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SH7705 USB Function Module Mass Storage Class (Bulk-Only Transport)

Application Note

Renesas SuperH™ RISC Engine

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Preface

This application note describes the Mass Storage Class (Bulk-Only Transport) firmware that uses the USB Function Module in the SH7705. This is provided to be used as a reference when the user creates USB Function Module firmware.

This application note and the described software are application examples of the USB Function Module, and their contents and operation are not guaranteed.

In addition to this application note, 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
- SH7705 Hardware Manual
- SH7705 Solution Engine (MS7705SE01) Instruction Manual
- SH7705 E10A Emulator User's Manual

[Caution] The sample programs described in this application note do not include firmware related to interrupts, which is a USB transport type. When using the transfer type (see page 18-1 of the SH7705 Hardware Manual), the user needs to create the program for it.

Also, the hardware specifications of the SH7705 and SH7705 Solution Engine, which will be necessary when developing the system described above, are described in this application note, but more detailed information is available in the SH7705 Hardware Manual and the SH7705 Solution Engine Instruction Manual.

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Section 1 Overview

This application note describes how to use the USB Function Module that is built into the SH7705, and contains examples of firmware programs.

The features of the USB Function Module contained in the SH7705 are listed below.

- An internal UDC (USB Device Controller) conforming to USB 1.1
- Automatic processing of USB protocols
- Automatic processing of USB standard commands for endpoint 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 based on clock oscillation CPG or external input (48 MHz) can be selected.
- Low power consumption mode provided
- An internal bus transceiver
- Power mode: Self mode

Endpoint Configurations

| Endpoint Name | Name | Transfer Type | Max. Packet Size | FIFO Buffer Capacity (bytes) | DMA Transfer |
|---------------|------|---------------|------------------|------------------------------|--------------|
| Endpoint 0 | EP0s | Setup | 8 bytes | 8 bytes | — |
| | EP0i | Control In | 8 bytes | 8 bytes | — |
| | EP0o | Control Out | 8 bytes | 8 bytes | — |
| Endpoint 1 | EP1 | Bulk-out | 64 bytes | 64 x 2 (128 bytes) | Possible |
| Endpoint 2 | EP2 | Bulk-in | 64 bytes | 64 x 2 (128 bytes) | Possible |
| Endpoint 3 | EP3 | Interrupt | 8 bytes | 8 bytes | — |

Figure 1.1 shows an example of a system configuration.

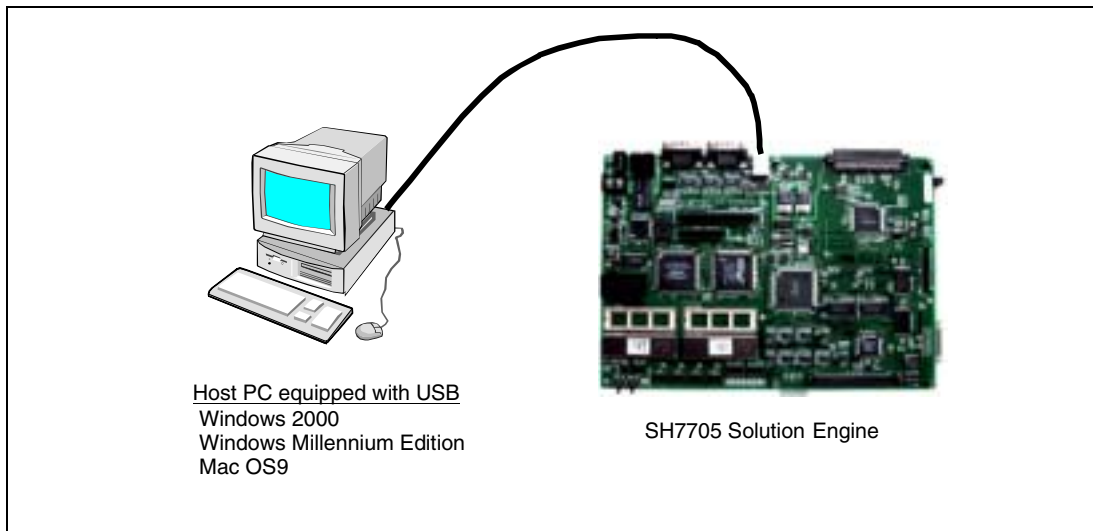


Figure 1.1 System Configuration Example

This system is configured of the SH7705 Solution Engine made by Hitachi ULSI Systems Co., Ltd. (hereafter referred to as the SH7705SE) and a PC containing Windows 2000/Windows Millennium Edition or Mac OS9 operating system.

By connecting the host PC and the SH7705SE through USB, the SDRAM in the SH7705SE can be accessed as a RAM disk, enabling data in the SDRAM of the SH7705SE 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 SH7705 quickly.
2. The sample program supports USB control transfer and bulk transport.
3. An E10A (PC card-type emulator) can be used, enabling efficient debugging.
4. Additional programs can be created to support interrupt transfer and isochronous transfer. *

Note: * Interrupt transfer program is 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.

In order to let the host PC know that a function is in this class, a value of 0x08 must be entered in the bInterface Class field of the Interface Descriptor. Also, the Serial Number should be known to the host PC in the Mass Storage Class by using String Descriptor. The sample programs provided here return 000000000000 in Unicode.

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.

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

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).

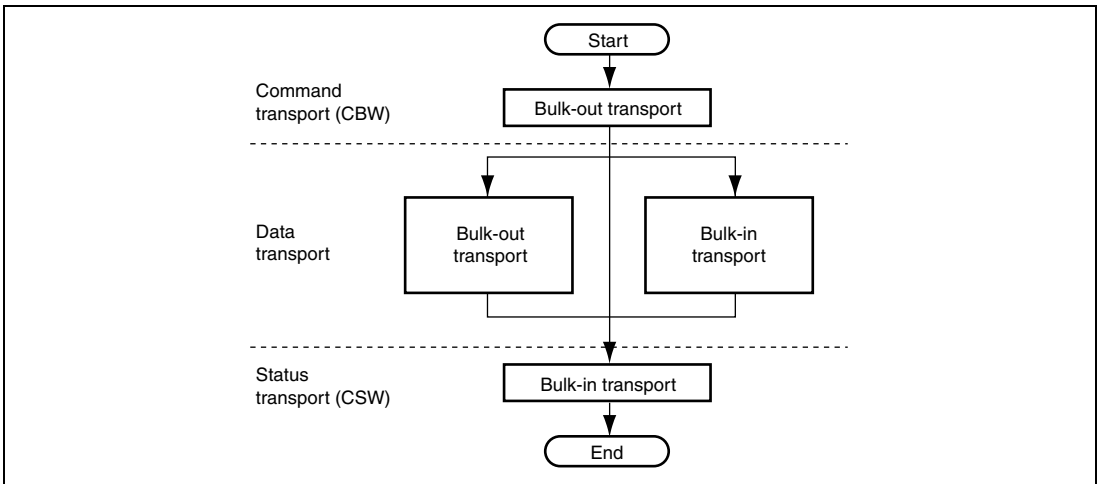


Figure 2.1 Relationship between Transfer Methods and Transports

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 ten 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(6) | 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. |
| 1B | STOP/START UNIT | Controls installing and removing media. |

Section 3 Development Environment

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

- SH7705 Solution Engine (hereafter called the SH7705SE; type number: MS7705SE01) manufactured by Hitachi ULSI Systems Co., Ltd.
- SH7705 E10A Emulator manufactured by Hitachi, Ltd.
- PC (Windows 95/98) equipped with a 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.

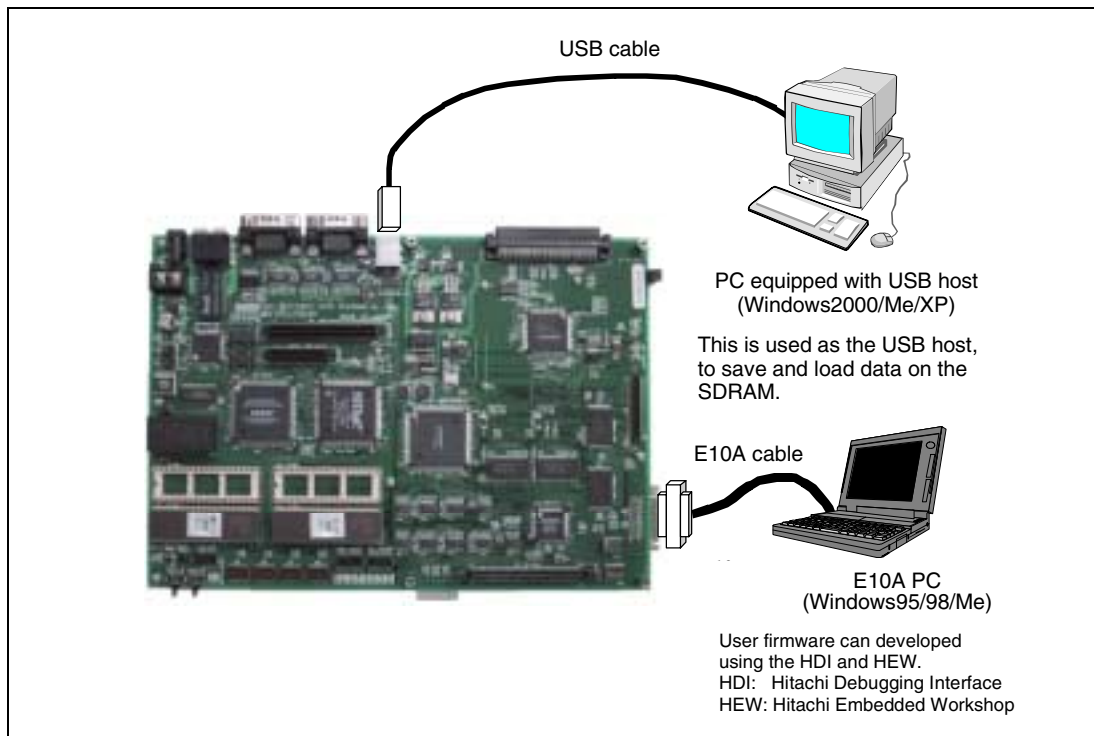


Figure 3.1 Device Connections

1. SH7705SE

Some DIP switch settings on the SH7705SE board must be changed from those at shipment. Before turning on the power, ensure that the switches are set as follows. There is no need to change any other DIP switches.

