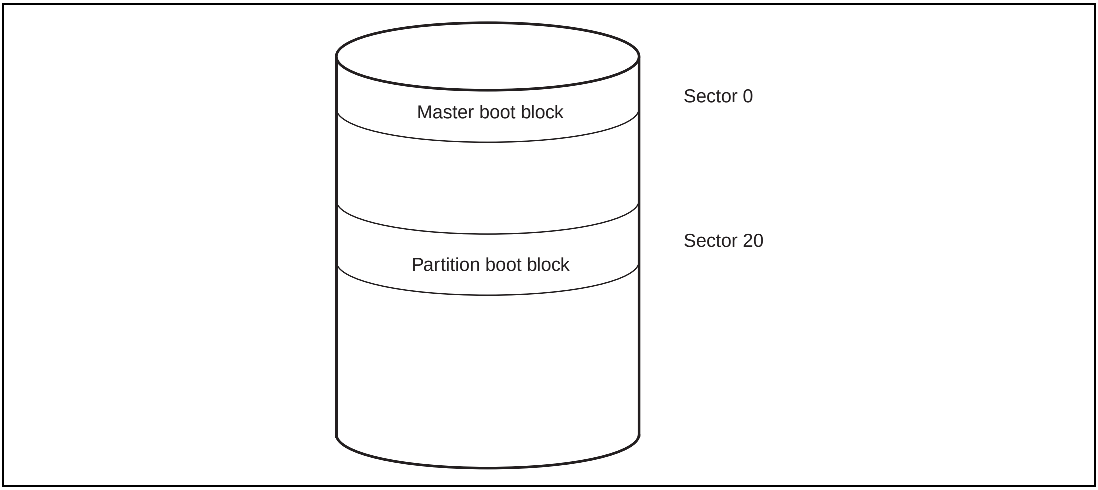


Figure 4.5 Disk Construction

SCSI commands are used to allow function access from the host PC (saving and loading data). In order to work with SCSI commands, the user needs to understand the construction shown in figure 4.5 and then write the operation.

4.6 Operation of SCSI Commands That Are Supported

Table 4.3 shows the SCSI commands that are supported by the sample program.

Table 4.3 SCSI Command Operations

Command Name	Transport Name	Operation Content
INQUIRY	CBW	This decodes a command and recognizes it as an INQUIRY command. It then prepares to send the INQUIRY information (96 bytes) stored in the ROM.
	Data	This sends the INQUIRY information to the host PC using bulk-in transport.
	CSW	This sends the results of executing a command to the PC. If the data being sent is 96 bytes or less, the transmission will end successfully.
READ CAPACITY	CBW	This decodes the command and recognizes it as a READ CAPACITY command. It then reads the number of bytes per sector, which is stored in the partition boot block on the disk device open on the SRAM, and the value stored for the total number of sectors on the disk, and prepares to send the READ CAPACITY information (8 bytes).
	Data	This sends the READ CAPACITY information to the host PC using bulk-in transport.
	CSW	This sends the results of the command execution to the host PC. The transmission is completed successfully as long as the data consists of 8 bytes or less.
READ(10)	CBW	This decodes the command and recognizes it as the READ (10) command. It then prepares to send the data for a specified read sector volume from the Disk device open on the SRAM.
	Data	This sends the data from the read sectors to the host PC using bulk-in transport.
	CSW	This sends the results of executing the READ (10) command to the host computer. The transmission is completed successfully as long as the transmitted data is less than the number of bytes read.

Command Name	Transport Name	Operation Content
WRITE(10)	CBW	This decodes the command and recognizes it as the WRITE (10) command. It then prepares to receive the data of the specified sector volume from the specified write sector in the Disk device open on the SRAM.
	Data	This receives the write sector data from the host PC using bulk-out transport.
	CSW	This notifies the host PC that the operation has been completed successfully.
REQUEST SENSE	CBW	This decodes the command and recognizes it as the REQUEST SENSE command. It then prepares to send the returned value (the results of executing the previous SCSI command).
	Data	This sends the returned value to the host PC using bulk-in transport.
	CSW	This sends the results of the command execution to the host PC. The transmission is completed successfully as long as the data consists of 8 bytes or less.
PREVENT ALLOW MEDIUM REMOVAL	CBW	This decodes the command and recognizes it as the PREVENT ALLOW MEDIUM REMOVAL command. It then prepares to notify the host PC that the operation has been successfully completed. The storage media used with the sample software is an SRAM that is permanently installed, and cannot be removed. For this reason, the returned value for this command always indicates that the operation has been successfully completed.
	Data	Data transport does not exist for this command.
	CSW	This notifies the host PC that the operation has been completed successfully.
TEST UNIT READY	CBW	This decodes the command and recognizes it as the TEST UNIT READY command. It then prepares to notify the host PC that the operation has been successfully completed. The storage medium used with this sample software is an SRAM, and access is always enabled while the program is being executed. For this reason, the returned value for this command always indicates that the operation has been successfully completed.
	Data	Data transport does not exist for this command.
	CSW	This notifies the host PC that the operation has been completed successfully.

Command Name	Transport Name	Operation Content
VERIFY(10)	CBW	This decodes the command and recognizes it as the VERIFY(10) command. It then prepares to notify the host PC that the operation has been successfully completed. The storage medium used with this sample software is an SRAM, and access is always enabled while the program is being executed. For this reason, the returned value for this command always indicates that the operation has been successfully completed.
	Data	Data transport does not exist for this command.
	CSW	This notifies the host PC that the operation has been completed successfully.
MODE SENSE(10)	CBW	This decodes the command and recognizes it as the MODE SENSE (10) command. It then prepares to send the mode parameters to the host PC. The sample software provides values for only the mode parameter header.
	Data	This sends the mode parameters to the host PC using bulk-in transport.
	CSW	This sends the results of the command execution to the host PC. The transmission is completed successfully as long as the data consists of 8 bytes or less.
Commands that are not supported	CBW	This decodes the command and, if it is an unsupported command, specifies INVALID FIELD IN CDB for the returned value of the REQUEST SENSE command. It then prepares to transport the data.
	Data	If the host PC has requested data using bulk-in transport, this sends the same volume of data (0x00) as that requested by the host PC.
		If the host PC has sent data using bulk-out transport, the number of bytes received are counted.
		If there is no data transport, no operation is carried out.
	CSW	This sends a command file to the host PC.

4.7 Processing If an Error Occurs

The errors that may occur during a Mass Storage Class (Bulk-Only Transport) transmission between the host PC and function, and how the function operates when an error occurs are described below.

The Bulk-Only Transport standard defines the following two types of errors:

- Invalid CBW
- Operation expected by the host PC and operation planned by the function (operation specified by the SCSI command) do not match (10 cases)

The Bulk-Only Transport standard does not cover any other states.

There are 13 states for data transfer between the host PC and a function as shown in Tables 4.4 and 4.5. Cases 1, 6 and 12 are normal transport states.

Table 4.4 Data Transport States between Host PC and Function.

		What the Host PC Expects		
		No Data Transport	**Data Reception from Function**	**Data Send to Function**
What the function plans	No data transport	(1) Hn = Dn	(4) Hi > Dn	(9) Ho > Dn
	Data send to host PC	(2) Hn < Di	(5) Hi > Di (6) Hi = Di (7) Hi < Di	(10) Ho < > Di
	Data reception from host PC	(3) Hn < Do	(8) Hi < > Do	(11) Ho > Do (12) Ho = Do (13) Ho < Do

Table 4.5 Explanation of Data Transport States between Host PC and Function

Case No.	Relation between Host PC and Function
1	The host PC expects no data transport and the function plans no data transport.
2	The host PC expects no data transport but the function plans to send data to the host PC
3	The host PC expects no data transport but the function plans to receive data from the host PC.
4	The host PC expects to receive data from the function but the function plans no data transport to the host PC.
5	The amount of data the function sends to the host PC is less than the amount of data the host PC expected to receive from the function.
6	The amount of data the function sends to the host PC is equal to the amount of data the host PC expected to receive from the function.
7	The amount of data the function sends to the host PC is greater than the amount of data the host PC expected to receive from the function.
8	The host PC expects to receive data from the function but the function plans to receive data from the host PC.
9	The host PC expects to send data to the function but the function plans no data transport to the host PC.
10	The host PC expects to send data to the function but the function plans to send data to the host PC.
11	The amount of data the function receives from the host PC is less than the amount of data the host PC expected to send to the function.
12	The amount of data the function receives from the host PC is equal to the amount of data the host PC expected to the function.
13	The amount of data the function receives from the host PC is greater than the amount of data the host PC expected to send to the function.

Table 4.6 shows sample error conditions that may be generated.

Table 4.6 Sample Error Conditions

Case No.	Relation between Host PC and Function
2	When a READ command is issued from the host PC, the amount of data to be transported in the USB data transport is 0 while the amount of data specified by the SCSI command is a value other than 0.
3	When a WRITE command is issued from the host PC, the amount of data to be transported in the USB data transport is 0 while the amount of data specified by the SCSI command is a value other than 0.
4	When a READ command is issued from the host PC, the amount of data to be transported in the USB data transport is 0 while the amount of data specified by the SCSI command is 0.
5	When a READ command is issued from the host PC, the amount of data specified by the SCSI command is less than the amount of data to be transported in the USB data transport.
7	When a READ command is issued from the host PC, the amount of data specified by the SCSI command is greater than the amount of data to be transported in the USB data transport.
8	Even though a WRITE command has been issued from the host PC, the host PC requests for data in the USB data transport.
9	When a WRITE command is issued from the host PC, the amount of data to be transported in the USB data transport is a value other than 0 while the amount of data specified by the SCSI command is 0.
10	Even though a READ command has been issued from the host PC, the host PC sends data in the USB data transport.
11	When a WRITE command is issued from the host PC, the amount of data specified by the SCSI command is less than the amount of data to be transported in the USB data transport.
13	When a WRITE command is issued from the host PC, the amount of data specified by the SCSI command is greater than the amount of data to be transported in the USB data transport.

Table 4.7 shows how a function operates when each error condition occurs.

Table 4.7 Function Operation for Each Error Condition

Case No.	Relation between Host PC and Function
2, 3	• Set 0x02 as the CSW status.
4, 5	• The function adds data to become equal to the data length set in dCBWDataTransferLength and then sends data to the host PC. • Set the amount of data added in the data transport in dCBWDataResidue of CSW. • Set 0x01 as the CSW status.
7, 8	• The function sends data to the host PC up to the data length set in dCBWDataTransferLength. • Set 0x02 as the CSW status.
9, 11	• The function receives data from the host PC up to the data length set in dCBWDataTransferLength. • Set the difference between the amount of data received in the data transport and the amount of data processed by the function in dCBWDataResidue of CSW. • Set 0x01 as the CSW status.
10, 13	• The function receives data from the host PC up to the data length set in dCBWDataTransferLength. • Set 0x02 as the CSW status.

Figures 4.6 to 4.8 show the processing when a data transport error occurs.

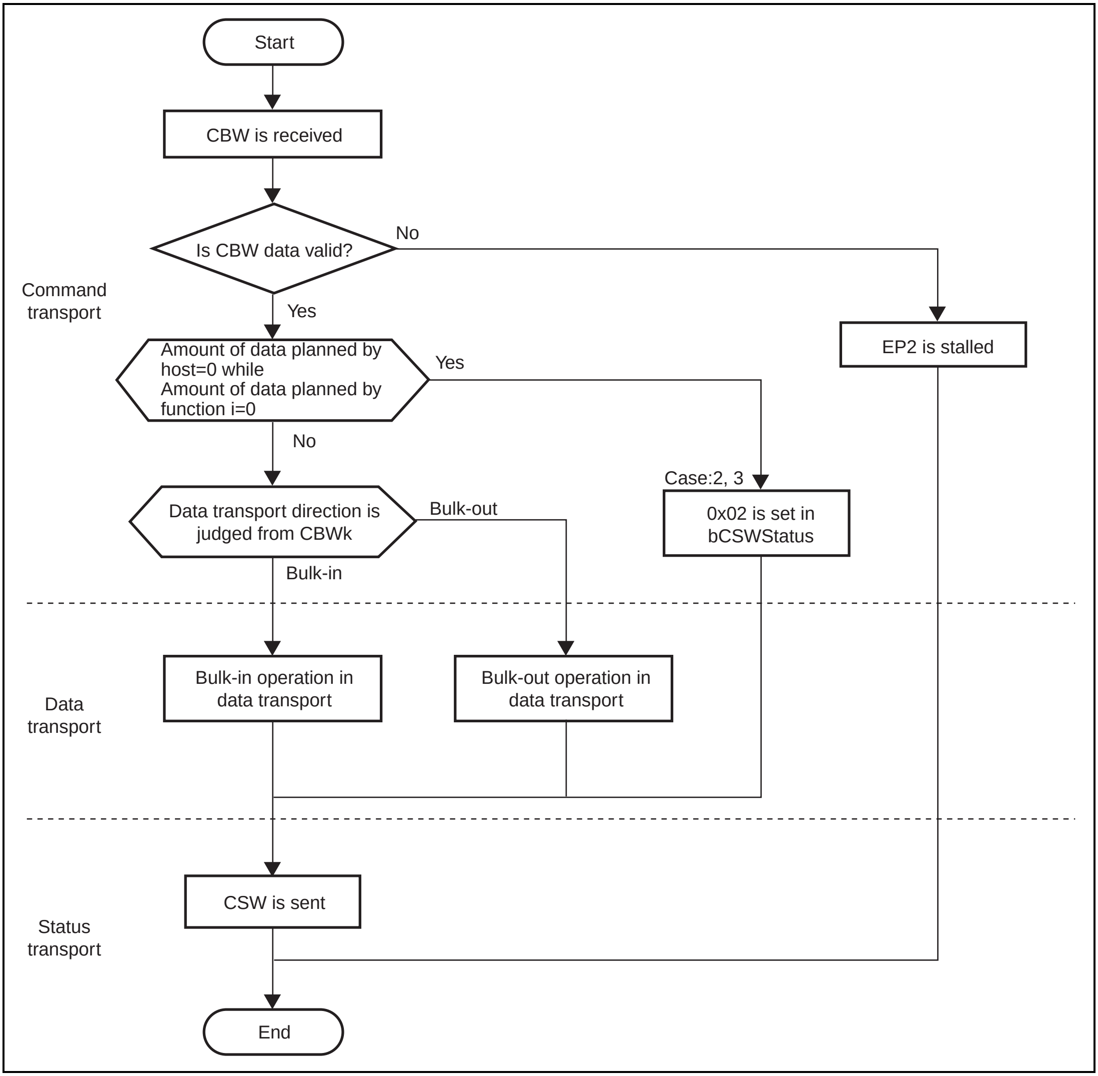


Figure 4.6 Error Processing Flow in Data Transport (1)

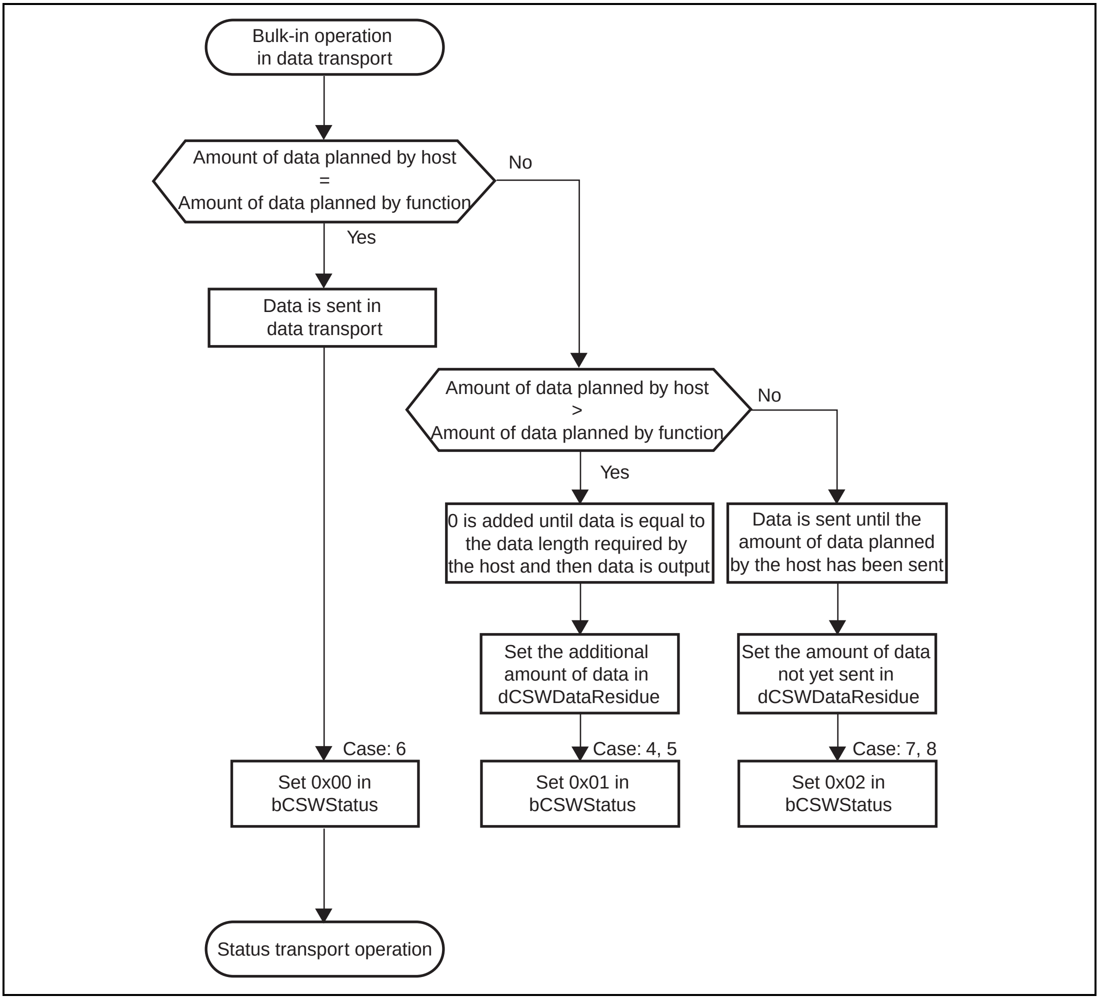


Figure 4.7 Error Processing Flow in Data Transport (2)