Table 3.1 DIP Switch Settings

| Switch | At Time of Shipment | After Change | DIP Switch Function |
|--------|---------------------|----------------|--------------------------------------|
| SW3-1 | ON | OFF | Select clock operating mode (Mode 5) |
| SW3-2 | ON | ON (No change) | |
| SW3-3 | ON | OFF | |
| SW3-6 | OFF | ON | Select endian |
| SW3-7 | OFF | ON | Select E10A emulator mode |
| SW3-8 | ON | OFF | Select E10A emulator mode |

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. E10A PC

The E10A should be inserted into a PC card slot and connected to the SH7705SE via an interface 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 SH7705 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.

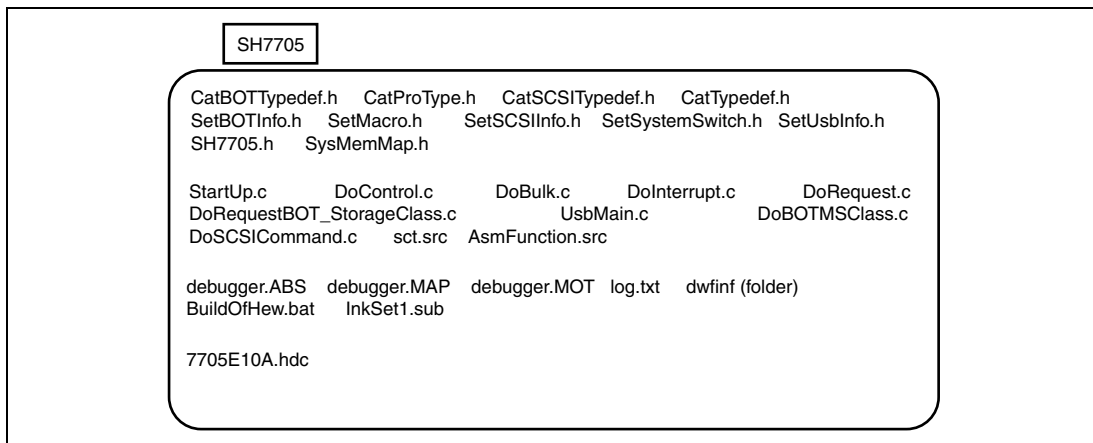


Figure 3.2 Files Included in the Folder

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).

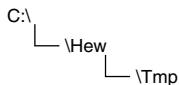


Figure 3.3 Creating a Working Folder

Next, the folder in which the sample program is stored (SH7705) should be copied to any arbitrary drive. In addition to the sample program, this folder contains a batch file named BuildOfHew.bat. This batch file sets the path, specifies compile options, specifies a log file indicating the compiling and linking results, and performs other operations. When BuildOfHew.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 to 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 shc.exe, and the setting for the environment variable shc_lib used by the compiler should be set to the folder of shc.exe; the shc_inc setting should be changed to the folder of machine.h, and the setting of shc_tmp should specify the work folder for the compiler. The library setting should specify the path of shcpic.lib.

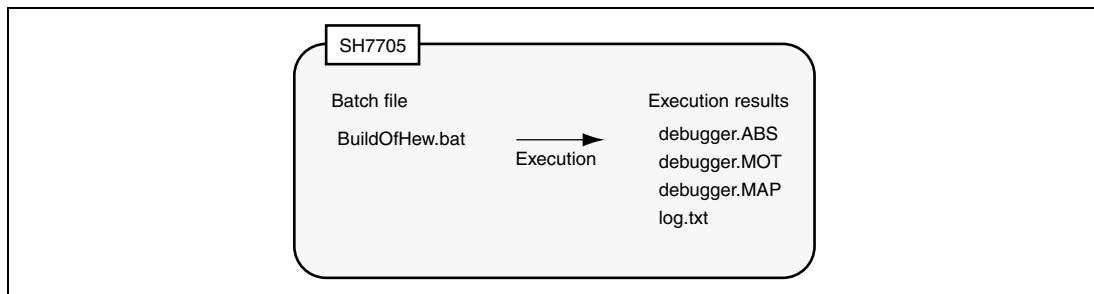


Figure 3.4 Compile Results

3.3 Loading and Executing the Program

Figure 3.5 shows the memory map for the sample program.

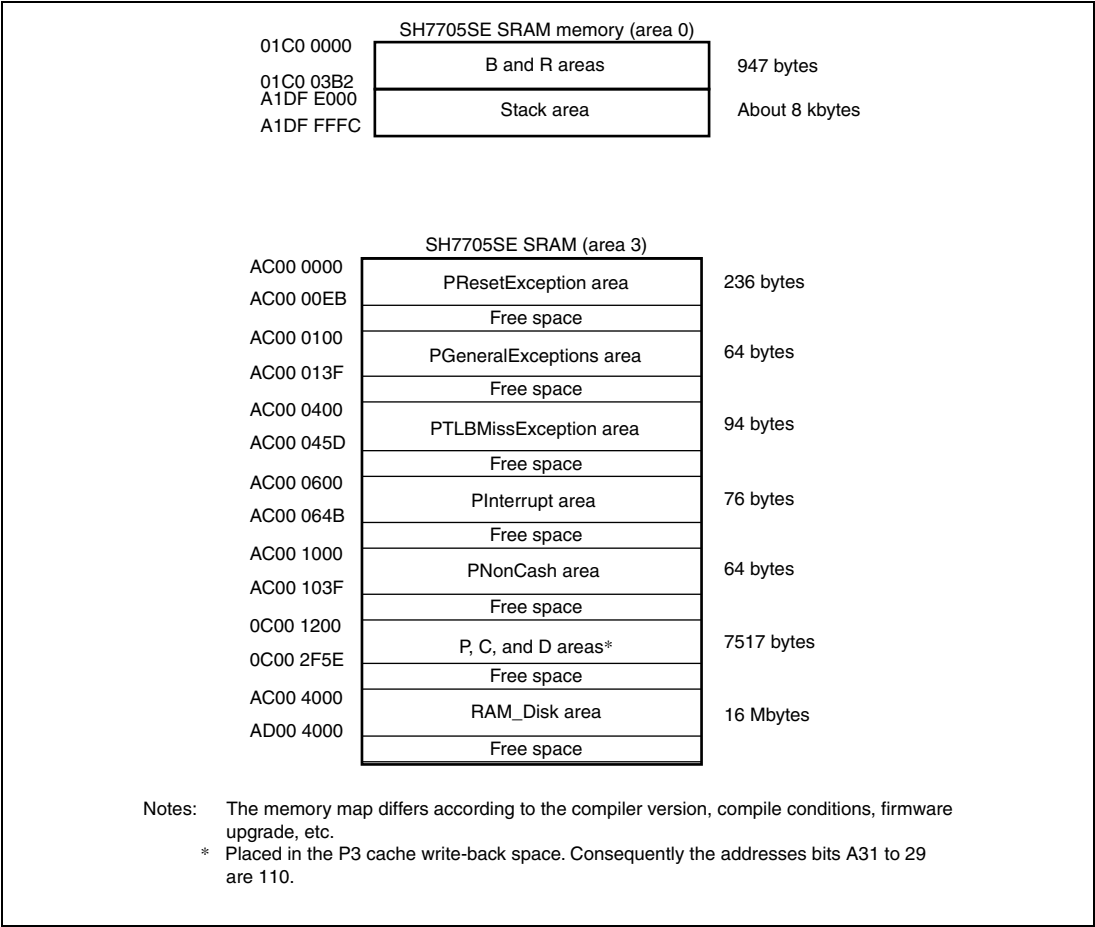


Figure 3.5 Memory Map

As shown in figure 3.5, this sample program allocates the PResetException, PGeneralExceptions, PTLBMissException, PInterrupt, PNonCash, and P, C, and D areas on SDRAM, the R and B areas on the SRAM. In order to use the E10A for break and other functions, the program must be placed in RAM in this way. These memory allocations are specified by the InkSet1.sub file in the SH7705 folder. When incorporating the program in ROM by writing it to flash memory or some other media, this file must be modified.

3.3.1 Loading the Program

In order to load the sample program into the RAM of the SH7705SE, the following procedure is used.

- Insert the E10A into the PC for use with the E10A, in which the HDI has been installed, and connect the E10A to the SH7705SE via a user system interface cable.
- Turn on the power to the E10A PC, to start up the machine.
- Start up the HDI.
- Turn on the power to the SH7705SE.
- A dialog (figure 3.6) is displayed on the PC screen; turn the SH7705SE reset switch (SW1) on, and after resetting the CPU, click the OK button, or press the Enter key.
- Select CommandLine in the View menu to open a window (figure 3.7), click the BatchFile button on the upper left, and specify the 7705E10A.hdc file in the SH7705 folder. As a result the access to the SDRAM is enabled and the program counter (PC) is set. To modify the values, change the contents of the 7705E10A.hdc.
- Select LoadProgram... from the File menu; in the Load Program dialog box, specify debugger.ABS in the SH7705 folder.

Through the above procedure, the sample program can be loaded into SDRAM of the SH7705SE.

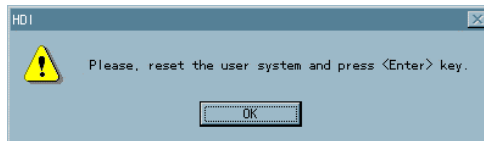


Figure 3.6 Reset Request Dialog

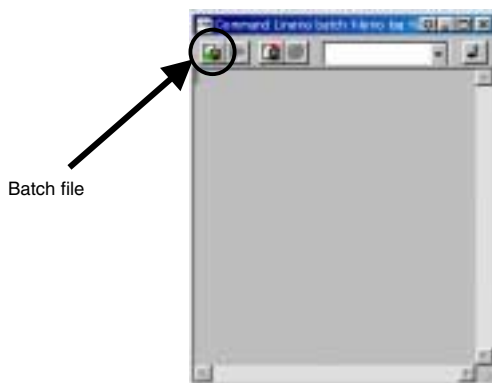


Figure 3.7 Command Line Input

3.3.2 Executing the Program

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 SH7705SE, 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, the USB large-size storage device is displayed under the USB controller in the device manager, and the Hitachi EX RAM Disk USB device is displayed under the disk drive. As a result, the host PC recognizes the SH7705SE 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 SH7705SE can now be used as the RAM disk for USB connection.

3.5 Changing the RAM Disk Setting

Changing the settings of the RAM disk used in this sample program provided here is described below.

3.5.1 Selection of Removable/Fixed Disk

In this sample program, the RAM disk is used as a removable disk.

Fixed disk can be used by commenting out `#define REMOVABLE_DISK` in `SetSystemSwitch.h` and enabling commented out `#undef REMOVABLE_DISK`.

3.5.2 Changing the Capacity of the RAM Disk

This sample program uses 16 Mbytes of SDRAM as the RAM disk. To change the capacity of the RAM disk the contents of `SysMemMap.h` need to be changed. First, specify the whole bytes*¹ for the RAM disk by `DISK_ALL_BYTE`. Then, specify the start and the end points of the area for the RAM disk by `SDRAM_DATA_S` and `SDRAM_DATA_E`*² respectively.

- Notes:
1. Specify 1.5 Mbytes or more. As some amount of area is used for such as the FAT information the capacity recognized by the computer is smaller than actual one. In this sample program, to configure FAT information up to 16 Mbytes and 2 Gbytes are used for FAT12 and FAT 16 respectively. Other FAT system information needs to be provided by the user.
 2. The area specified by `SDRAM_DATA_S` and `SDRAM_DATA_E` must be larger than the area specified by `DISK_ALL_BYTE`.

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 SH7705SE, 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 SH7705SE, there are two interrupts related to the USB function module: USBFI0 and USBFI1, but in this sample program, only USBFI0 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 three states.

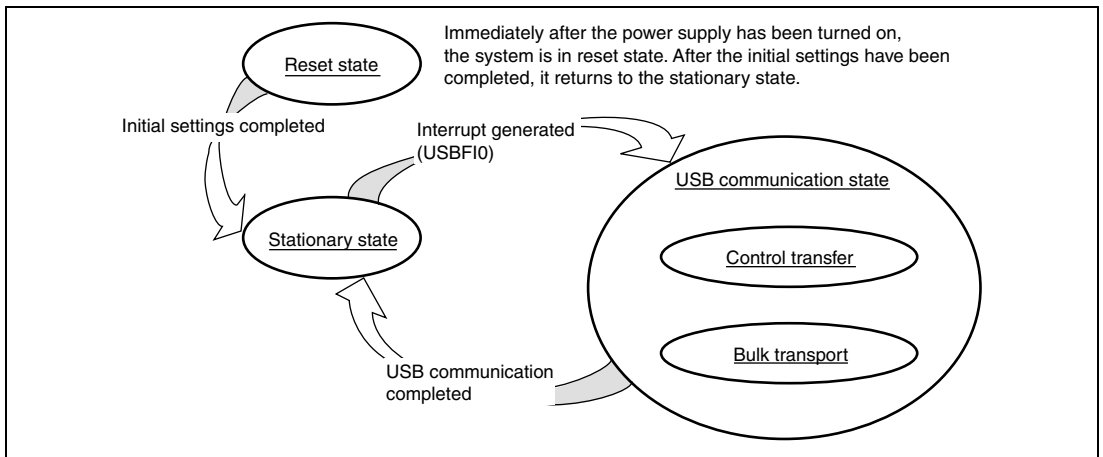


Figure 4.1 State Transition Diagram

- **Reset State**

Upon power-on reset and manual reset, this state is entered. In the reset state, the SH7705 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 register 0 (USBIFR0), and there are eight interrupt types in all. When an interrupt factor occurs, the corresponding bits in USBIFR0 are set.

4.2 USB Communication State

The USB communication state can be further divided into three 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.

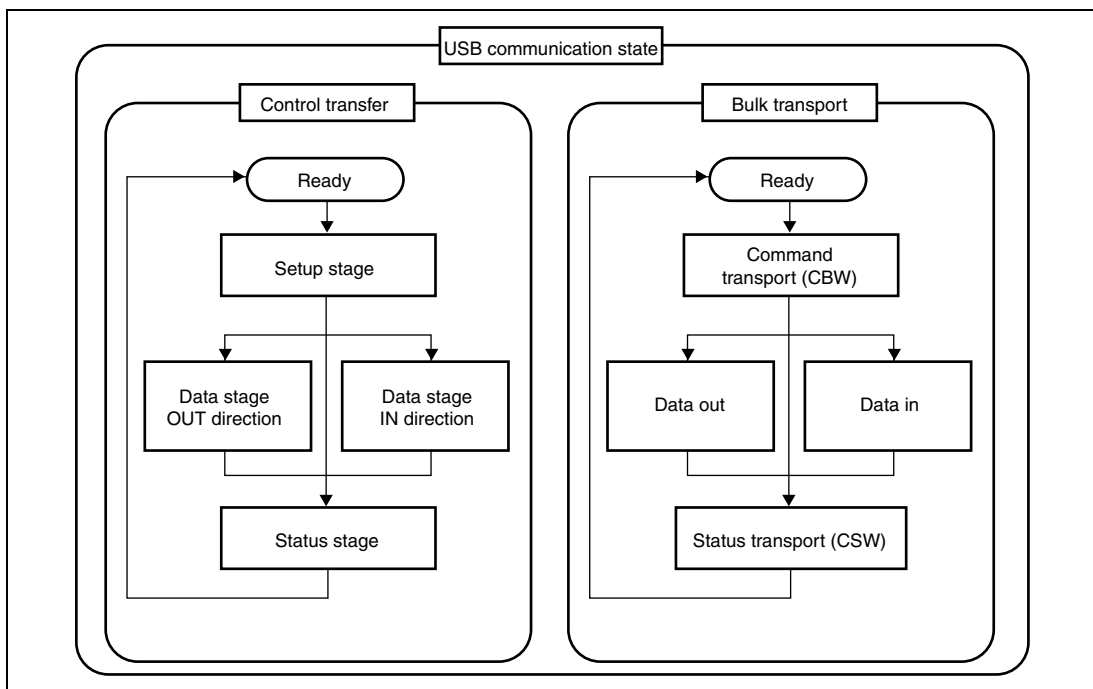


Figure 4.2 USB Communication State

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 nine 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 |
| AsmFunction.src | Making stack settings |
| SH7705.h | Defining SH7705 registers |
| SysMemMap.h | Defining SH7705SE 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, and defining macros for configuring FAT information |
| 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 |