RENESAS

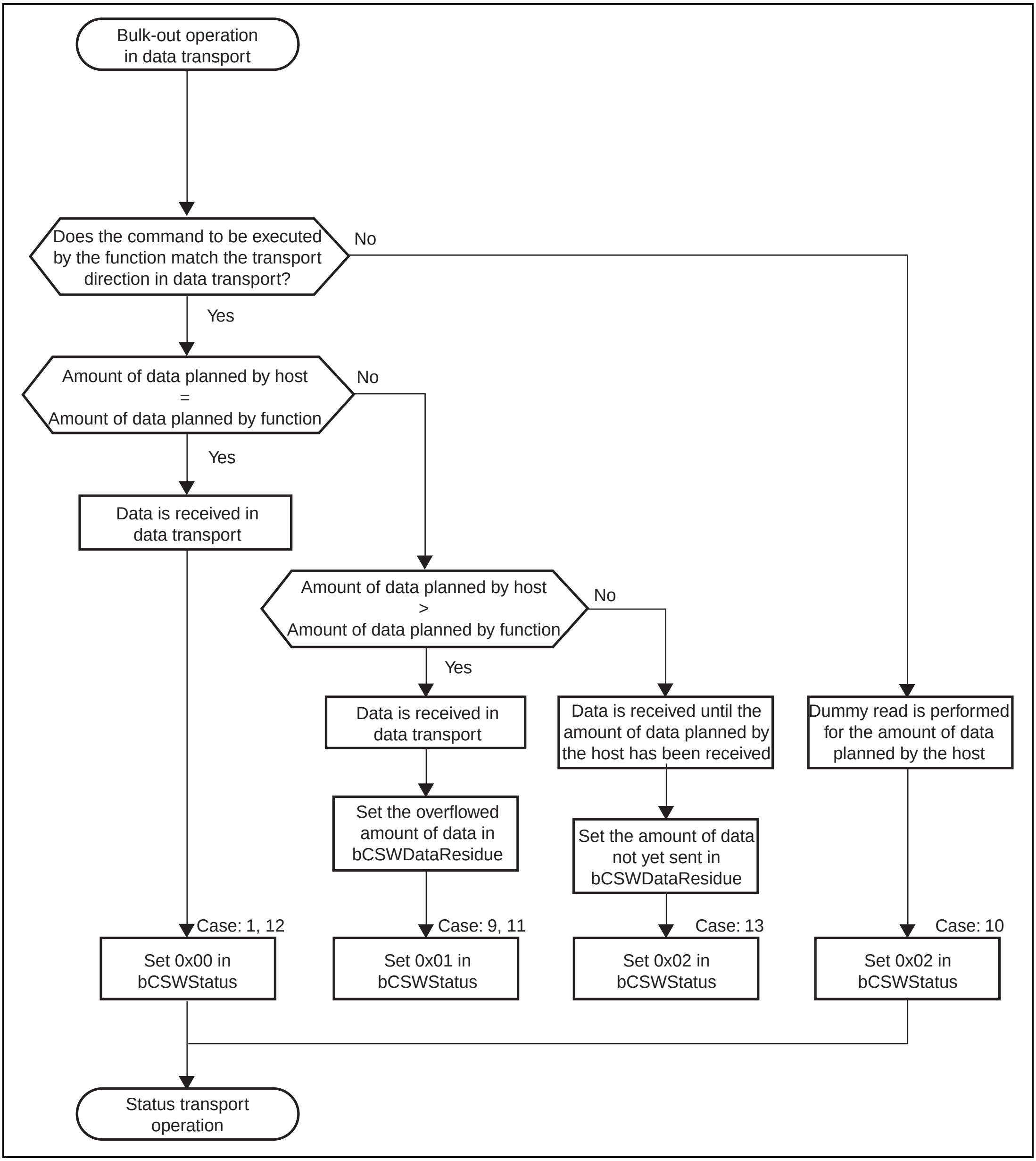


Figure 4.8 Error Processing Flow in Data Transport (3)

When a Mass Storage Class (Bulk-Only Transport) transmission is carried out, transport of the CBW initiates a series of data transfers, and when the CSW is transported to the host PC, a series of data transfers is processed. This status contains two items: dCSWStatus that indicates the transport result, and dCSWDataResidue that indicates the number of error bytes.

In this sample program, the following two fields are used to create these two items.

- dCBWDataTransferLength field of CBW packet
- dCSWDataTransferResidue field of CSW packet

The dCBWDataTransferLength field of the CBW packet is used as the variable in which the number of data bytes the host PC specifies to be handled in the data transport is entered.

The dCSWDataTrasferResidue field of the CSW packet is used as the variable in which the number of data bytes the function handles in the data transport is entered.

When the CBW transport has been completed, the number of data bytes planned to be handled in the data transport by the host PC and the function are stored in the dCBWDataTransferLength and dCSWDataTransferResidue fields, respectively.

Data is transferred in the data transport according to the flowcharts.

If data transport between the host PC and function has been processed without errors, the values in the dCBWDataTransferLength and dCSWDataTransferResidue fields are both subtracted by the number of bytes that have been transferred for every data transfer in the data transport. For other cases, the difference between the number of data bytes the host PC requires to be handled in the data transport and the number of data bytes the function has handled in the data transport is stored in the dCSWDataTransferResidue field of the CSW packet, and operation then moves to the status transport.

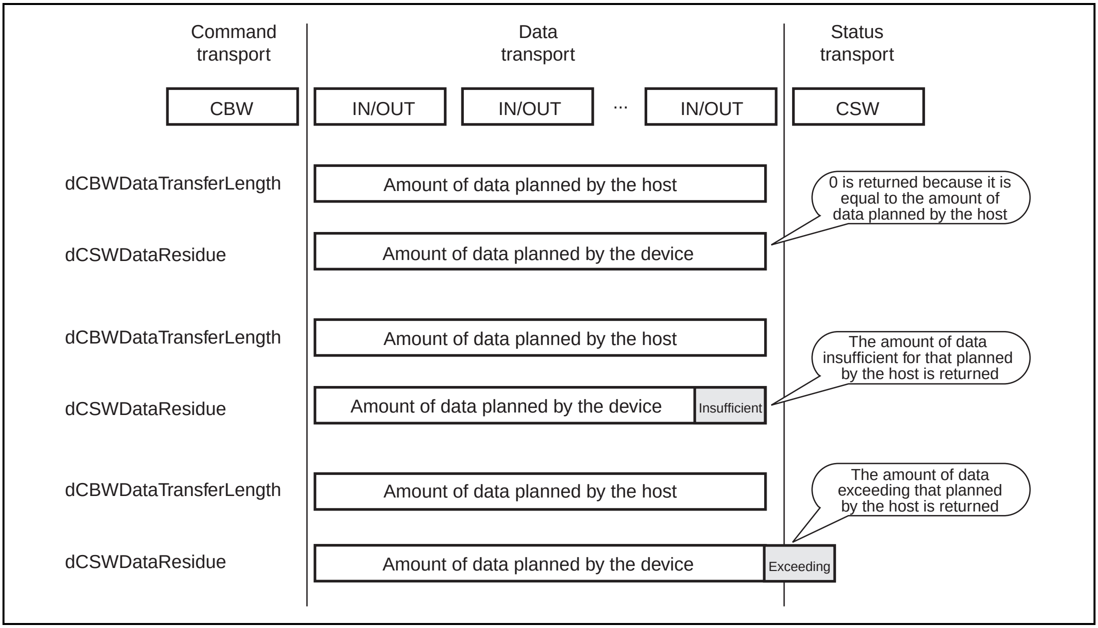


Figure 4.9 Each Stage in Bulk-Only Transport

Section 5 Sample Program Operation

In this chapter, the operation of the sample program is explained, relating it to the operation of the USB function module.

5.1 Main Loop

When the microcomputer is in the reset state, the internal state of the CPU and the registers of internal peripheral modules are initialized. Next, the function SetPowerOnSection in StartUp.c is called, and the CPU is initialized. Figure 5.1 is a flow chart for the SetPowerOnSection function operation.

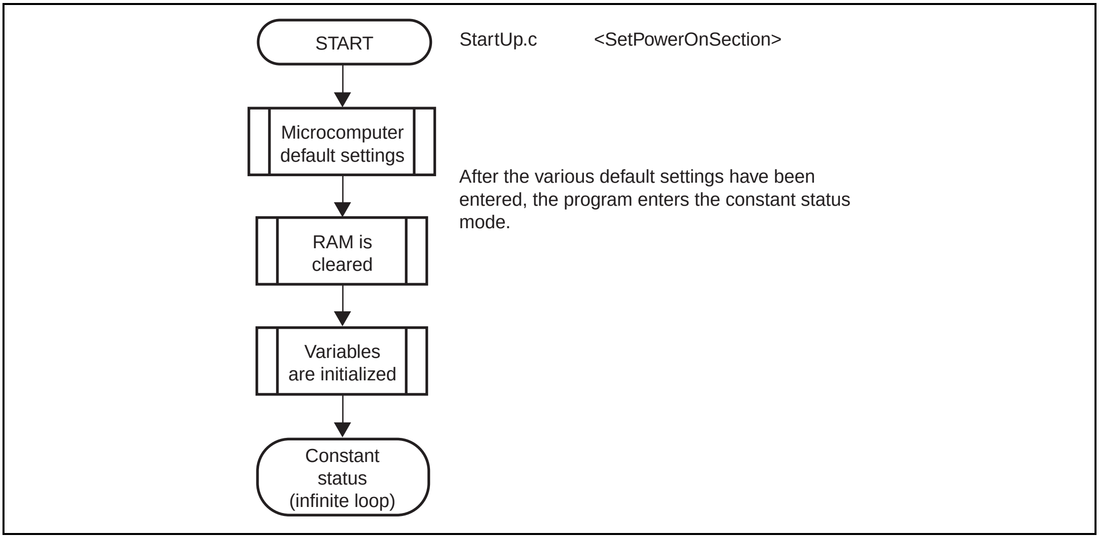


Figure 5.1 Main Loop

5.2 Types of Interrupts

As explained in section 4, the interrupts used in this sample program are indicated by the interrupt flag registers 0 to 3 (UIFR0 to UIFR3); there are a total of nine types of interrupts. When an interrupt factor occurs, the corresponding bits in the interrupt flag registers are set to 1, and an EXIRQ0 interrupt request is sent to the CPU. In the sample program, the interrupt flag registers are read as a result of this interrupt request, and the corresponding USB communication is performed. Figure 5.2 shows the interrupt flag registers and their relation to USB communication.

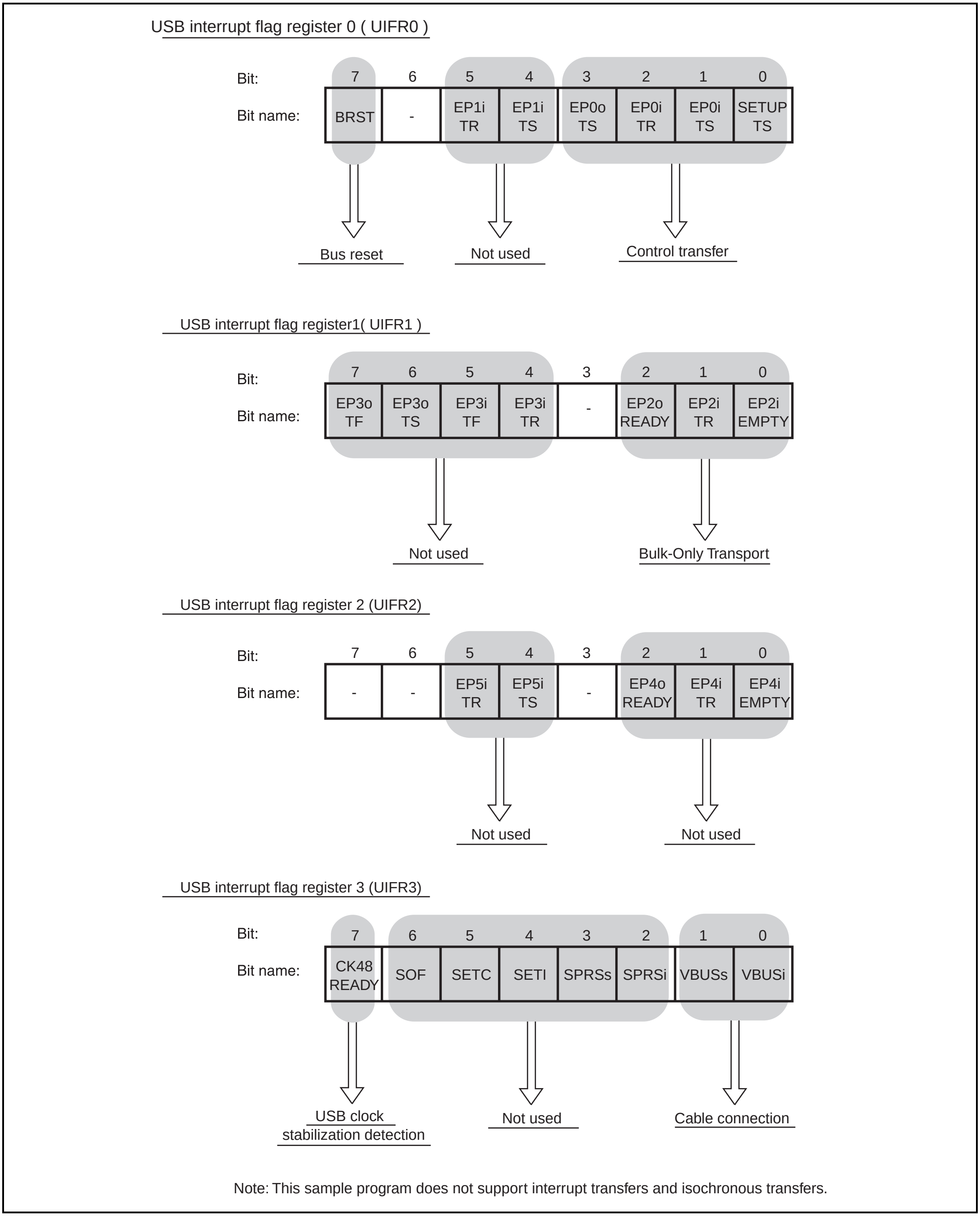


Figure 5.2 Types of Interrupt Flags

5.2.1 Method of Branching to Different Transfer Processes

In this sample program the transfer method is determined by the type of interrupt from the USB module. Branching to the different transfer methods is executed by BranchOfInt in UsbMain.c. Table 5.1 shows the relations between the types of interrupts and the functions called by BranchOfInt.

Table 5.1 Interrupt Types and Functions Called on Branching

Register Name	Bit	Bit Name	Name of Function Called
UIFR0	7	BRST	ActBusReset
	6	-	-
	5	EP1i TR	-
	4	EP1i TS	-
	3	EP0o TS	ActControlIn•ActControlOut
	2	EP0i TR	ActControlOut
	1	EP0i TS	ActControlIn•ActControlOut
	0	SETUP TS	ActControl
UIFR1	7	EP3o TF	-
	6	EP3o TS	-
	5	EP3i TF	-
	4	EP3i TR	-
	3	-	-
	2	EP2o READY	ActBulkOut
	1	EP2i TR	ActBulkOut
	0	EP2i EMPTY	ActBulkOut
UIFR3	7	CK48 READY	SetUSBModule
	6	SOF	-
	5	SETC	-
	4	SETI	-
	3	SPRSs	-
	2	SPRSi	-
	1	VBUSs	-
	0	VBUSi	ActBusVcc

The EP0iTS and EP0oTS interrupts are used both for control-in and control-out transfer. Hence in order to manage the direction and stage of control transfer, the sample program has three states: TRANS_IN, TRANS_OUT, and WAIT. For details, refer to section 5.4, Control Transfers.