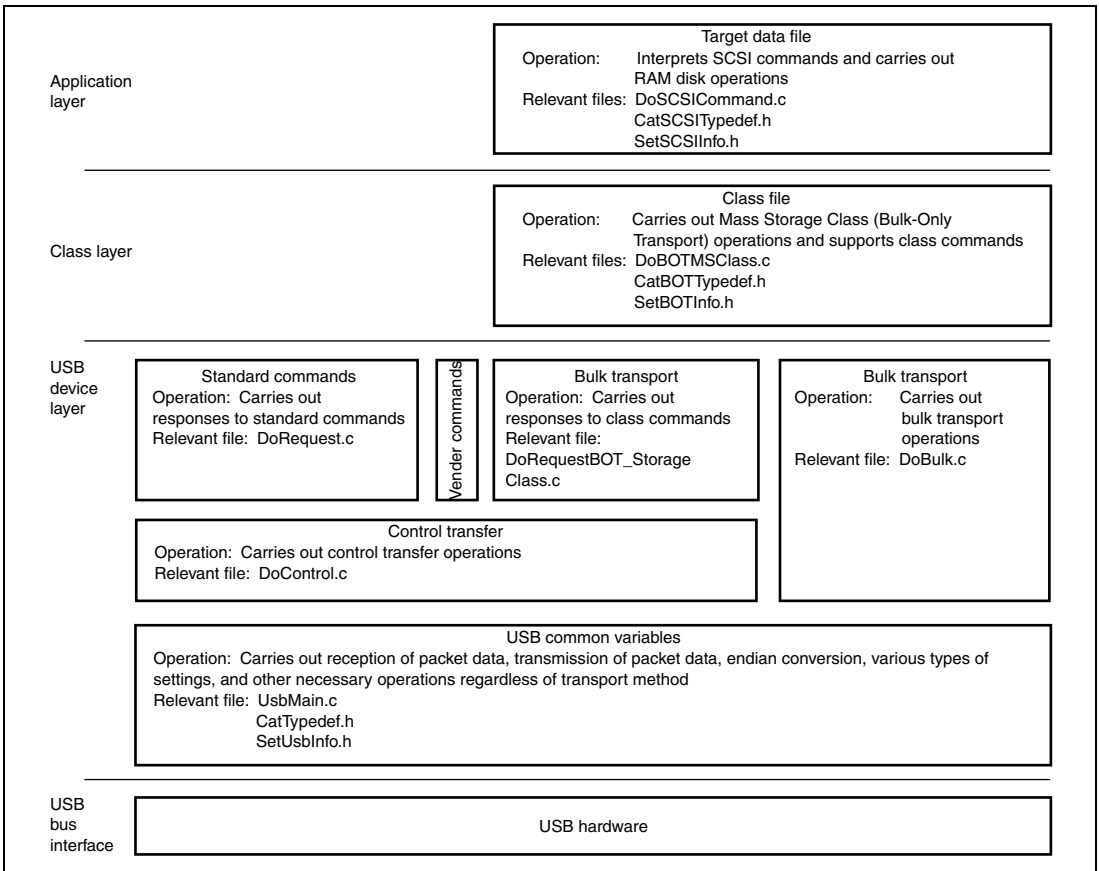


Figure 4.3 Layered Configuration of the Storage Class (BOT) Firmware

4.4 Purposes of Functions

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

Table 4.2-1 StartUp.c

| File in which stored | Function Name | Purpose |
|----------------------|----------------------|---|
| StartUp.c | CallReseException | Performs the operation for the reset exception and calls the following function |
| | CallGeneralException | Calls the function for the general exception except for the TLB miss |
| | CallTLBMissException | Calls the function for the TLB miss |
| | CallInterrupt | Calls the function for the interrupt request |
| | SetPowerOnSection | Initializes module and memory, 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 | Pull-up control of the USB bus |

When a power-on reset or manual reset is carried out, the SetPowerOnSection of the StartUp.c file is called. At this point, the SH7705 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 (provided for ring-buffer, not used for the Mass Storage Class) |
| | GetPacket4S | Writes data transferred from the host controller to RAM in longwords (not provided for ring-buffer, high-speed version) |
| | 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 (provided for ring-buffer, not used for the Mass Storage Class) |
| | PutPacket4S | Writes data for transfer to the host controller to the USB module in longwords (not provided for ring-buffer, high-speed version) |
| | SetControlOutContents | Overwrites data with that sent from the host |
| | SetUsbModule | Makes USB module initial settings |
| | ActBusReset | Clears FIFO on receiving bus reset, etc. |
| | ActBusVcc | Carries out USB cable connection interrupts (not used in this sample application) |
| | 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, DecVendorCommands 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) |
| | ActControlInOut | Allocates the data stage and the status stage of control transfer to ActControlIn and ActControlOut |

When a control transfer interrupt (SETUP TS) is generated, ActControl obtains the command, and decoding is carried out by DecStandardCommands to discern the transfer direction of the command. Next, when a control transfer interrupt (EP0o TS, EP0i TR, or EP0i TS) occurs, ActControlIn or ActControlOut is called depending on the transfer direction of the command, and the data stage and status stage are carried out by ActControlInOut.

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 |
|----------------------|--------------------|--|
| DoBOTMSClass.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 |
| | SetBotCmdErr | Handles SCSI command error |

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, CallResetException calls other functions, and in the case of a transition to the USB communication state which occurs on an interrupt, interrupt function CallInterrupt calls BranchOfInt, and 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.

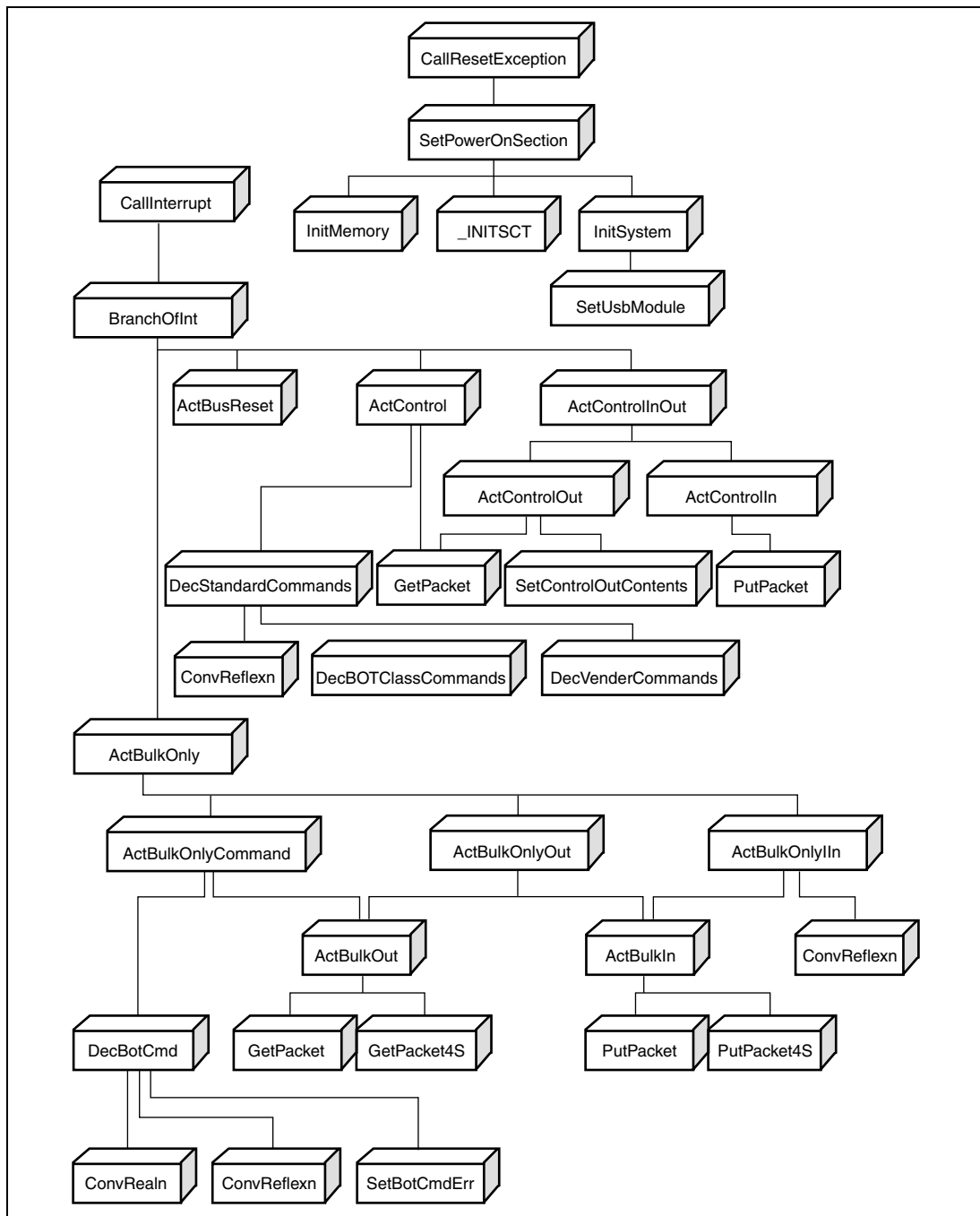


Figure 4.4 Interrelationship between Functions

4.5 RAM Disk

In the sample program provided here, the SDRAM in the SH7705SE is selected as the disk device, and the host PC is notified that the SH7705SE (function) is the 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 SDRAM.

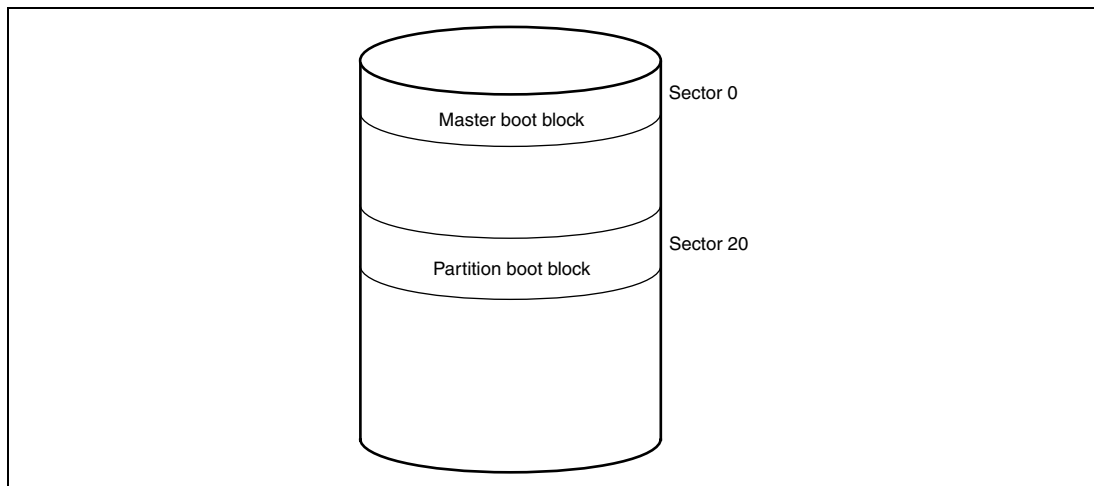


Figure 4.5 Disk Construction

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 | <p>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 SDRAM, and the value stored for the total number of sectors on the disk, and prepares to send the READ CAPACITY information (8 bytes).</p> <p>When the medium is inaccessible (the lowest bit of unit_state[0] is 1), this module recognizes there is no data to transfer, and follows the procedure described in section 4.7, Processing If an Error Occurs (4). It also specifies the value returned by REQUEST SENSE as NOT READY.</p> |
| | Data | <p>This sends the READ CAPACITY information to the host PC using bulk-in transport.</p> <p>When the medium is inaccessible, the same volume of data (0x00) as that requested by the host PC is sent back.</p> |
| | CSW | <p>This sends the results of the command execution to the host PC.</p> <p>When the medium is inaccessible, the command Fail (CSW status 0x01) is sent back.</p> |

| Command Name | Transport Name | Operation Content |
|--------------|----------------|--|
| READ(10) | CBW | <p>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 SDRAM.</p> <p>When the medium is inaccessible (the lowest bit of unit_state[0] is 1), this module recognizes there is no data to transfer, and follows the procedure described in section 4.7, Processing If an Error Occurs (4). It also specifies the value returned by REQUEST SENSE as NOT READY.</p> |
| | Data | <p>This sends the data from the read sectors to the host PC using bulk-in transport.</p> <p>When the medium is inaccessible, the same volume of data (0x00) as that requested by the host PC is sent back.</p> |
| | CSW | <p>This sends the results of executing the READ(10) command to the host PC.</p> <p>When the medium is inaccessible, the command Fail (CSW status 0x01) is sent back.</p> |
| WRITE(10) | CBW | <p>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 SDRAM.</p> <p>When the medium is inaccessible (the lowest bit of unit_state[0] is 1), this module recognized there is no data to transfer, and follows the procedure described in section 4.7, Processing If an Error Occurs (9). It also specifies the value returned by REQUEST SENSE as NOT READY.</p> |
| | Data | <p>This receives the write sector data from the host PC using bulk-out transport.</p> <p>When the medium is inaccessible, the data sent from the host PC is skipped.</p> |
| | CSW | <p>This notifies the host PC that the operation has been completed successfully.</p> <p>When the medium is inaccessible, the command Fail (CSW status 0x01) is sent back.</p> |

| Command Name | Transport Name | Operation Content |
|------------------------------|----------------|---|
| 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 18 bytes or less. |
| PREVENT ALLOW MEDIUM REMOVAL | CBW | <p>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.</p> <p>When the medium is inaccessible (the lowest bit of unit_state[0] is 1), the command is specified as Fail, and the value returned by REQUEST SENSE is specified as NOT READY.</p> |
| | Data | Data transport does not exist for this command. |
| | CSW | <p>This notifies the host PC that the operation has been completed successfully.</p> <p>When the medium is inaccessible, the command Fail (CSW status 0x01) is sent back.</p> |
| TEST UNIT READY | CBW | <p>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.</p> <p>When the medium is inaccessible (the lowest bit of unit_state[0] is 1), the command is specified as Fail, and the value returned by REQUEST SENSE is specified as NOT READY.</p> |
| | Data | Data transport does not exist for this command. |
| | CSW | <p>This notifies the host PC that the operation has been completed successfully.</p> <p>When the medium is inaccessible, the command Fail (CSW status 0x01) is sent back.</p> |

| Command Name | Transport Name | Operation Content |
|---------------------------------|----------------|---|
| VERIFY(10) | CBW | <p>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.</p> <p>When the medium is inaccessible (the lowest bit of unit_state[0] is 1), the command is specified as Fail, and the value returned by REQUEST SENSE is specified as NOT READY.</p> |
| | Data | Data transport does not exist for this command. |
| | CSW | <p>This notifies the host PC that the operation has been completed successfully.</p> <p>When the medium is inaccessible, the command Fail (CSW status 0x01) is sent back.</p> |
| STOP/START UNIT | CBW | <p>This decodes the command and recognizes it as the STOP/START UNIT command. It then sets the lowest bit of the global variable unit_state[0] to 1 when the removal or halt of the medium was specified by the command. In other case, the lowest bit of the global variable unit_state[0] is set to 0.</p> <p>To recover from the inaccessible condition, the user must set the lowest bit of unit_state[0] to 0.</p> |
| | Data | Data transport does not exist for this command. |
| | CSW | This notifies the host PC that the operation has been completed successfully. |
| MODE SENSE(6) | CBW | This decodes the command and recognizes it as the MODE SENSE(6) command. It then prepares to send the MODE SENSE information required. |
| | Data | This sends the MODE SENSE information to the host PC using bulk-in transport. |
| | CSW | This sends the results of the command execution to the host PC. |
| 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 back the command Fail (CSW status 0x01) 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) $H_n = D_n$ | (4) $H_i > D_n$ | (9) $H_o > D_n$ |
| | Data send to host PC | (2) $H_n < D_i$ | (5) $H_i > D_i$ | (10) $H_o < > D_i$ |
| | | | (6) $H_i = D_i$ | |
| | | | (7) $H_i < D_i$ | |
| | Data reception from host PC | (3) $H_n < D_o$ | (8) $H_i < > D_o$ | (11) $H_o > D_o$ |
| | | | | (12) $H_o = D_o$ |
| (13) $H_o < D_o$ | | | | |

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 | <ul style="list-style-type: none">• Set 0x02 as the CSW status. |
| 4, 5 | <ul style="list-style-type: none">• 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 0x00 as the CSW status. |
| 7, 8 | <ul style="list-style-type: none">• The function sends data to the host PC up to the data length set in dCBWDataTransferLength.• Set 0x02 as the CSW status. |
| 9, 11 | <ul style="list-style-type: none">• 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 | <ul style="list-style-type: none">• 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.

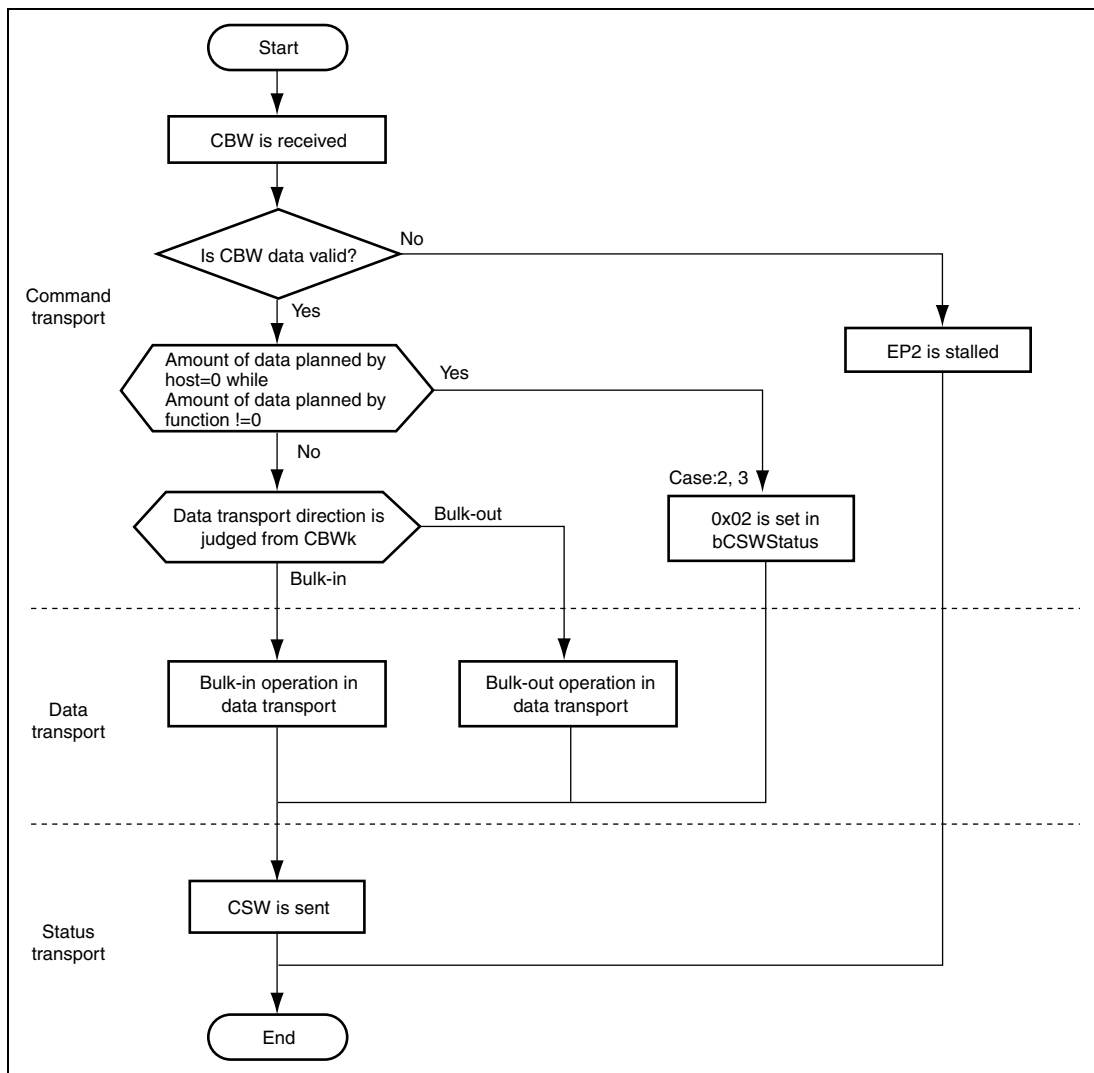


Figure 4.6 Error Processing Flow in Data Transport (1)