In the H8S/2215 hardware manual, operation of the USB function module when an interrupt occurs, and a summary of operation on the application side are described. From the next section, details of application-side firmware are explained for each USB transfer method.

5.3 USB Operating Clock Stabilization Interrupt

This interrupt occurs when the USB operating clock (48 MHz) stabilization time is automatically counted after USB module stop is canceled. After receiving the interrupt, the sample program writes the endpoint configuration information to the USB endpoint information registers (UEPIR00_0 to 22_4), makes necessary interrupt settings, and waits for USB cable connection.

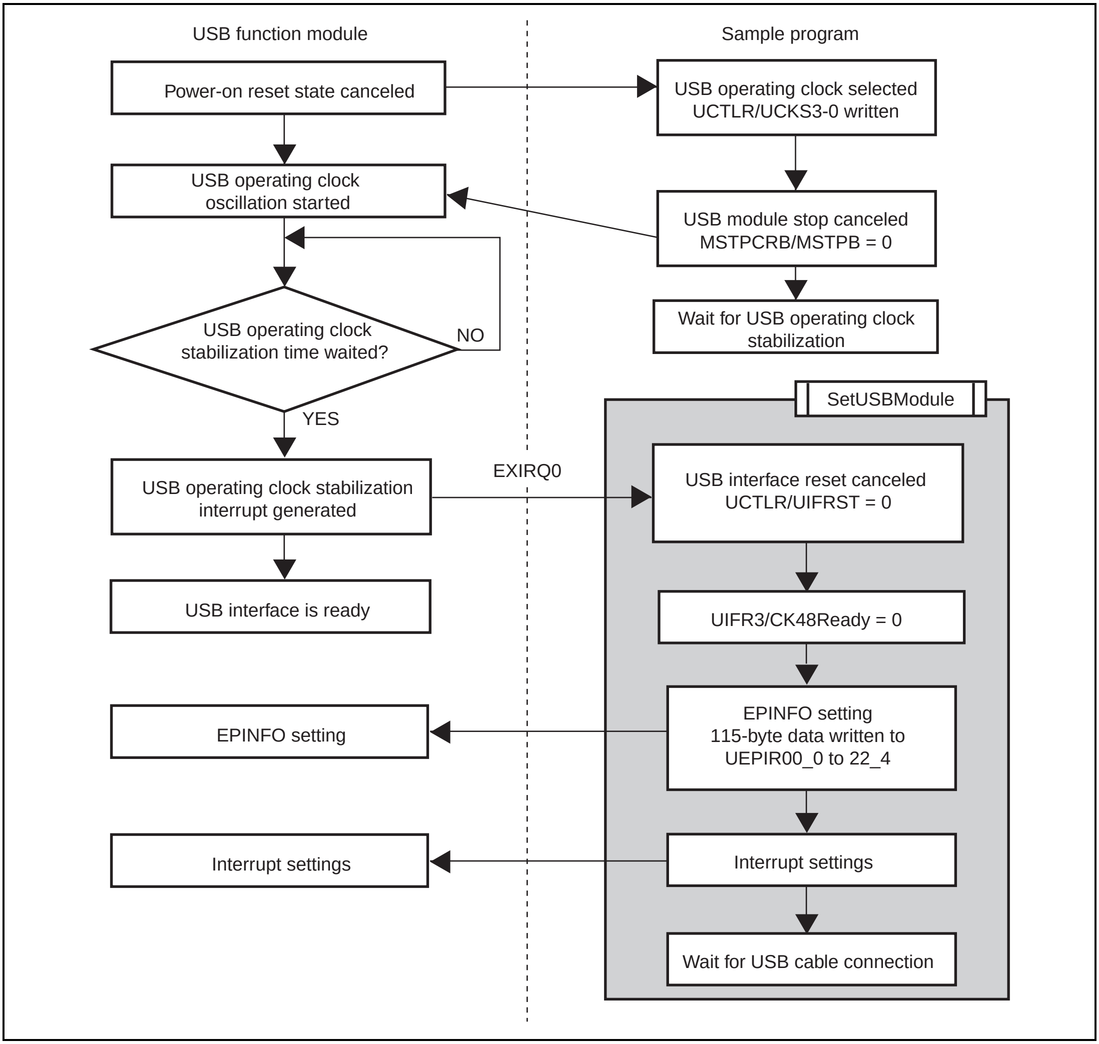


Figure 5.3 USB Operating Clock Stabilization Interrupt

5.3.1 EPINFO

In the USB function module in the H8S/2215, the endpoint configuration can be specified at initialization by software. The following transfer types can be specified:

- Control transfer: One endpoint
- Bulk-in transfer: Two endpoints
- Bulk-out transfer: Two endpoints
- Interrupt-in transfer: One endpoint
- Isochronous-in transfer: One endpoint
- Isochronous-out transfer: One endpoint

The endpoint number, interface number, alternate number, and maximum packet size can be specified for the above transfers (excluding control transfer) with the USB endpoint information registers (UEPIRs).

Table 5.2 shows transfer types and their corresponding UEPIRs.

Table 5.2 Transfer Types and UEPIRs

Transfer Type	Endpoints	Corresponding UEPIRs
Control transfer	1	00
Interrupt-in transfer	2	01 and 02
Bulk-in transfer	2	02 and 20
Bulk-out transfer	2	03 and 21
Isochronous-in transfer	1	04, 06, 08, 10, 12, 14, 16, and 18
Isochronous-out transfer	1	05, 07, 09, 11, 13, 15, 17, and 19

The H8S/2215 Hardware Manual assumes that endpoint information is configured based on the Bluetooth standard. Figure 5.4 shows the comparison between the endpoint configuration used by this sample program and the endpoint numbers described in the H8S/2215 Hardware Manual.

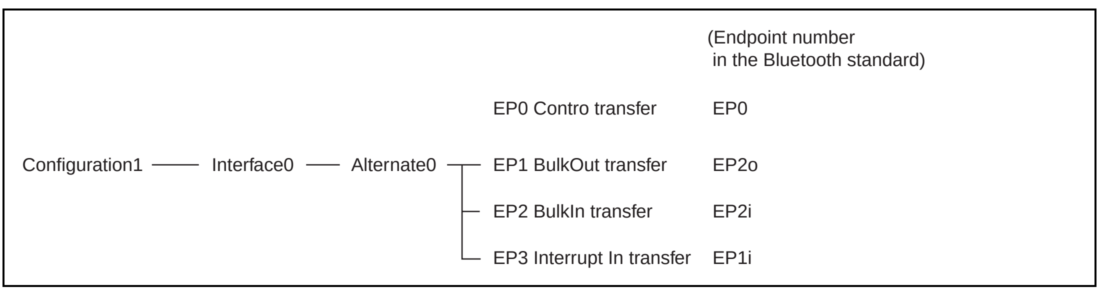


Figure 5.4 Endpoint Configuration in the Sample Program

Table 5.3 shows the UEPIR00_0 to 22_4 settings for the endpoint configuration shown in figure 5.4. Dummy data (0) must be written to the unused endpoints.

Table 5.3 UEPIR Settings

UEPIR	Set Value (Hexadecimal)	Transfer Type	EP No.	Interface No.	Alternate No.	Maximum Packet Size (Byte)
00	00_00_40_00_00	Control	0	0	0	64
01	34_1C_08_00_01	Interrupt In	3	0	0	8
02	24_14_40_00_02	BulkIn	2	0	0	64
03	14_10_40_00_03	BulkOut	1	0	0	64
04	04_1C_00_00_04	Isochronous In	0	0	0	0
05	04_08_00_00_05	Isochronous Out	0	0	0	0
06	04_1C_00_00_06	Isochronous In	0	0	0	0
07	04_08_00_00_07	Isochronous Out	0	0	0	0
08	04_1C_00_00_08	Isochronous In	0	0	0	0
09	04_08_00_00_09	Isochronous Out	0	0	0	0
10	04_1C_00_00_0A	Isochronous In	0	0	0	0
11	04_08_00_00_0B	Isochronous Out	0	0	0	0
12	04_1C_00_00_0C	Isochronous In	0	0	0	0
13	04_08_00_00_0D	Isochronous Out	0	0	0	0
14	04_1C_00_00_0E	Isochronous In	0	0	0	0
15	04_08_00_00_0F	Isochronous Out	0	0	0	0
16	04_1C_00_00_10	Isochronous In	0	0	0	0
17	04_08_00_00_11	Isochronous Out	0	0	0	0
18	04_1C_00_00_12	Isochronous In	0	0	0	0
19	04_08_00_00_13	Isochronous Out	0	0	0	0
20	04_14_00_00_14	BulkIn	0	0	0	0
21	04_10_00_00_15	BulkOut	0	0	0	0
22	04_10_00_00_16	Interrupt In	0	0	0	0

5.4 Interrupt on Cable Connection (VBUS)

This interrupt occurs when the cable of the USB function module is connected to the host controller. On the application side, after completion of initial microcomputer settings, a general-purpose output port is employed to pull-up the USB data bus D+. By means of this pull-up, the host controller recognizes that the device has been connected. (figure 5.5)

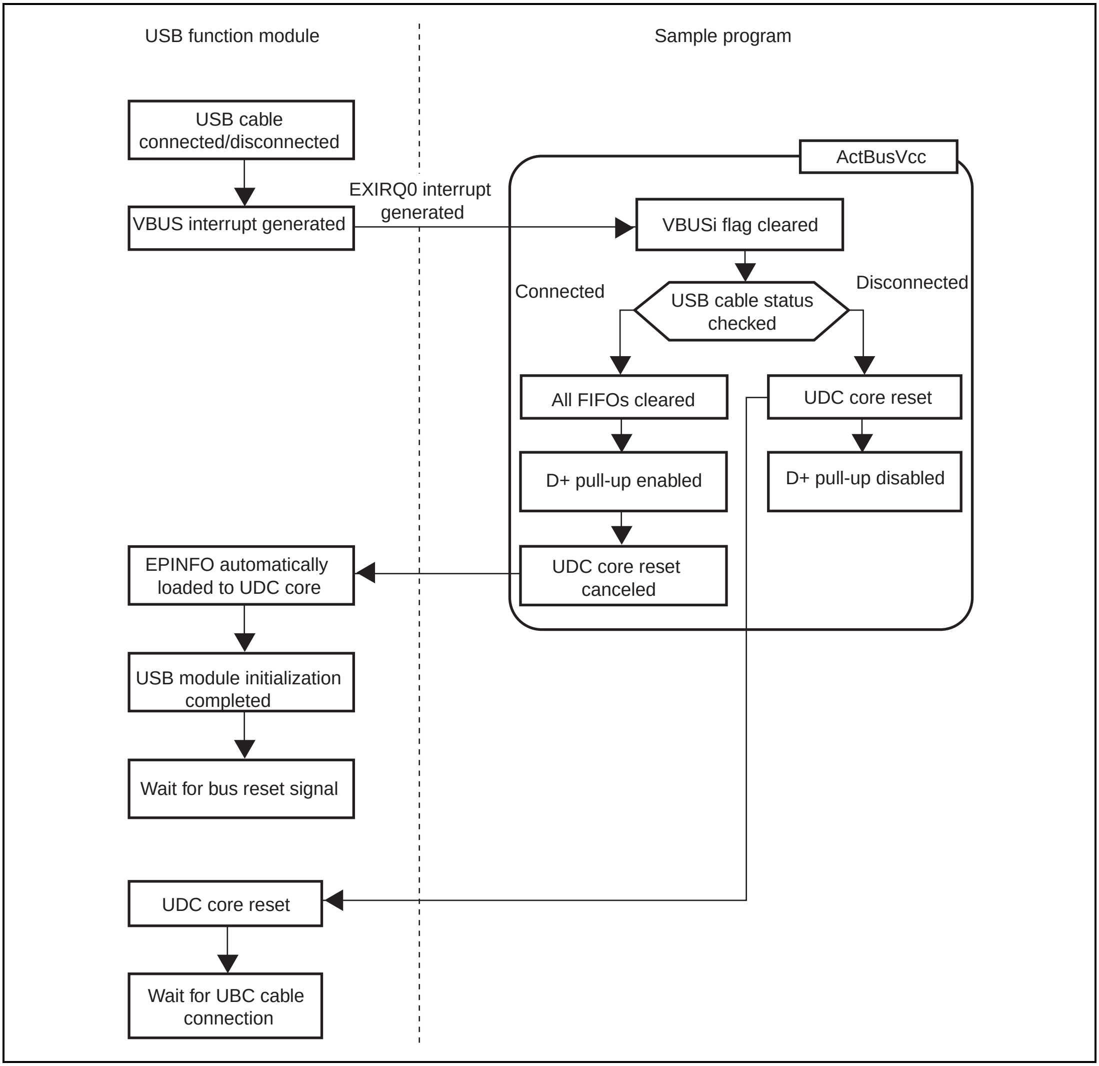


Figure 5.5 Interrupt on Cable Connection

5.5 Bus Reset Interrupt (BRST)

When the host controller detects that a device has been connected to the USB data bus, it outputs a bus reset signal. When receiving this bus reset signal, the USB function module generates a bus reset.

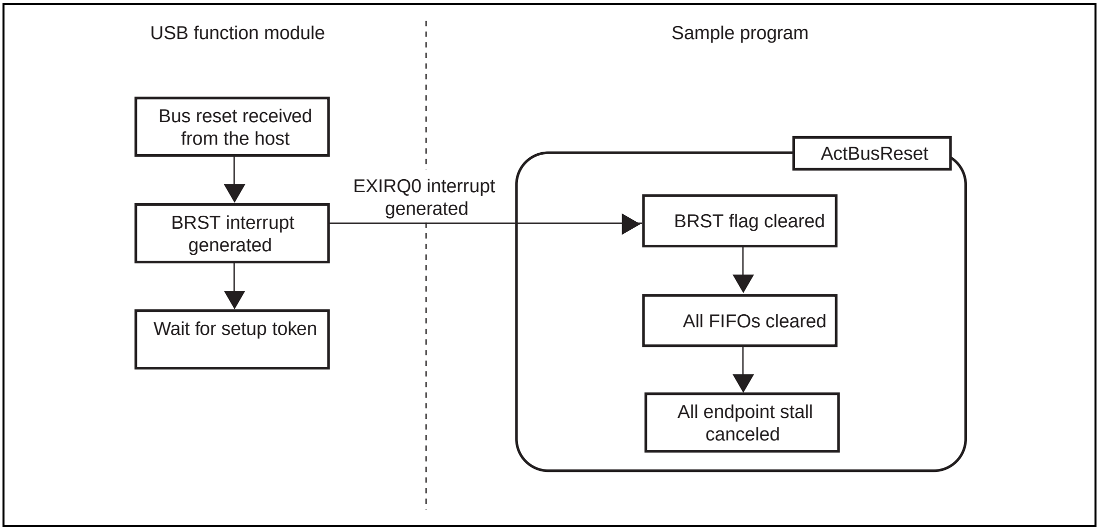


Figure 5.6 Bus Reset Interrupt

5.6 Control Transfers

In control transfers, bits 0 to 3 of the interrupt flag registers are used. Control transfers can be divided into two types according to the direction of data in the data stage. (figure 5.7) In the data stage, data transfers from the host controller to the USB function module are control-out transfers, and transfers in the opposite direction are control-in transfers.

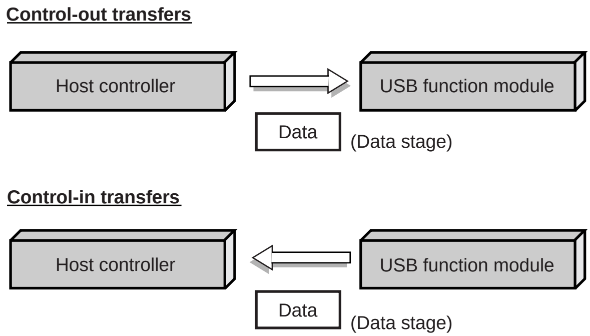


Figure 5.7 Control Transfers

Control transfers consist of three stages: setup, data (no data is possible), and status (figure 5.8). Further, the data stage consists of multiple bus transactions.

In control transfers, stage changes are recognized through the reversal of the data direction. Hence the same interrupt flag is used to call a function to perform control-in or control-out transfers (table 5.1). For this reason, the firmware must use states to manage the type of control transfer currently being performed, whether control-in or control-out, (figure 5.8) and must call the appropriate function. States in the data stage (TRANS_IN and TRANS_OUT) are determined by commands received in the setup stage.