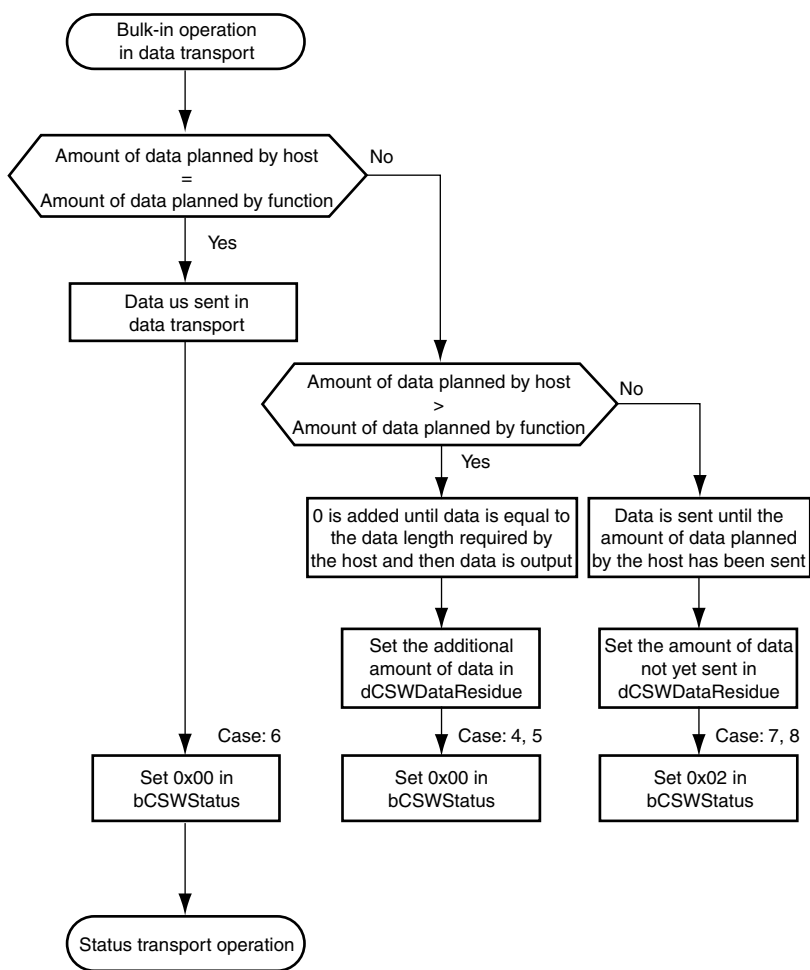


Figure 4.7 Error Processing Flow in Data Transport (2)

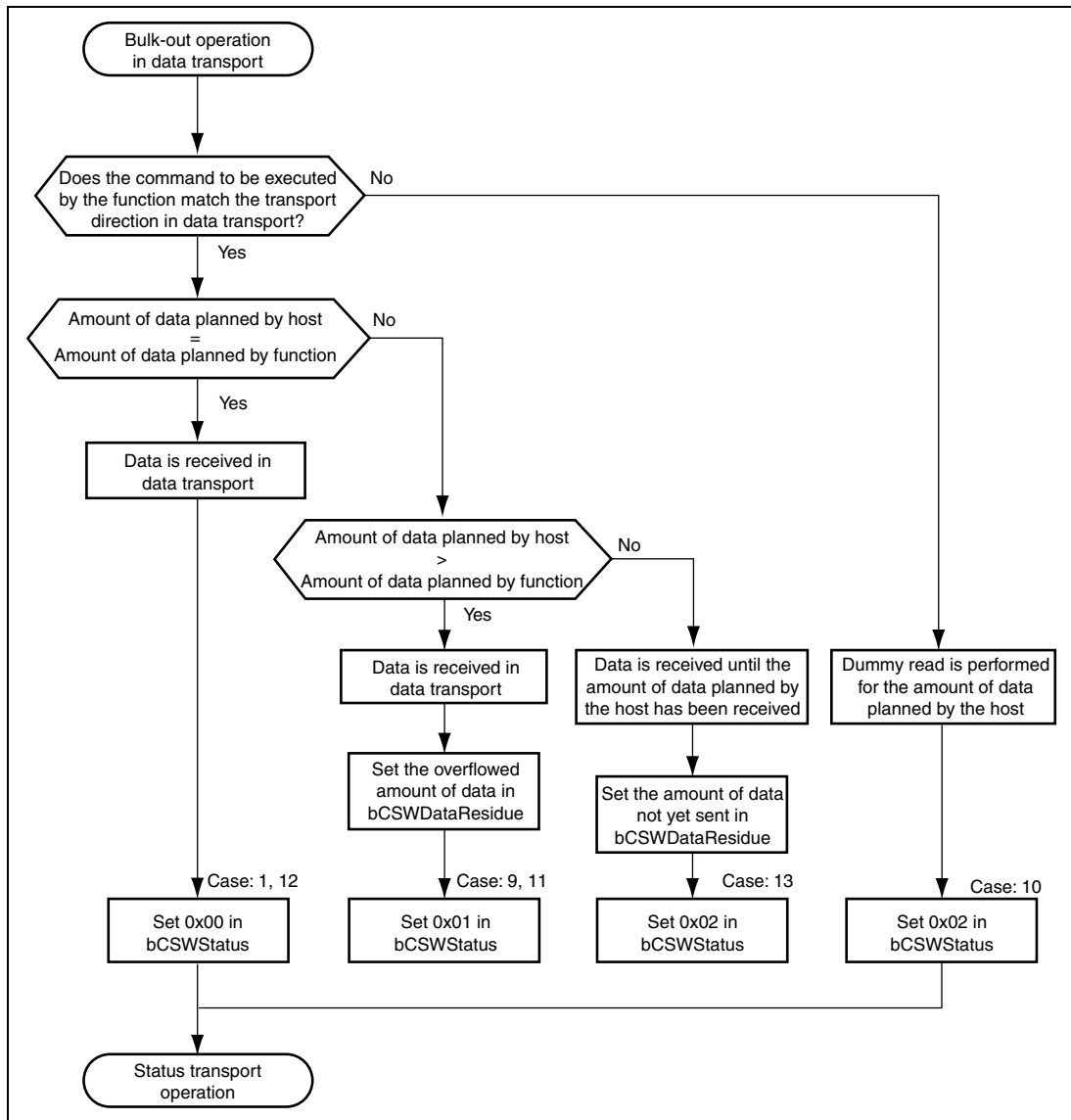


Figure 4.8 Error Processing Flow in Data Transport (3)

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 dCSWDataTransferResidue 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.

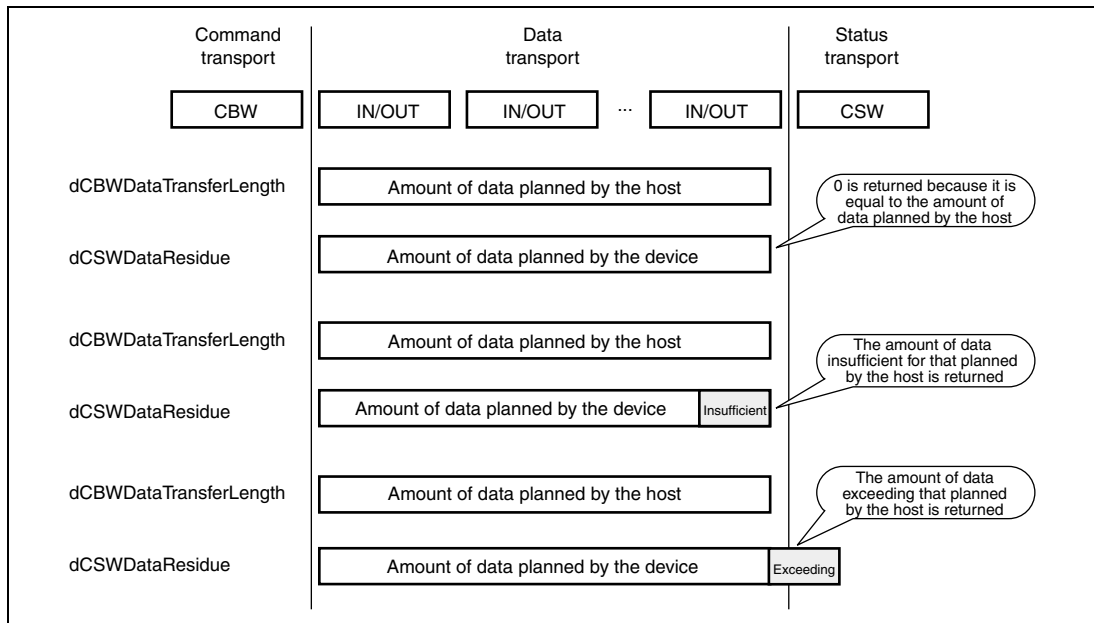


Figure 4.9 Each Stage in Bulk-Only Transport

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, reset interrupt function `CallResetException` is called to process the reset exception and to call function `SetPowerOnSection`. Figure 5.1 is a flow chart for the operation from the reset interrupt to the stationary state.