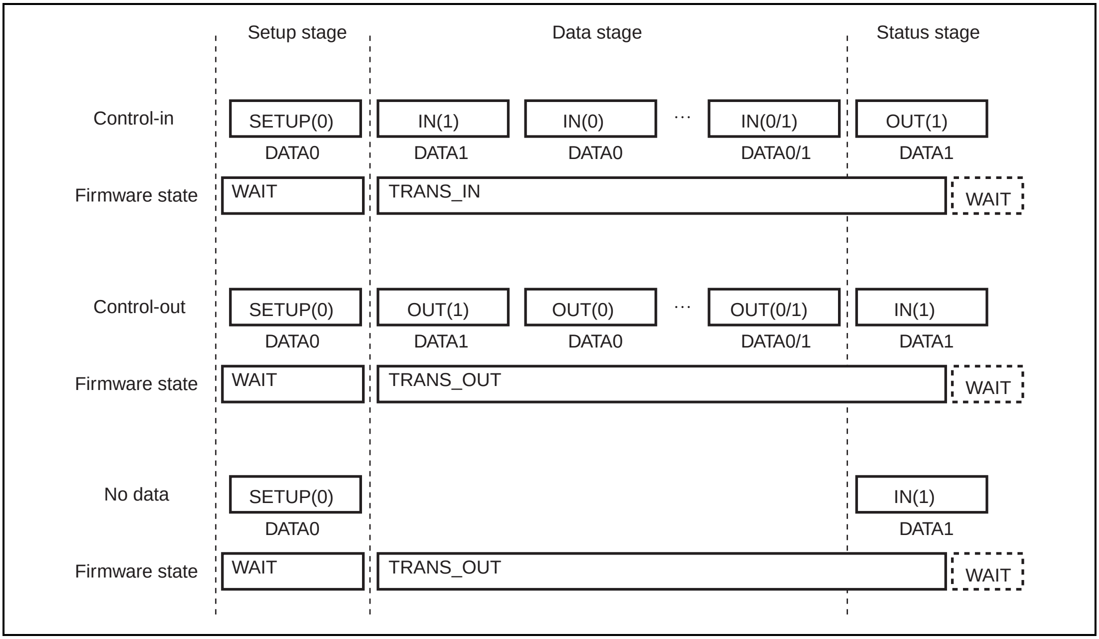


Figure 5.8 Status in Control Transfers

5.6.1 Setup Stage

In the setup stage, the host and function modules exchange commands. For both control-in and control-out transfer, the firmware goes into the WAIT state. Depending on the type of command issued, discrimination between control-in transfer and control-out transfer is performed, and the state of the firmware in the data stage (TRANS_IN or TRANS_OUT) is determined.

- Commands for control-in transfers: GetDescriptor (Standard command)
  Get Max LUN (Class command)
- Commands for control-out transfers: Bulk-Only Mass Storage Reset (Class command)

Figure 5.9 shows operation of the sample program in the setup stage. The figure on the left shows operation of the USB function module.

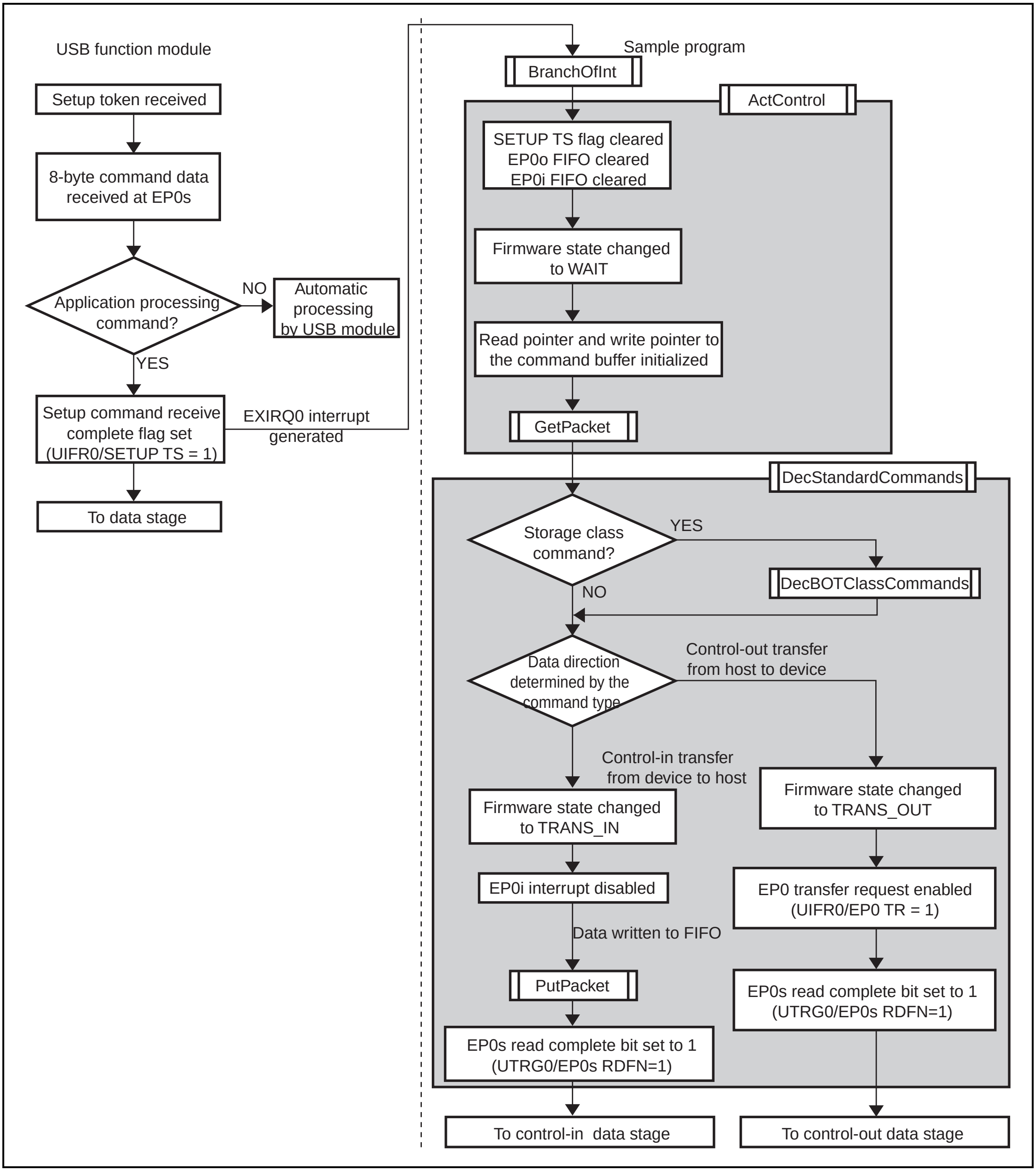


Figure 5.9 Setup Stage

5.6.2 Data Stage

In the data stage, the host and function module exchange data. The firmware state becomes TRANS_IN for control-in transfers, and TRANS_OUT for control-out transfers, according to the result of decoding of the command in the setup stage. Figures 5.10 and 5.11 show the operation of the sample program in the data stage of control transfer.

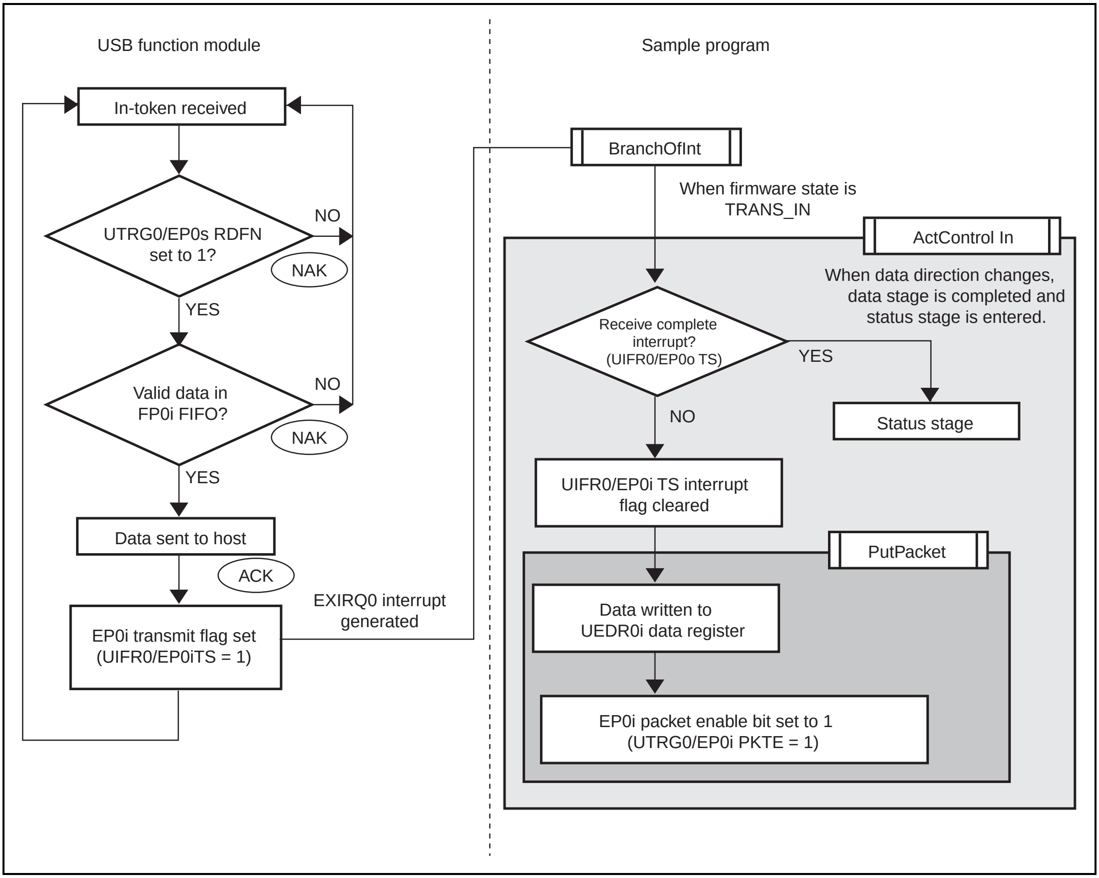


Figure 5.10 Data Stage (Control-In Transfer)

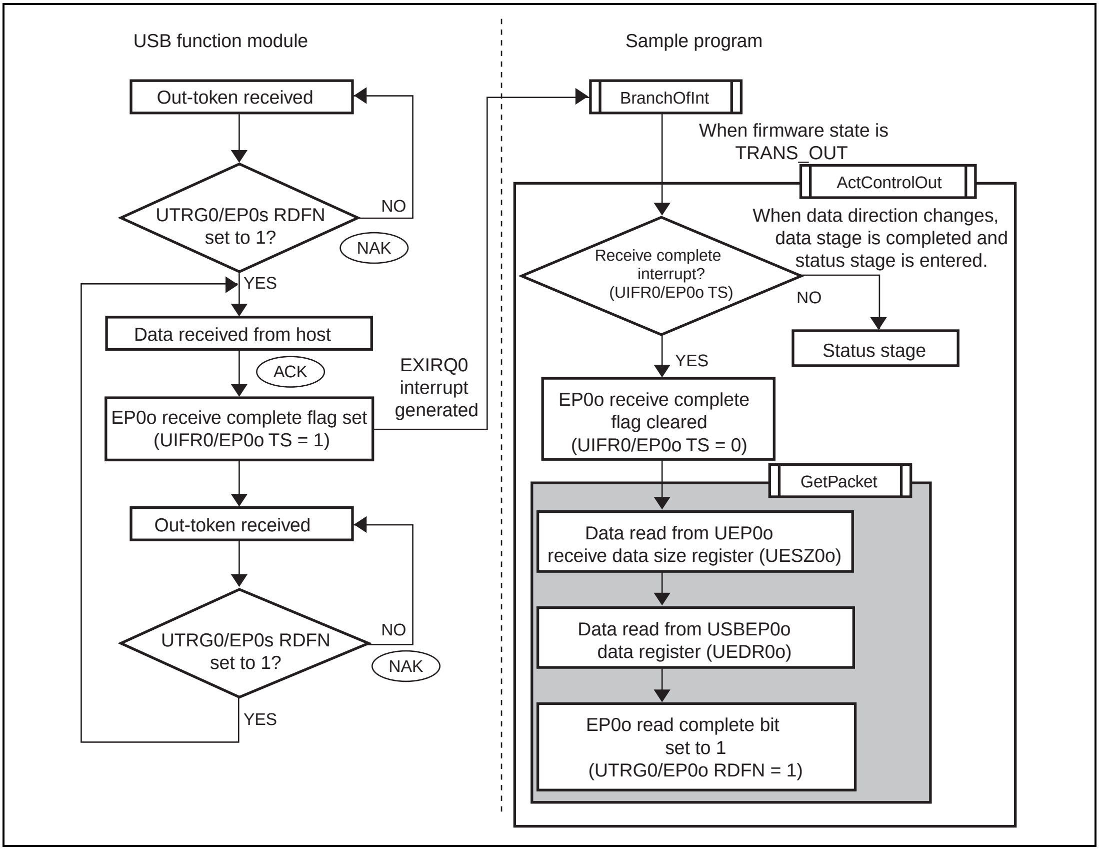


Figure 5.11 Data Stage (Control-Out Transfer)

5.6.3 Status Stage

The status stage begins with a token for the opposite direction from the data stage. That is, in control-in transfer, the status stage begins with an out-token from the host controller; in control-out transfer, it begins with an in-token from the host controller.

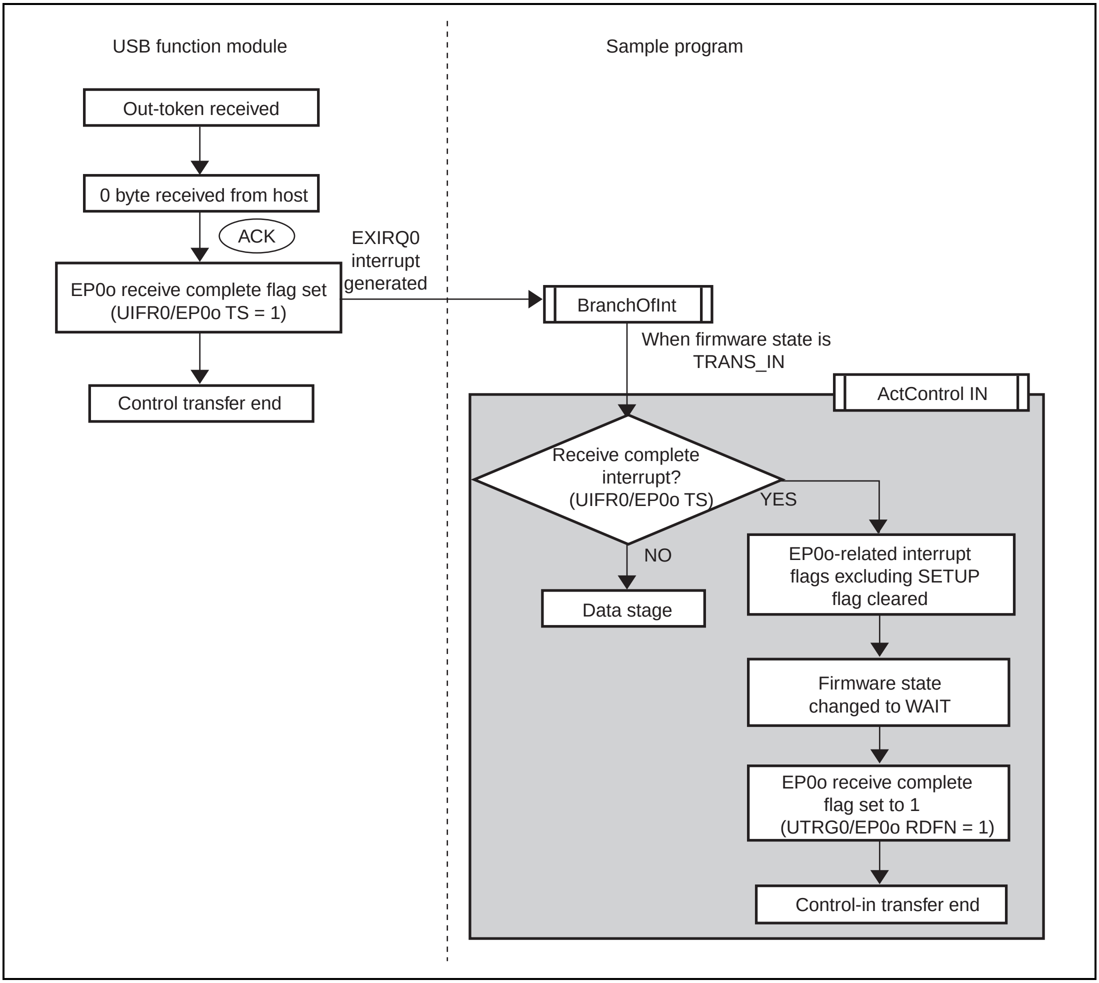


Figure 5.12 Status Stage (Control-In Transfer)

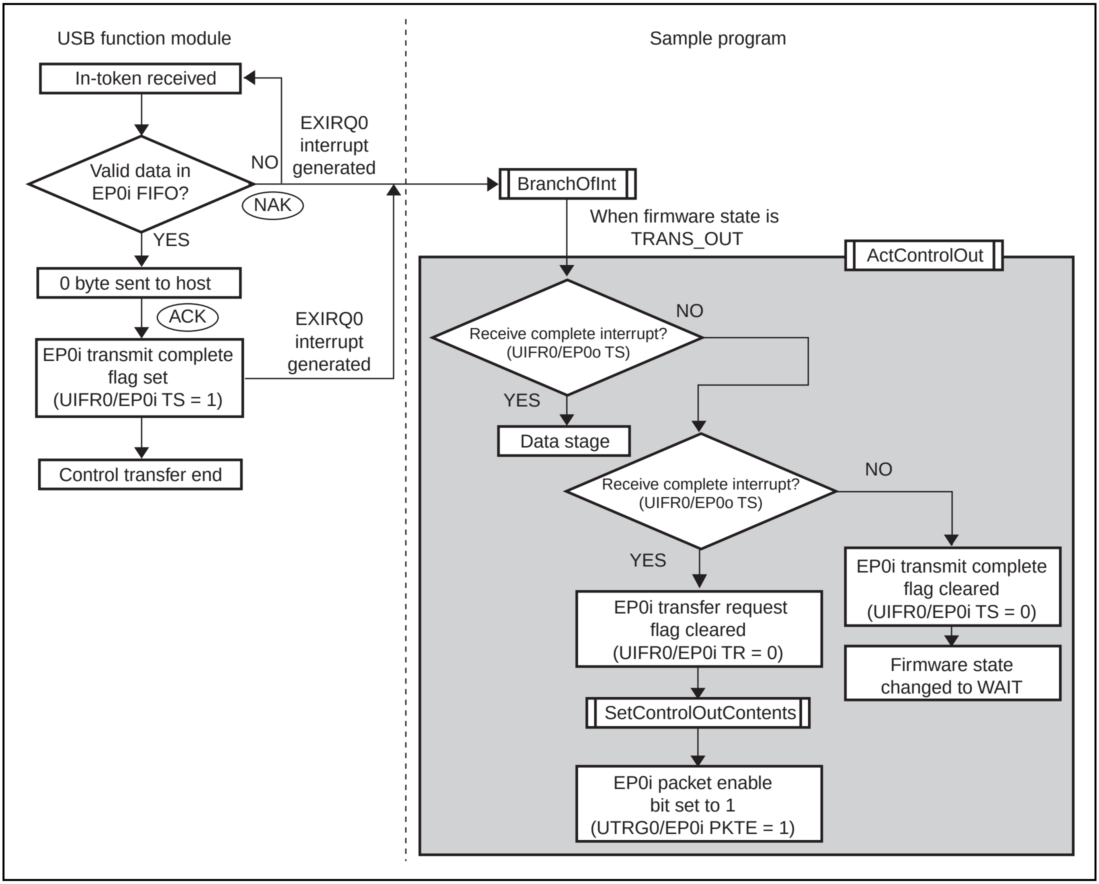


Figure 5.13 Status Stage (Control-Out Transfer)

5.7 Bulk Transfers

In bulk transfers, bits 0 to 2 of interrupt flag register 1 are used. Bulk transfers can also be divided into two types according to the direction of data transmission. (figure 5.14)

When data is transferred from the host controller to the USB function module, the transfer is called a bulk-out transfer; when data is transferred in the opposite direction, it is a bulk-in transfer.

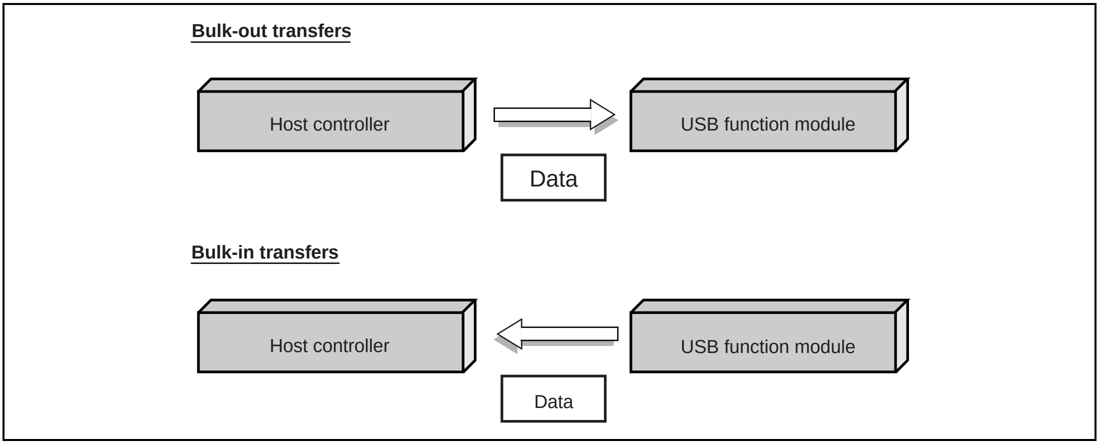


Figure 5.14 Bulk Transfers

The Bulk-Only Transport used in the USB Mass Storage Class consists of bulk-in and bulk-out transfers.

Bulk-Only Transfer comprises two or three stages (see figure 5.15): command transport (CBW), data transport (this is sometimes not included), and status transport (CSW). In addition, data transfer is made up of multiple bus transactions.

With Bulk-Only transport, the command transport (CBW) is done using bulk-out transfer, while the status transport (CSW) is done using bulk-in transfer. Either bulk-in transfer or bulk-out transfer may be used for data transport, depending on the direction in which the data is being sent.

Whether bulk-in or bulk-out transfer is used for data transport is determined by the CBW data received using command transport. In the firmware, whether bulk-in or bulk-out is used for data transport is controlled by states (TRANS_IN and TRANS_OUT) (see figure 5.15). The appropriate functions must be called by the firmware.

Additionally, the transition in stages from data transport to status transport is handled by data of a planned length being sent or received using data transport requested by the host PC. Consequently, the firmware manages the data length sent or received using data transport, and after the transition between stages, status transport must be used to send the data to the host PC.

If the CBW data received using command transport cannot be acknowledged as valid, the endpoint is stalled, and no bulk transfer is carried out.

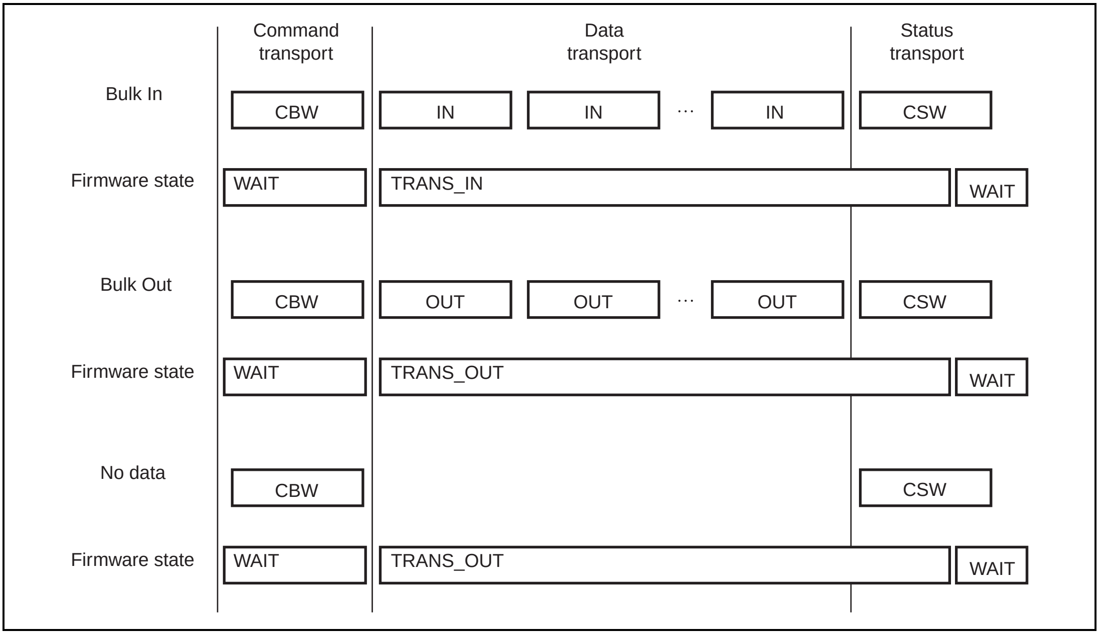


Figure 5.15 Various Stages in Bulk-Only Transport

5.7.1 Command Transport

With command transport, the CBW data is transferred from the host to the function.

At this point, the firmware is in the WAIT state. At the stage following reception of the CBW data, the five types of processing listed below are carried out.

1. The CBW data is stored from the EP1 data register to the work area.
2. A judgment is made as to whether the CBW data is valid.
3. The CSW data is prepared.
4. The contents of the CBW data are decoded, and if there is any data to be sent using data transport, the data is prepared. (Processing is carried out in the DecBotCmd function.)
5. A distinction is made as to whether the data transport is bulk-in or bulk-out, and the firmware state (TRANS_IN or TRANS_OUT) is determined.

Figure 5.16 shows the operation carried out by the sample program when command transport is used. The operation of the USB function module is shown at the left of the illustration.

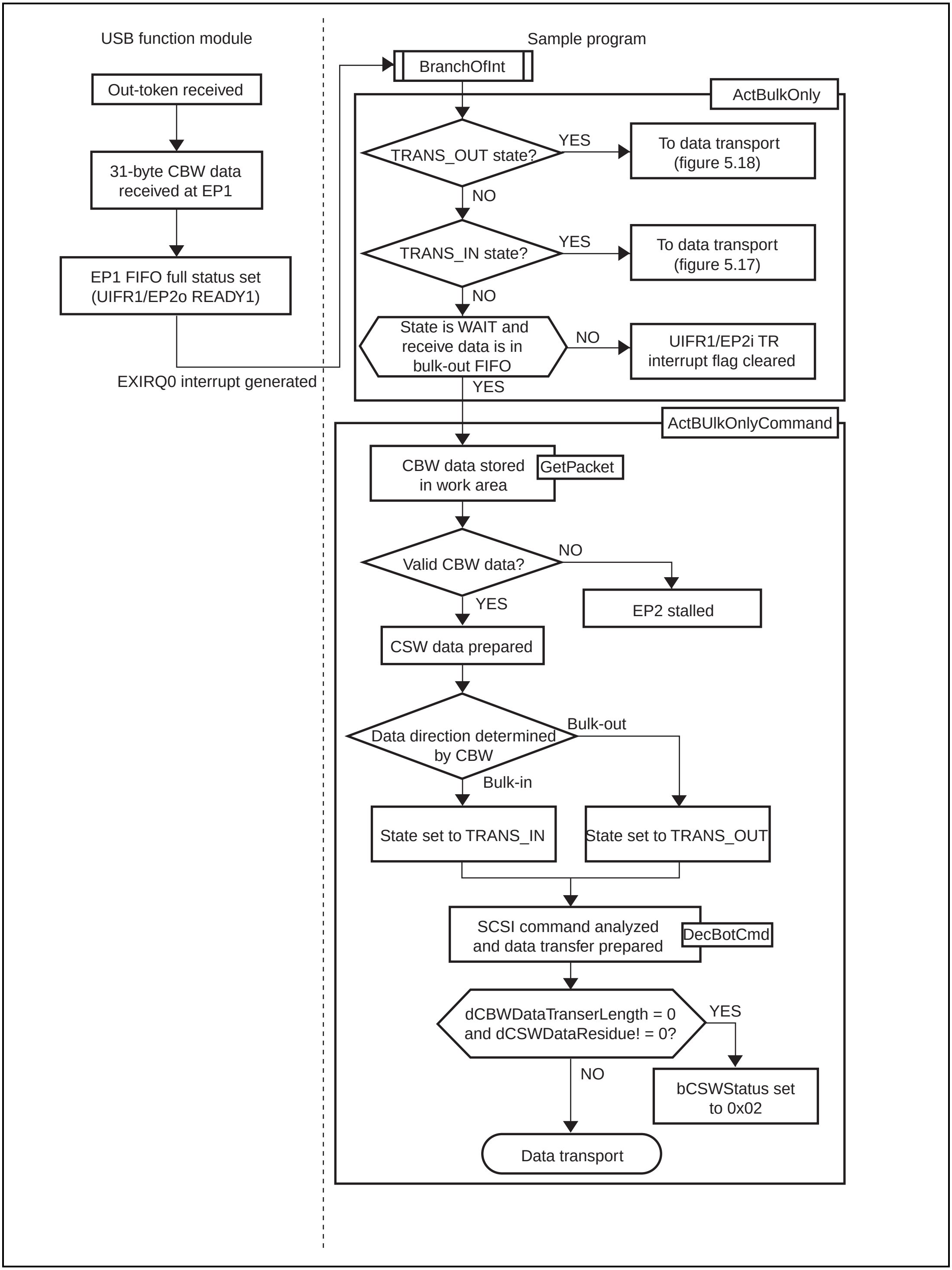


Figure 5.16 Command Transport

5.7.2 Data Transport

With data transport, data is sent and received between the host and the function.

At this point, the firmware is in either the TRANS_IN or TRANS_OUT state.

If the firmware state is TRANS_IN (bulk-in transport), the following three types of processing are carried out.

1. Data is sent from the function to the host.
2. If the length of the data sent by the function is shorter than the length planned by the host, 0 is added.
3. The information to be sent by the CSW is created.

Figure 5.17 shows the operations that take place when data transport (bulk-in transport) is carried out in the sample program. The operation of the USB function module is shown at the left side of the illustration.

In this sample software, if the length of the data sent by the function is shorter than the length of the data requested by the host, 0 is added after the data sent by the function, as noted in the Bulk-Only Transport of the USB Mass Storage Class, and after data of the length requested by the host has been sent, the number of 0 bytes added is reported, using status transport.

In order to carry out this operation, the following is used as global variables: the dCBWDataTransferLength of the CBW data, the dCSWDataResidue of the CSW data, and the bCSWStatus of the CSW data.

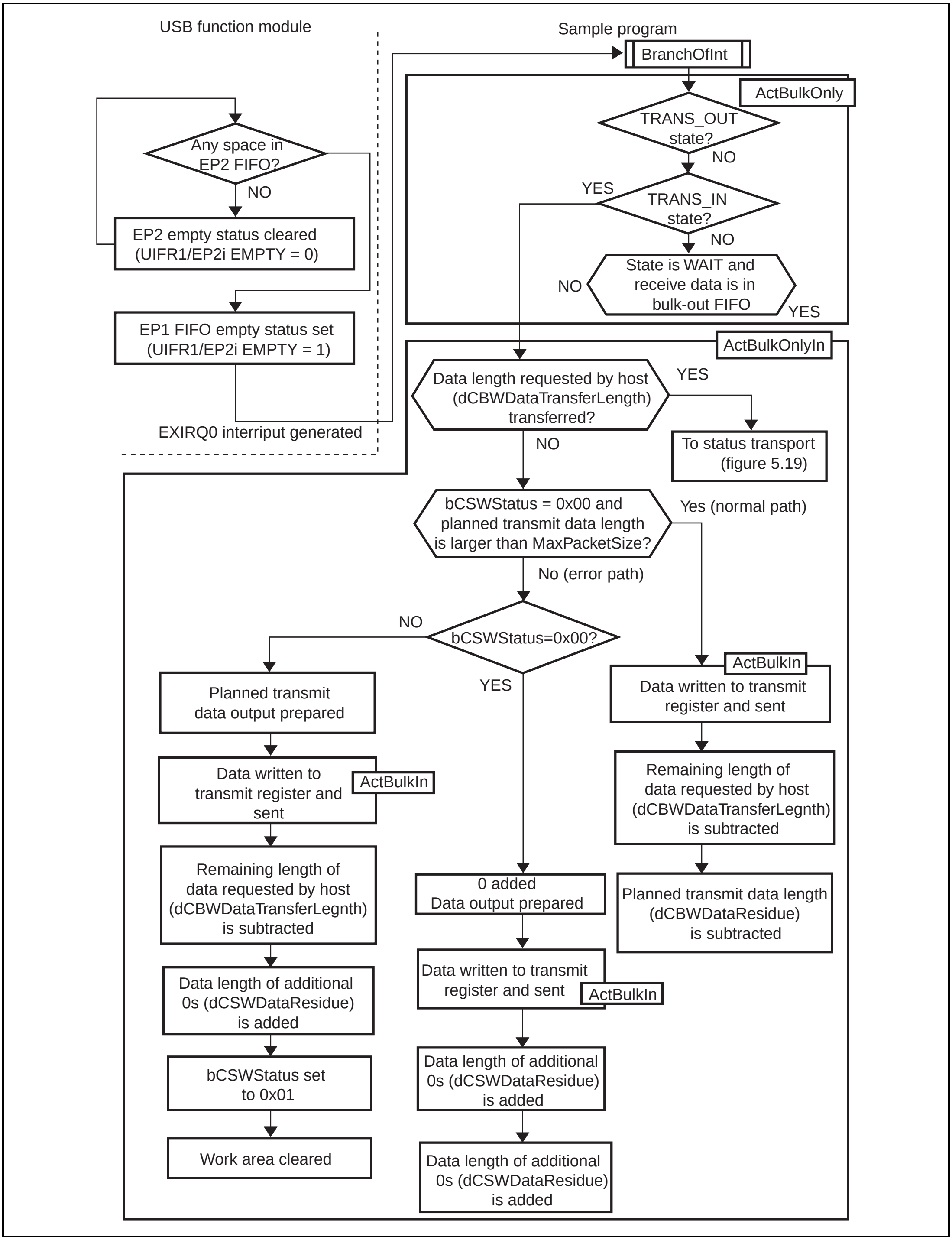


Figure 5.17 Data Transport (Bulk-In Transport)

Figure 5.18 shows the operations that take place when data transport (bulk-out transport) is carried out in the sample program. The operation of the USB function module is shown at the left side of the illustration.