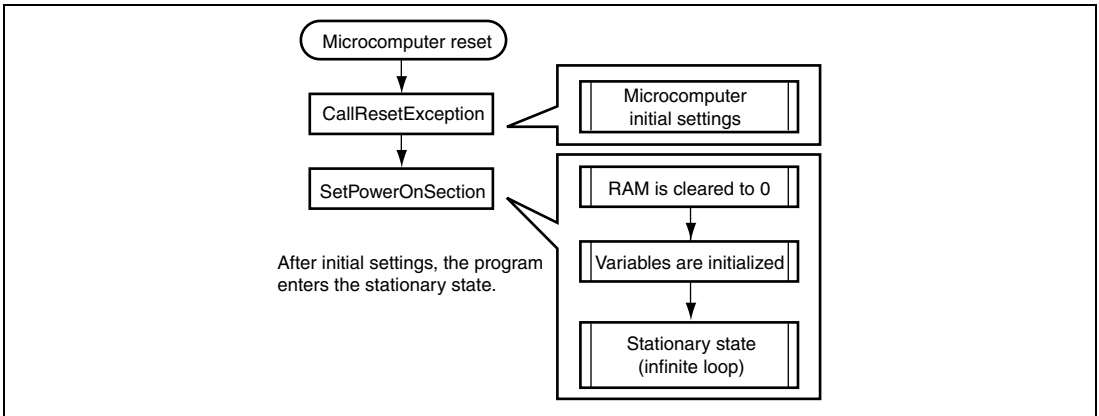


Figure 5.1 Main Loop

5.2 Types of Interrupts

As explained in section 4, the interrupts used in this sample program are indicated by the interrupt flag register 0 (USBIFR0); there are a total of eight types of interrupts. When an interrupt source occurs, the corresponding bits in the interrupt flag register are set to 1, and a USBFIO 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.

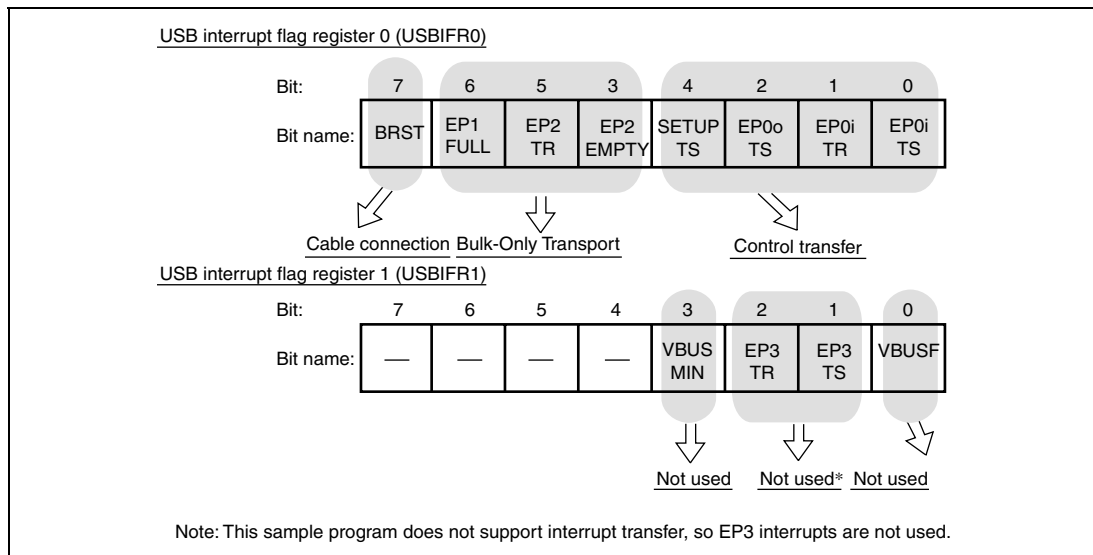


Figure 5.2 Types of Interrupt Flags

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 |
|---------------|-----|-----------|-------------------------|
| USBIFRO | 0 | EP0i TS | ActControllnOut |
| | 1 | EP0i TR | ActControllnOut |
| | 2 | EP0o TS | ActControllnOut |
| | 3 | SETUP TS | ActControl |
| | 4 | EP2 EMPTY | ActBulkOnly |
| | 5 | EP2 TR | ActBulkOnly |
| | 6 | EP1 FULL | ActBulkOnly |
| | 7 | BRST | ActBusReset |

The EP0i TS and EP0o TS 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 SH7705 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 Interrupt on Cable Connection (BRST)

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, an USB D+ PULLUP output port is employed to pull-up the USB data bus D+. By means of this pull-up, the host controller can recognize that the device has been connected (figure 5.3).

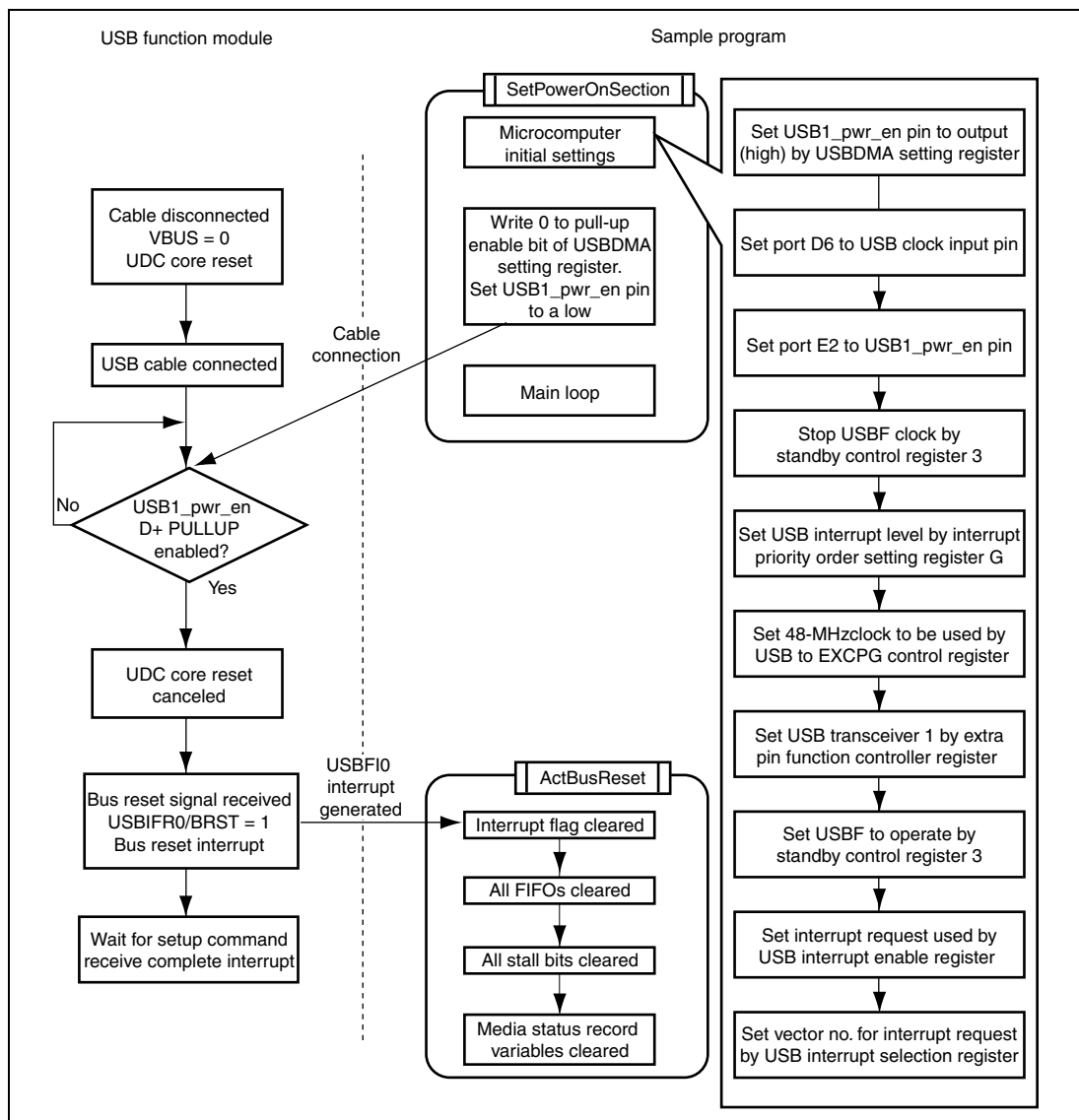


Figure 5.3 Interrupt on Cable Connection

5.4 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 5.4). 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.

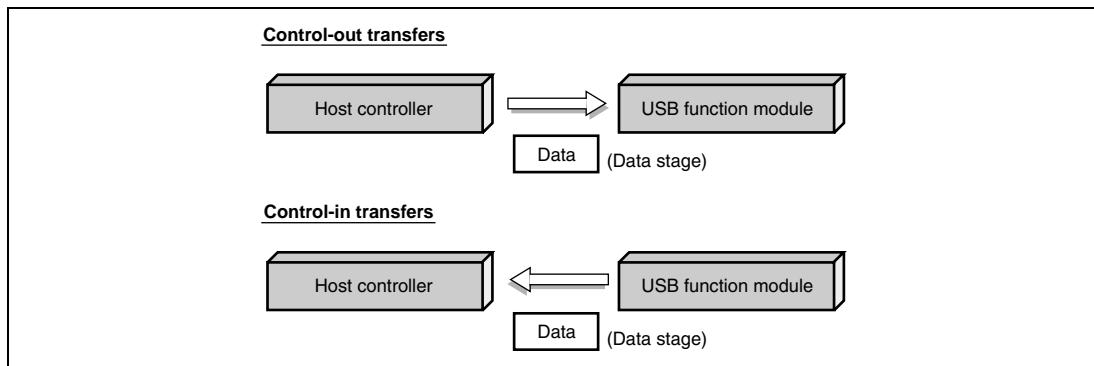


Figure 5.4 Control Transfers

Control transfers consist of three stages: setup, data (no data is possible), and status (figure 5.5). 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 (cf. 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 5.5) 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.