If the firmware state is TRANS_OUT (bulk-out transport), the following three types of processing are carried out.

1. Data from the host is received in the function.
2. Data length is calculated.
3. The information to be sent by the CSW is created.

In this sample software, if the length of the data received by the function is shorter than the length of the data that the host planned to send, the missing length of data received by the function using data transport is reported using status transport, as noted in the Bulk-Only Transport of the USB Mass Storage Class.

In order to carry out this operation, the following is used as global variables: the dCBWDataTransferLength of the CBW data and the dCSWDataResidue of the CSW data.

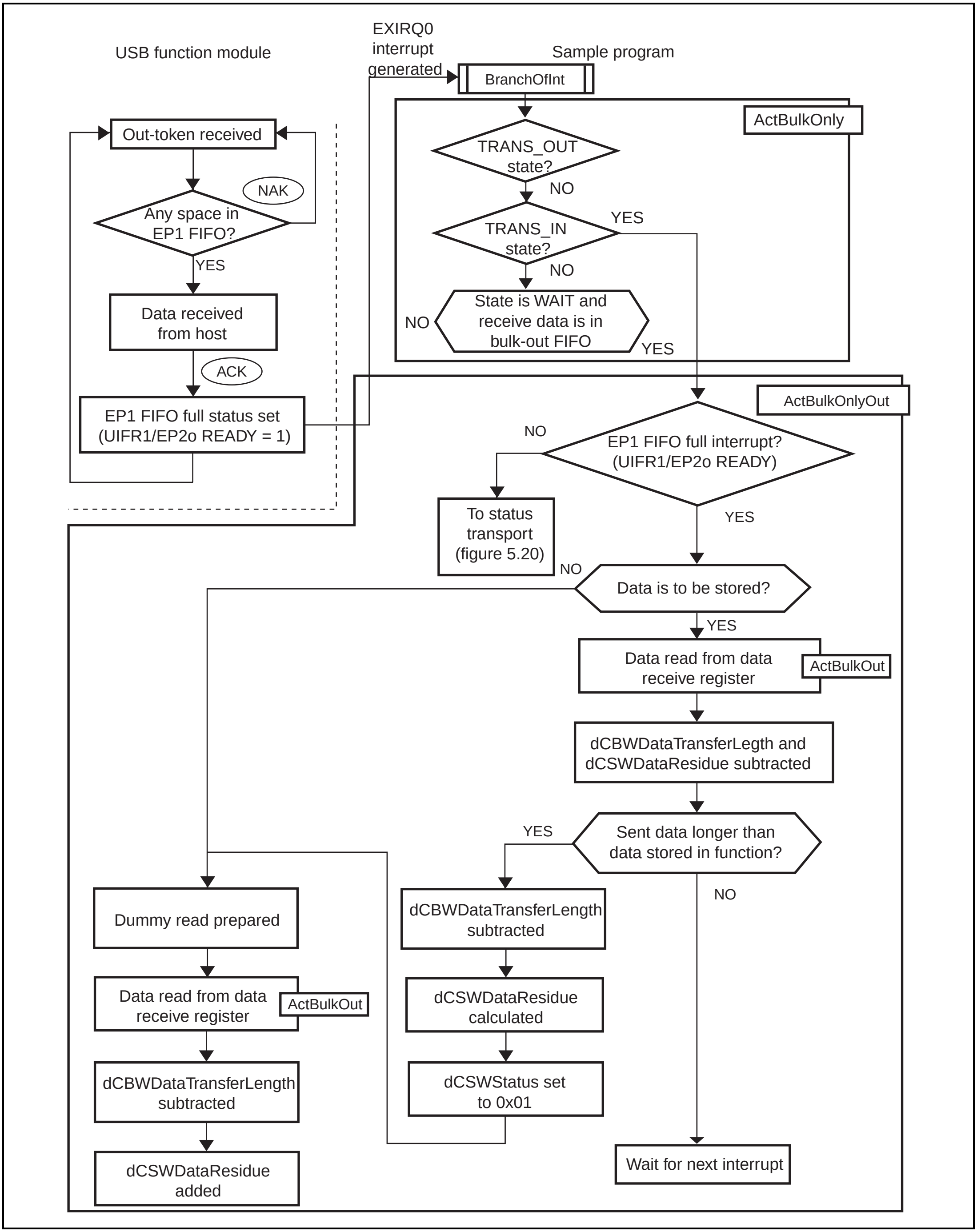


Figure 5.18 Data Transport (Bulk-Out Transport)

5.7.3 Status Transport

With status transport, data is sent from the function to the host.

At this point, the firmware is in either the TRANS_IN or TRANS_OUT state.

If the firmware state is TRANS_IN (bulk-in transport), the following four types of processing are carried out.

1. EP2 empty status interrupts are inhibited.
2. The system prepares to send the CSW data.
3. The CSW data is issued.
4. The firmware state is set to WAIT.

Figure 5.19 shows the operations that take place when status transport (data transport bulk-in transport) is carried out in the sample program. The operation of the USB function module is shown at the left side of the illustration.

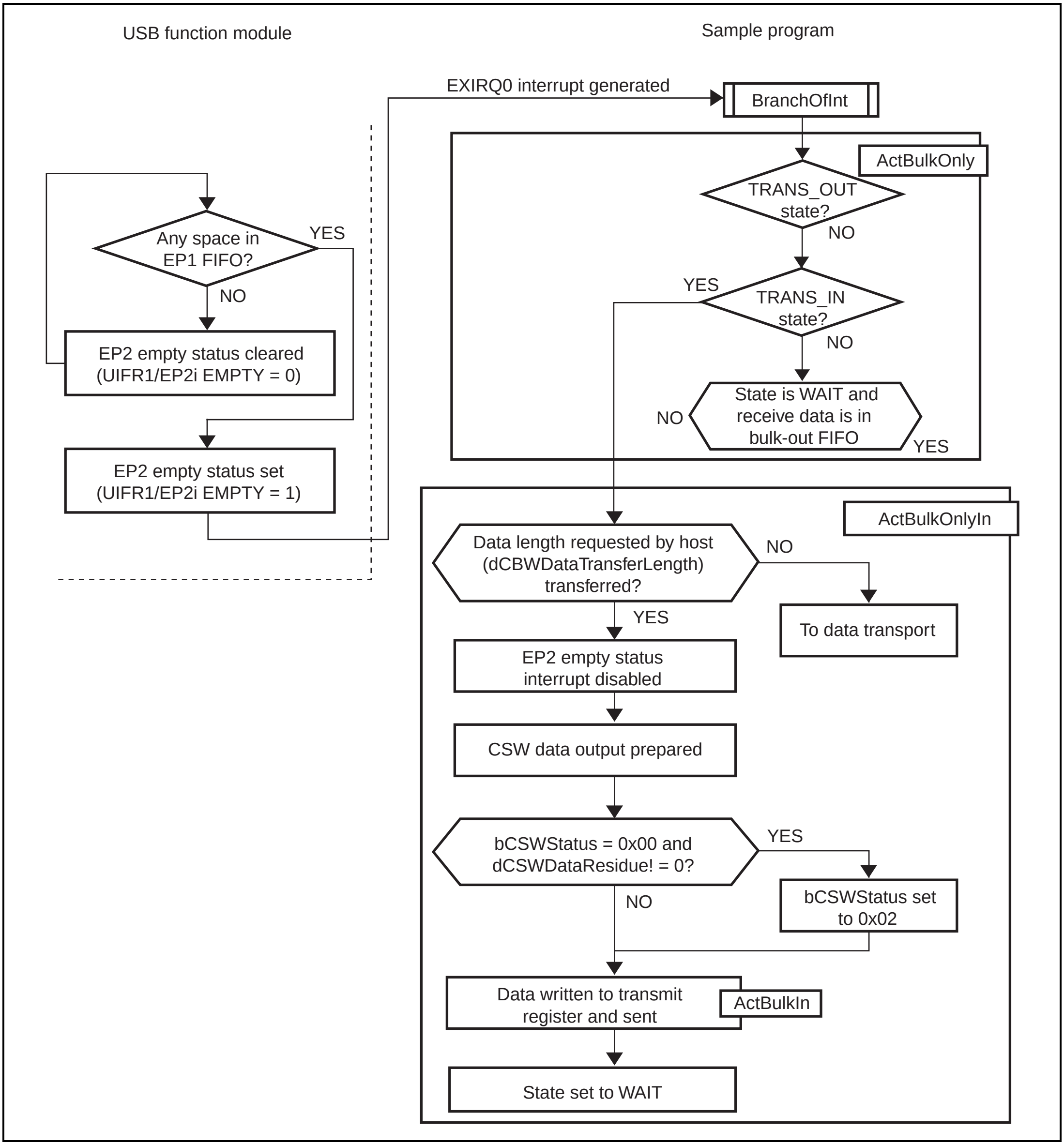


Figure 5.19 Status Transport (Data Transport Bulk-In Transport)

Figure 5.20 shows the operations that take place when status transport (data transport bulk-out transport) is carried out in the sample program. The operation of the USB function module is shown at the left side of the illustration.

If the firmware state is TRANS_OUT (bulk-out transport), the following four types of processing are carried out.

1. Preparation is made to send the CSW data.
2. The data is checked to see if any data is missing from the reception.
3. The CSW data is issued.
4. The firmware state is set to WAIT.

In this sample software, if the length of the data received by the function is shorter than the length of the data that the host planned to send, the missing length of data received by the function using data transport is reported using status transport, as noted in the Bulk-Only Transport of the USB Mass Storage Class. In order to do this, a check is made to see if there is any data missing that should have been received by the function, and if there is, the value of the bCSWStatus of the CSW data is set to 0x02 (phase error).

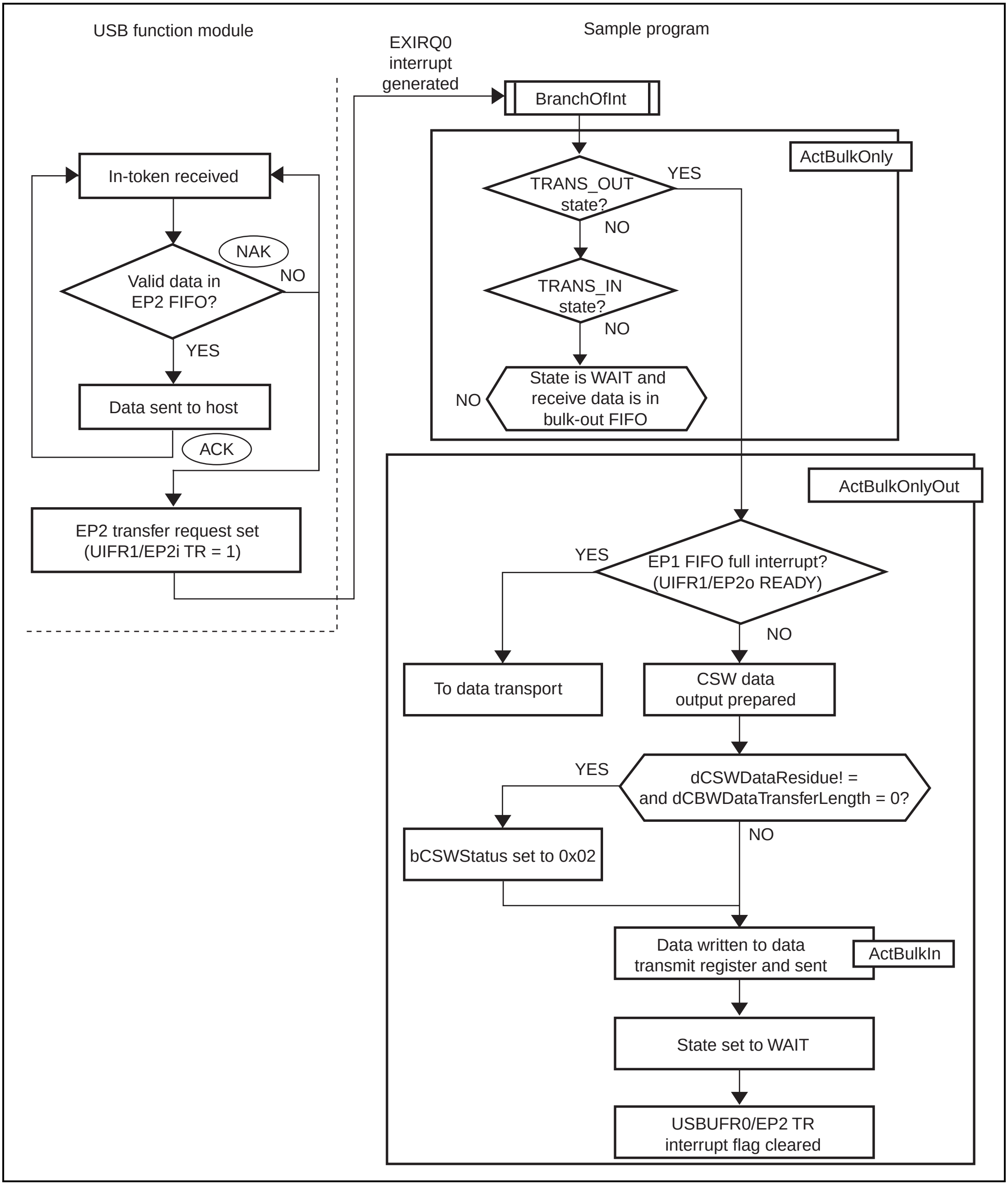
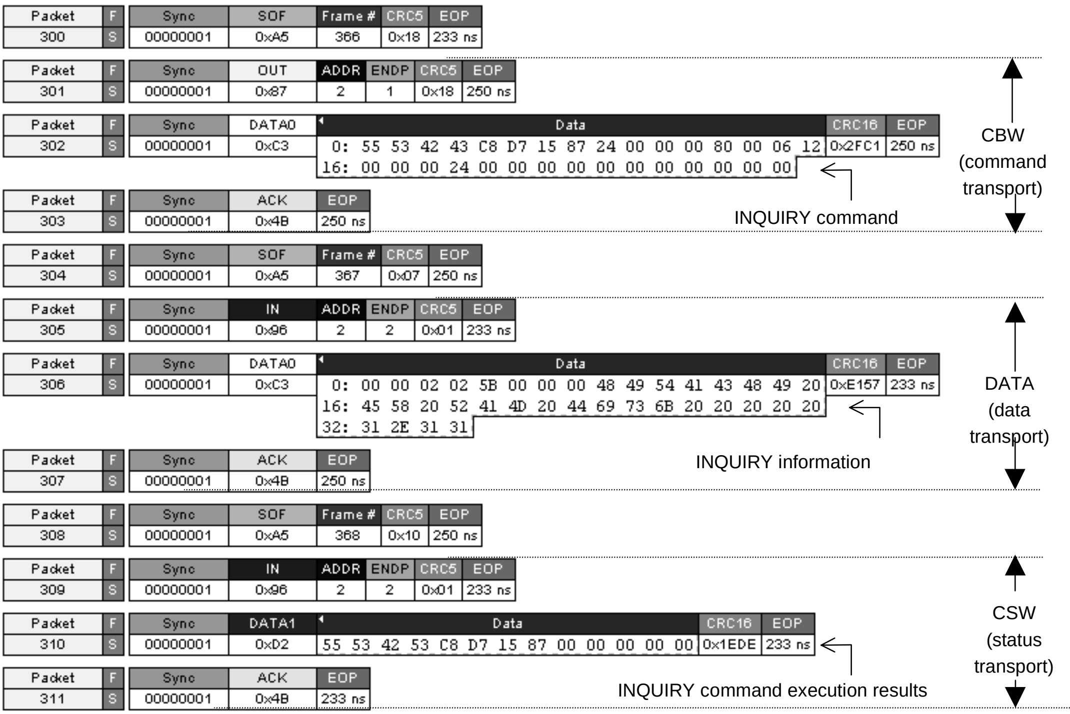


Figure 5.20 Status Transport (Data Transport Bulk-Out Transport)

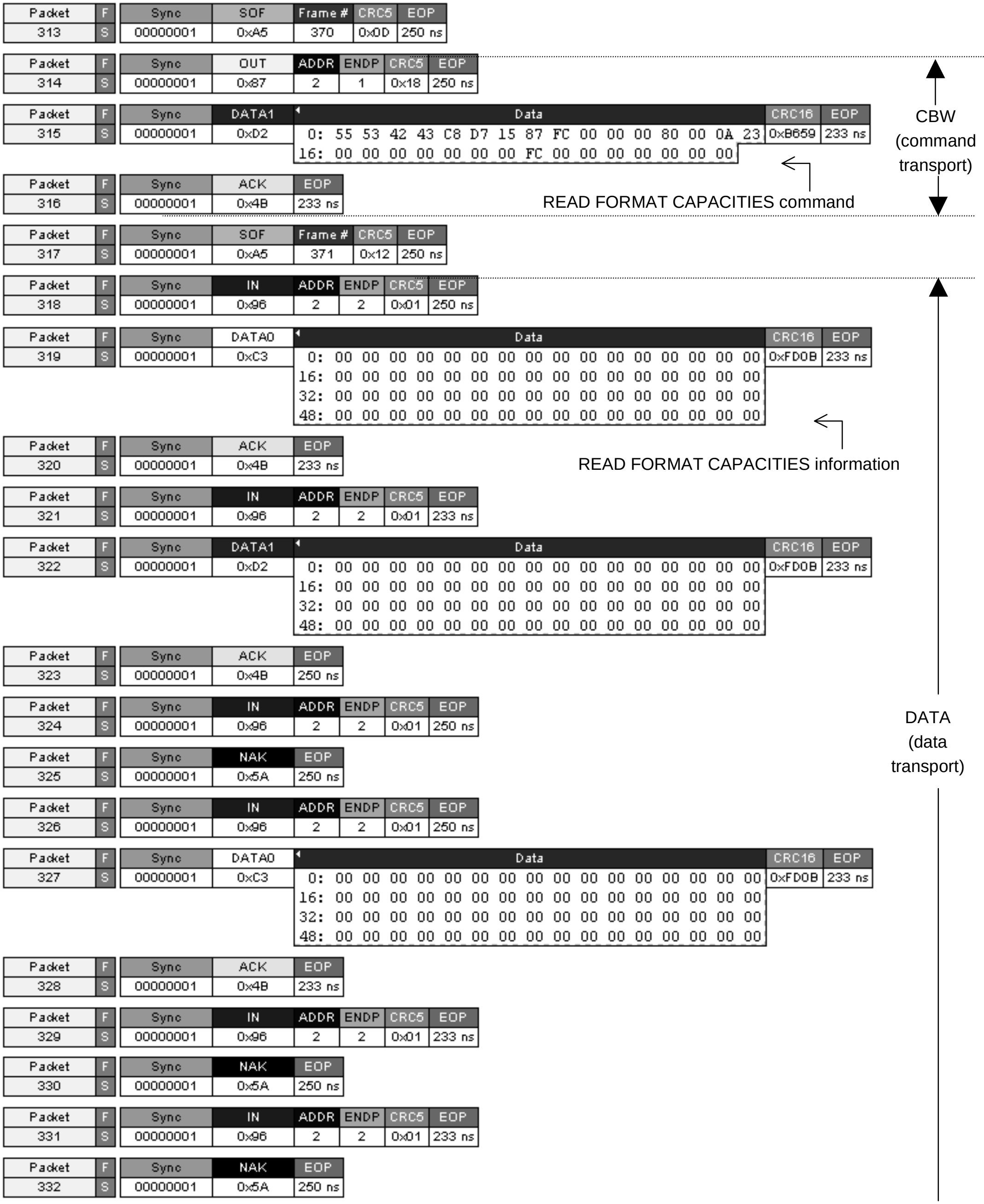
In this chapter, we look at how measurement is carried out with the USB Inspector, a USB protocol analyzer made by CATC (http://www.catc.com), using the USB function module in the H8S/2215, and at what happens to the data as it actually flows along the bus. For more detailed information on the packets, please see section 2.3.

Note: The Packet found in front of each packet is the packet number used when measuring.

- INQUIRY command



- READ FORMAT CAPACITIES command



RENESAS

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
333	S	00000001	0x96	2	2	0x01	233 ns

Packet	F	Sync	DATA1	Data	CRC16	EOP
334	S	00000001	0xD2	0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 32: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 48: 00 00 00 00 00 00 00 00 00 00 00 00	0x0024	250 ns

Packet	F	Sync	ACK	EOP
335	S	00000001	0x4B	250 ns

Packet	F	Sync	SOF	Frame #	CRC5	EOP
336	S	00000001	0xA5	372	0x0C	233 ns

CSW (status transport)

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
337	S	00000001	0x96	2	2	0x01	250 ns

Packet	F	Sync	DATA0	Data	CRC16	EOP
338	S	00000001	0xC3	0: 55 53 42 53 C8 D7 15 87 8: FC 00 00 00 01	0x97F5	233 ns

Packet	F	Sync	ACK	EOP
339	S	00000001	0x4B	250 ns

Packet	F	Sync	SOF	Frame #	CRC5	EOP
340	S	00000001	0xA5	373	0x13	233 ns

- READ CAPACITY command

Packet	F	Sync	SOF	Frame #	CRC5	EOP
438	S	00000001	0xA5	396	0x03	250 ns

CBW (command transport)

Packet	F	Sync	OUT	ADDR	ENDP	CRC5	EOP
439	S	00000001	0x87	2	1	0x18	250 ns

Packet	F	Sync	DATA1	Data	CRC16	EOP
440	S	00000001	0xD2	0: 55 53 42 43 C8 D7 15 87 08 00 00 00 80 00 0A 25 16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	0x1B59	250 ns

READ CAPACITY command

Packet	F	Sync	ACK	EOP
441	S	00000001	0x4B	233 ns

Packet	F	Sync	SOF	Frame #	CRC5	EOP
442	S	00000001	0xA5	397	0x1C	250 ns

DATA (data transport)

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
443	S	00000001	0x96	2	2	0x01	233 ns

Packet	F	Sync	DATA1	Data	CRC16	EOP
444	S	00000001	0xD2	00 00 08 00 00 00 02 00	0xFD3B	233 ns

READ CAPACITY information

Packet	F	Sync	ACK	EOP
445	S	00000001	0x4B	233 ns

Packet	F	Sync	SOF	Frame #	CRC5	EOP
446	S	00000001	0xA5	398	0x1E	250 ns

CSW (status transport)

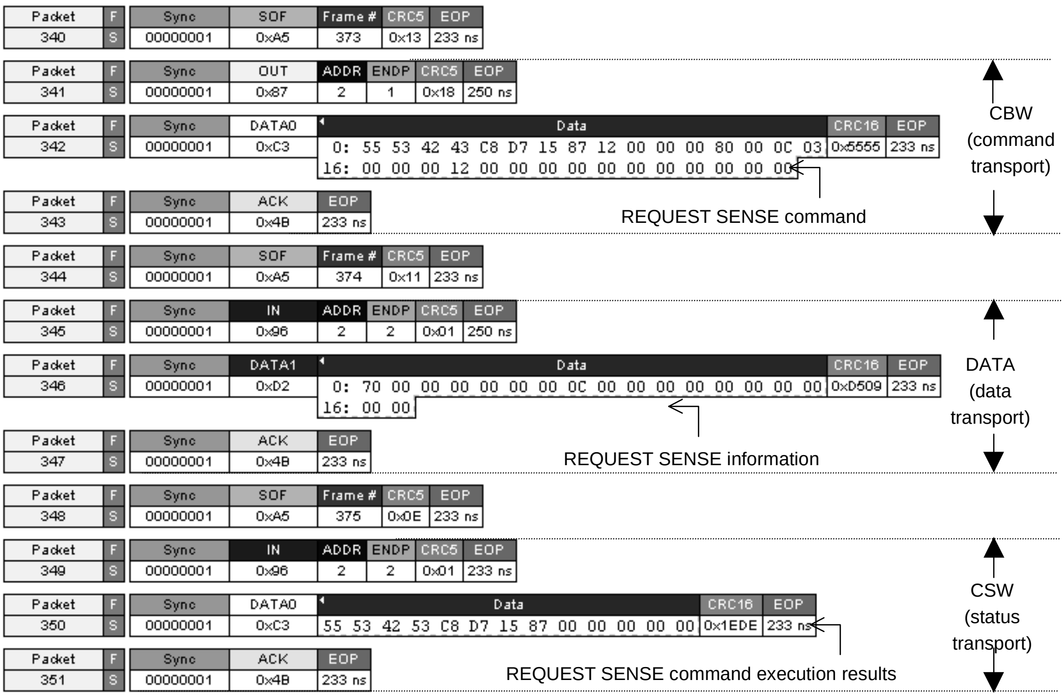
Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
447	S	00000001	0x96	2	2	0x01	233 ns

Packet	F	Sync	DATA0	Data	CRC16	EOP
448	S	00000001	0xC3	55 53 42 53 C8 D7 15 87 00 00 00 00 00	0x1EDE	250 ns

READ CAPACITY command

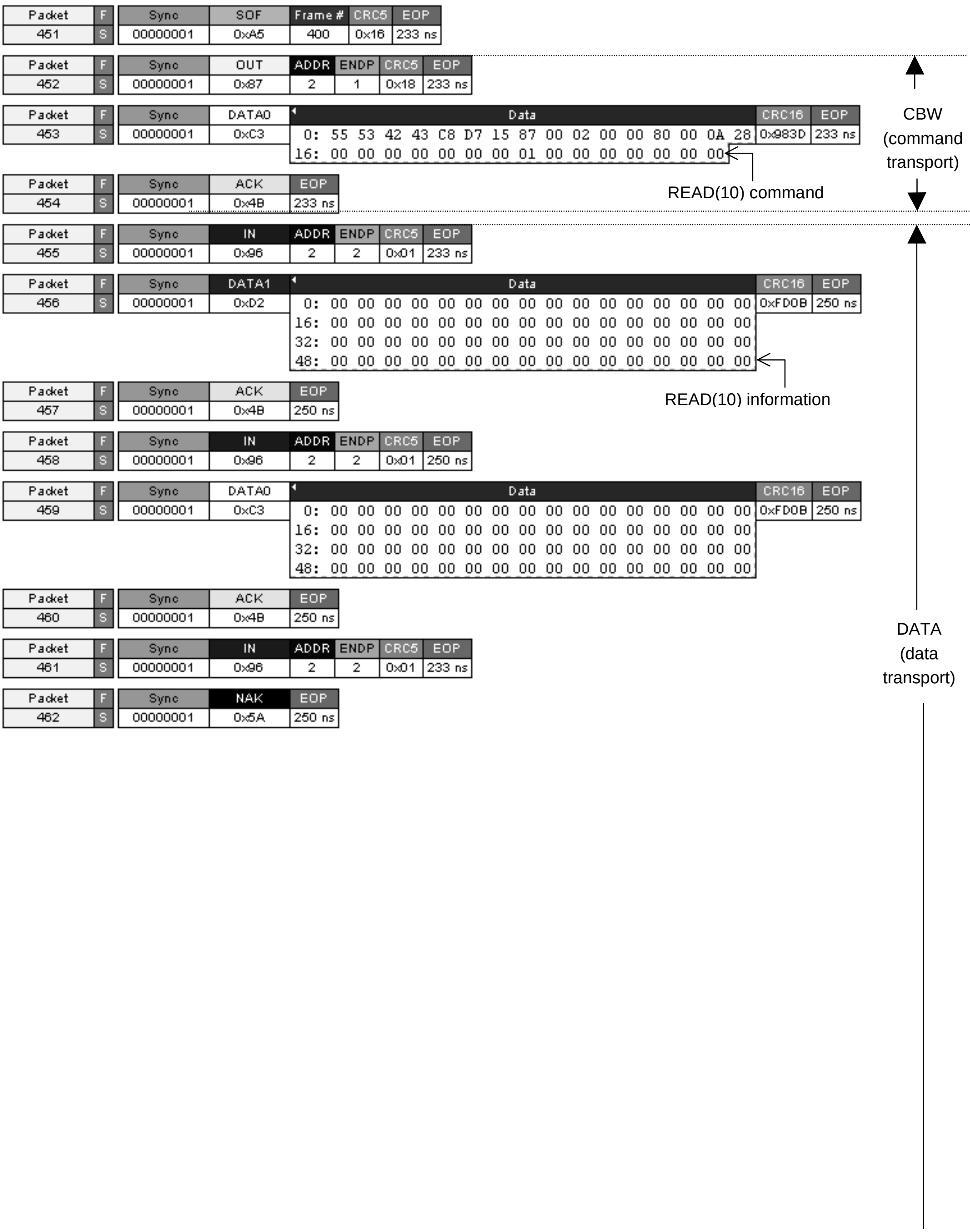
Packet	F	Sync	ACK	EOP
449	S	00000001	0x4B	233 ns

- REQUEST SENSE command



RENESAS

- READ(10) command



Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
463	S	00000001	0x96	2	2	0x01	233 ns

Packet	F	Sync	DATA1	Data	CRC16	EOP
464	S	00000001	0xD2	0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	0xFD0B	250 ns
				16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				32: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				48: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		

Packet	F	Sync	ACK	EOP
465	S	00000001	0x4B	250 ns

Packet	F	Sync	SOF	Frame #	CRC5	EOP
466	S	00000001	0xA5	401	0x09	233 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
467	S	00000001	0x96	2	2	0x01	233 ns

Packet	F	Sync	DATA0	Data	CRC16	EOP
468	S	00000001	0xC3	0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	0xFD0B	233 ns
				16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				32: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				48: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		

DATA (data transport)

Packet	F	Sync	ACK	EOP
469	S	00000001	0x4B	250 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
470	S	00000001	0x96	2	2	0x01	250 ns

Packet	F	Sync	DATA1	Data	CRC16	EOP
471	S	00000001	0xD2	0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	0xFD0B	233 ns
				16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				32: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				48: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		

Packet	F	Sync	ACK	EOP
472	S	00000001	0x4B	233 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
473	S	00000001	0x96	2	2	0x01	233 ns

Packet	F	Sync	NAK	EOP
474	S	00000001	0x5A	233 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
475	S	00000001	0x96	2	2	0x01	233 ns

Packet	F	Sync	DATA0	Data	CRC16	EOP
476	S	00000001	0xC3	0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	0xFD0B	233 ns
				16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				32: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				48: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		

Packet	F	Sync	ACK	EOP
477	S	00000001	0x4B	250 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
478	S	00000001	0x96	2	2	0x01	250 ns

Packet	F	Sync	NAK	EOP
479	S	00000001	0x5A	250 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
480	S	00000001	0x96	2	2	0x01	233 ns

Packet	F	Sync	NAK	EOP
481	S	00000001	0x5A	250 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
482	S	00000001	0x96	2	2	0x01	233 ns

Packet	F	Sync	DATA1	Data	CRC16	EOP
483	S	00000001	0xD2	0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	0x7B08	250 ns
				16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				32: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				48: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 80 00		

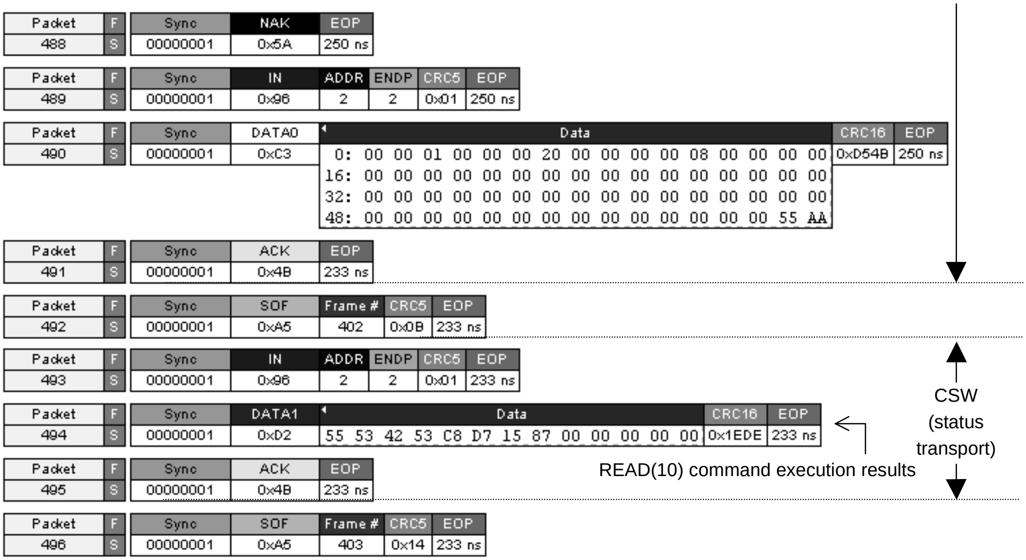
Packet	F	Sync	ACK	EOP
484	S	00000001	0x4B	250 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
485	S	00000001	0x96	2	2	0x01	250 ns

Packet	F	Sync	NAK	EOP
486	S	00000001	0x5A	250 ns

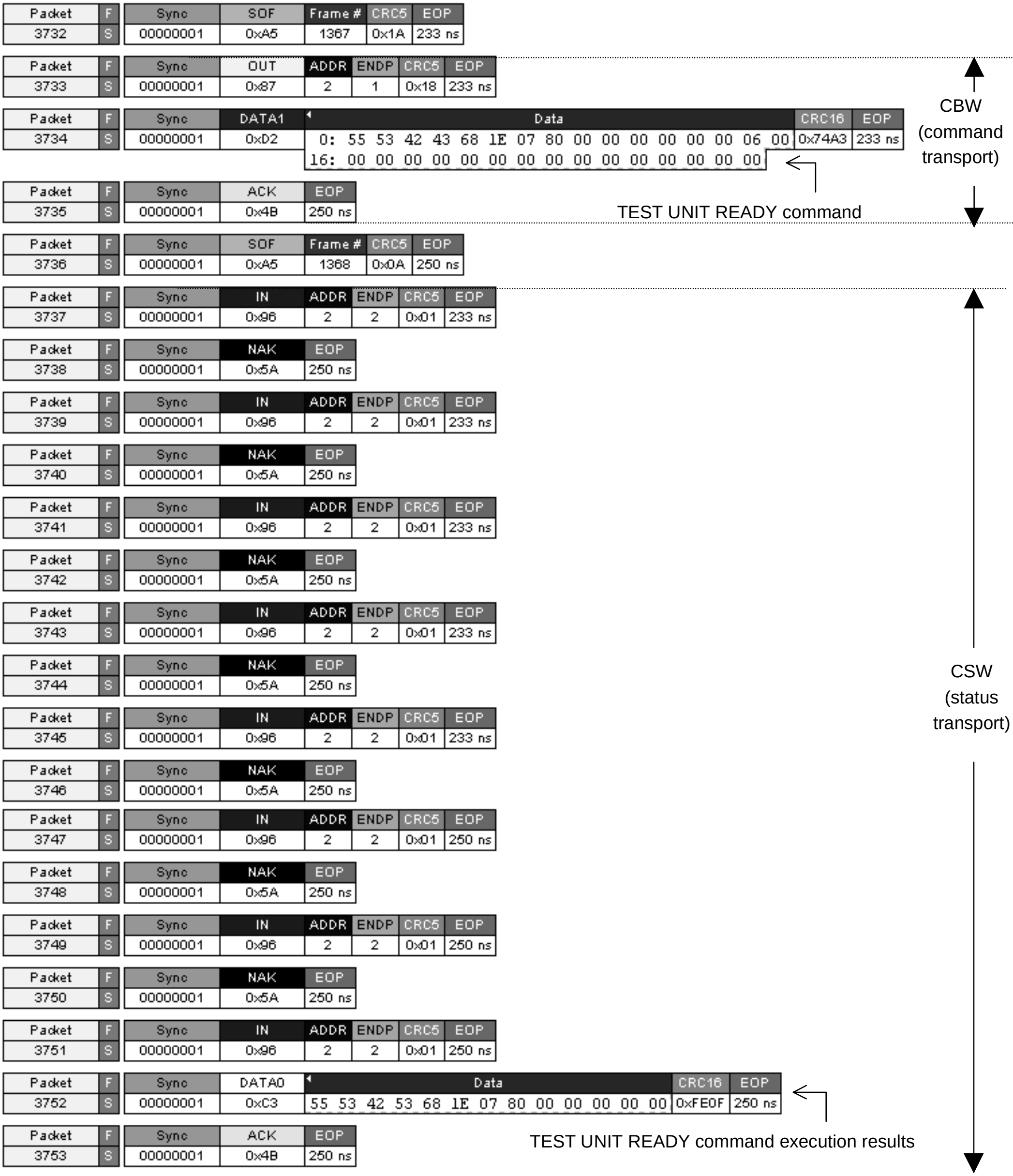
Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
487	S	00000001	0x96	2	2	0x01	250 ns

DATA
(data
transport)

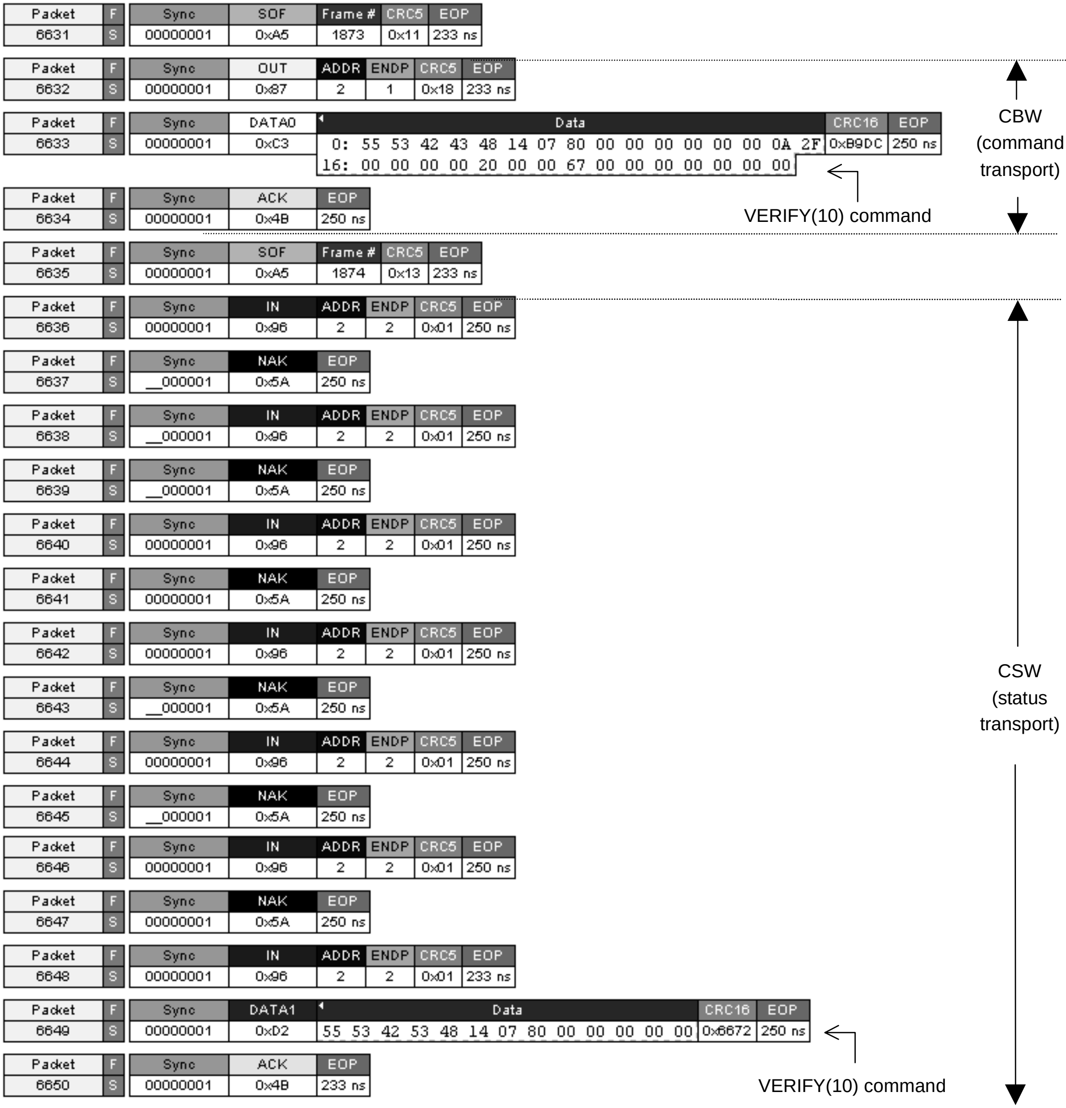

Packet 488 F S Sync 00000001 NAK 0x5A EOP 250 ns
Packet 489 F S Sync 00000001 IN 0x96 ADDR 2 ENDP 2 CRC5 0x01 EOP 250 ns
Packet 490 F S Sync 00000001 DATA0 0xC3 Data CRC16 0xD54B EOP 250 ns
0: 00 00 01 00 00 00 20 00 00 00 00 08 00 00 00 00
16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
32: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
48: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 55 AA
Packet 491 F S Sync 00000001 ACK 0x4B EOP 233 ns
Packet 492 F S Sync 00000001 SOF 0xA5 Frame # 402 CRC5 0x0B EOP 233 ns
Packet 493 F S Sync 00000001 IN 0x96 ADDR 2 ENDP 2 CRC5 0x01 EOP 233 ns
Packet 494 F S Sync 00000001 DATA1 0xD2 Data 55 53 42 53 C8 D7 15 87 00 00 00 00 00 CRC16 0x1EDE EOP 233 ns
Packet 495 F S Sync 00000001 ACK 0x4B EOP 233 ns
Packet 496 F S Sync 00000001 SOF 0xA5 Frame # 403 CRC5 0x14 EOP 233 ns
CSW
(status
transport)
READ(10) command execution results

RENESAS

TEST UNIT READY command

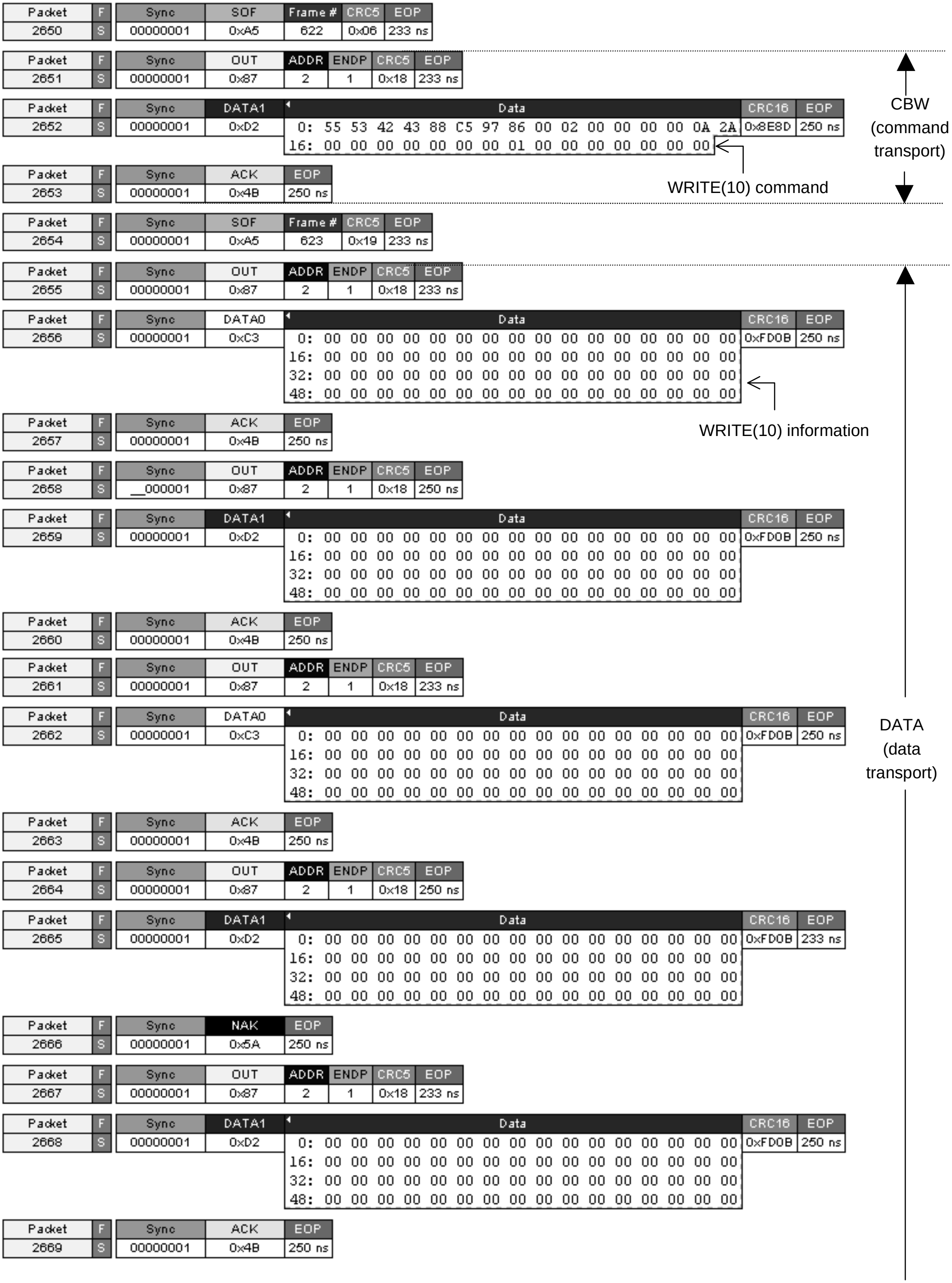


- VERIFY(10) command



RENESAS

- WRITE(10) command



Packet	F	Sync	OUT	ADDR	ENDP	CRC5	EOP
2670	S	00000001	0x87	2	1	0x18	250 ns

Packet	F	Sync	DATA0	Data	CRC16	EOP
2671	S	00000001	0xC3	0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	0xFD0B	233 ns
				16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				32: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				48: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		

Packet	F	Sync	ACK	EOP
2672	S	00000001	0x4B	250 ns

Packet	F	Sync	OUT	ADDR	ENDP	CRC5	EOP
2673	S	00000001	0x87	2	1	0x18	233 ns

Packet	F	Sync	DATA1	Data	CRC16	EOP
2674	S	00000001	0xD2	0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	0xFD0B	250 ns
				16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				32: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				48: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		

Packet	F	Sync	ACK	EOP
2675	S	00000001	0x4B	250 ns

Packet	F	Sync	OUT	ADDR	ENDP	CRC5	EOP
2676	S	00000001	0x87	2	1	0x18	250 ns

Packet	F	Sync	DATA0	Data	CRC16	EOP
2677	S	00000001	0xC3	0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	0xF311	233 ns
				16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				32: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				48: 00 00 00 00 00 00 00 00 70 77 CA C0 00 00 80 00		

Packet	F	Sync	NAK	EOP
2678	S	00000001	0x5A	250 ns

Packet	F	Sync	OUT	ADDR	ENDP	CRC5	EOP
2679	S	00000001	0x87	2	1	0x18	233 ns

Packet	F	Sync	DATA0	Data	CRC16	EOP
2680	S	00000001	0xC3	0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	0xF311	250 ns
				16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				32: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				48: 00 00 00 00 00 00 00 00 70 77 CA C0 00 00 80 00		

Packet	F	Sync	ACK	EOP
2681	S	00000001	0x4B	250 ns

Packet	F	Sync	OUT	ADDR	ENDP	CRC5	EOP
2682	S	00000001	0x87	2	1	0x18	250 ns

Packet	F	Sync	DATA1	Data	CRC16	EOP
2683	S	00000001	0xD2	0: 00 00 01 00 00 00 20 00 00 00 00 08 00 00 00 00	0xD54B	233 ns
				16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				32: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00		
				48: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 55 AA		

Packet	F	Sync	ACK	EOP
2684	S	00000001	0x4B	250 ns

DATA (data transport)

Packet	F	Sync	SOF	Frame #	CRC5	EOP
2685	S	00000001	0xA5	624	0x0E	233 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
2686	S	00000001	0x96	2	2	0x01	233 ns

Packet	F	Sync	NAK	EOP
2687	S	00000001	0x5A	250 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
2688	S	00000001	0x96	2	2	0x01	233 ns

Packet	F	Sync	NAK	EOP
2689	S	00000001	0x5A	250 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
2690	S	00000001	0x96	2	2	0x01	233 ns

Packet	F	Sync	NAK	EOP
2691	S	00000001	0x5A	250 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
2692	S	00000001	0x96	2	2	0x01	233 ns

Packet	F	Sync	NAK	EOP
2693	S	00000001	0x5A	250 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
2694	S	00000001	0x96	2	2	0x01	250 ns

Packet	F	Sync	NAK	EOP
2695	S	00000001	0x5A	250 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
2696	S	00000001	0x96	2	2	0x01	250 ns

Packet	F	Sync	NAK	EOP
2697	S	00000001	0x5A	250 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
2698	S	00000001	0x96	2	2	0x01	250 ns

Packet	F	Sync	NAK	EOP
2699	S	00000001	0x5A	250 ns

Packet	F	Sync	IN	ADDR	ENDP	CRC5	EOP
2700	S	00000001	0x96	2	2	0x01	250 ns

Packet	F	Sync	DATA1	Data	CRC16	EOP
2701	S	00000001	0xD2	55 53 42 53 88 C5 97 86 00 00 00 00 00	0x562D	250 ns

WRITE(10) command execution results

Packet	F	Sync	ACK	EOP
2702	S	00000001	0x4B	250 ns

CSW (status transport)

H8S/2215, HD64F2215-USB Function Module

Mass Storage Class (Bulk-Only Transport)

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