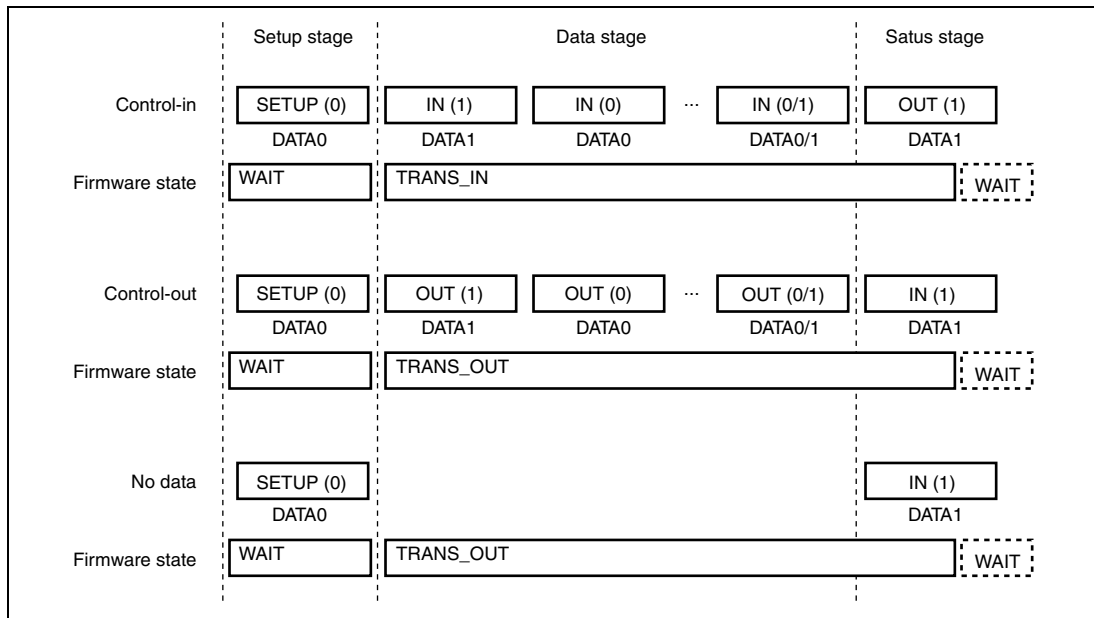


Figure 5.5 Status in Control Transfers

5.4.1 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 5.6 shows operation of the sample program in the setup stage. The figure on the left shows operation of the USB function module.

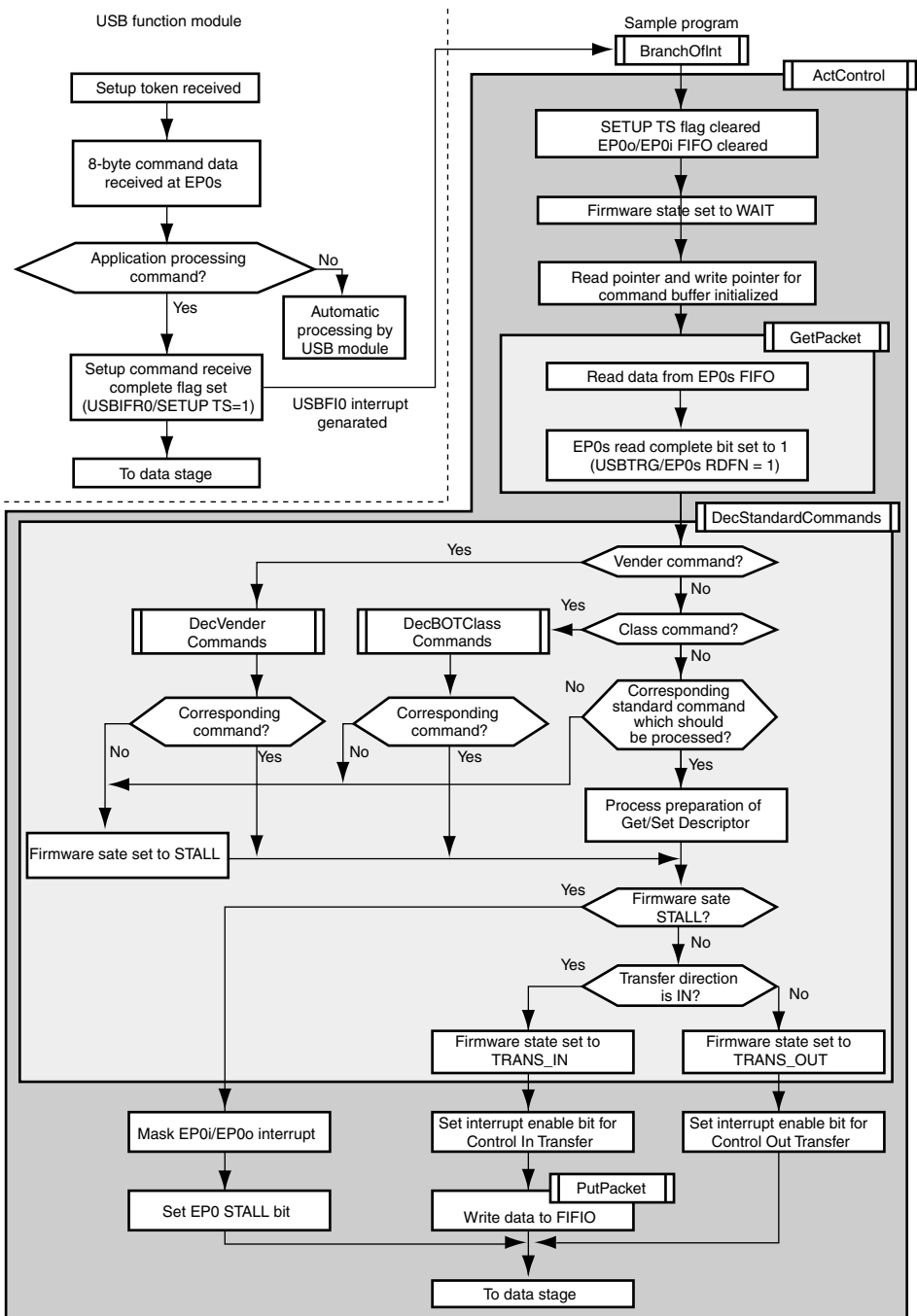


Figure 5.6 Setup Stage

5.4.2 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 5.7 and 5.9 show the operation of the sample program in the data stage of control transfer.

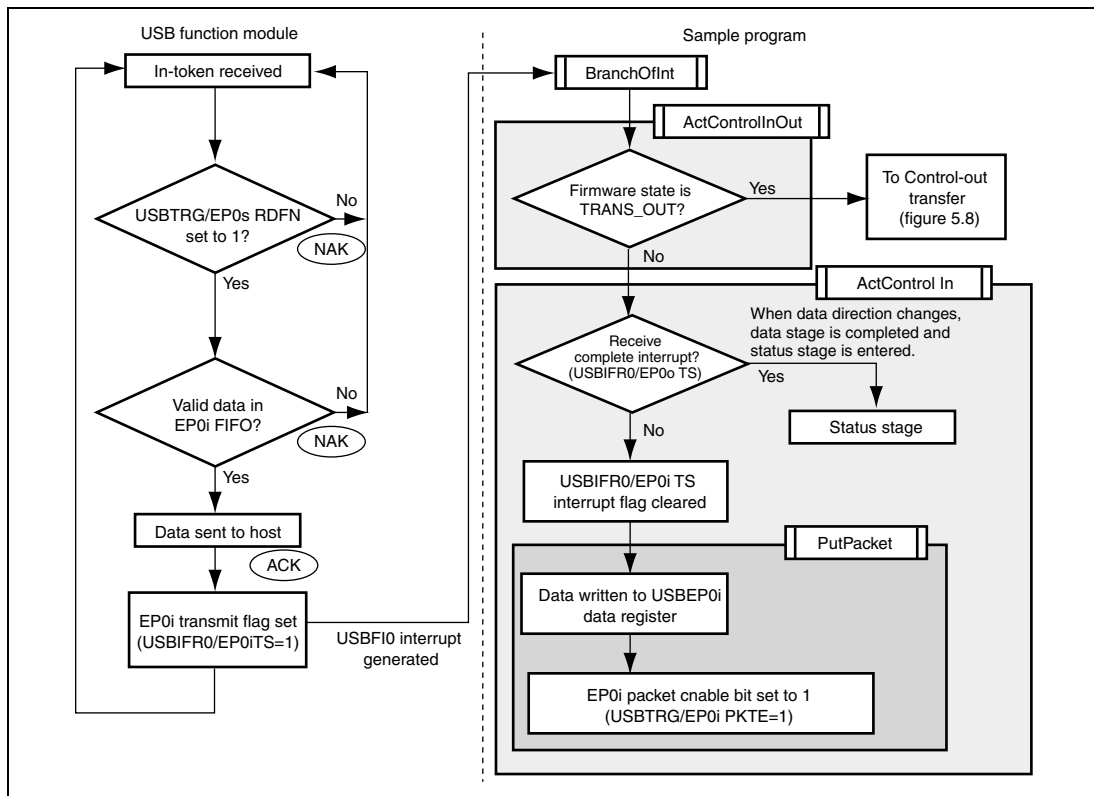


Figure 5.7 Data Stage (Control-In Transfer)

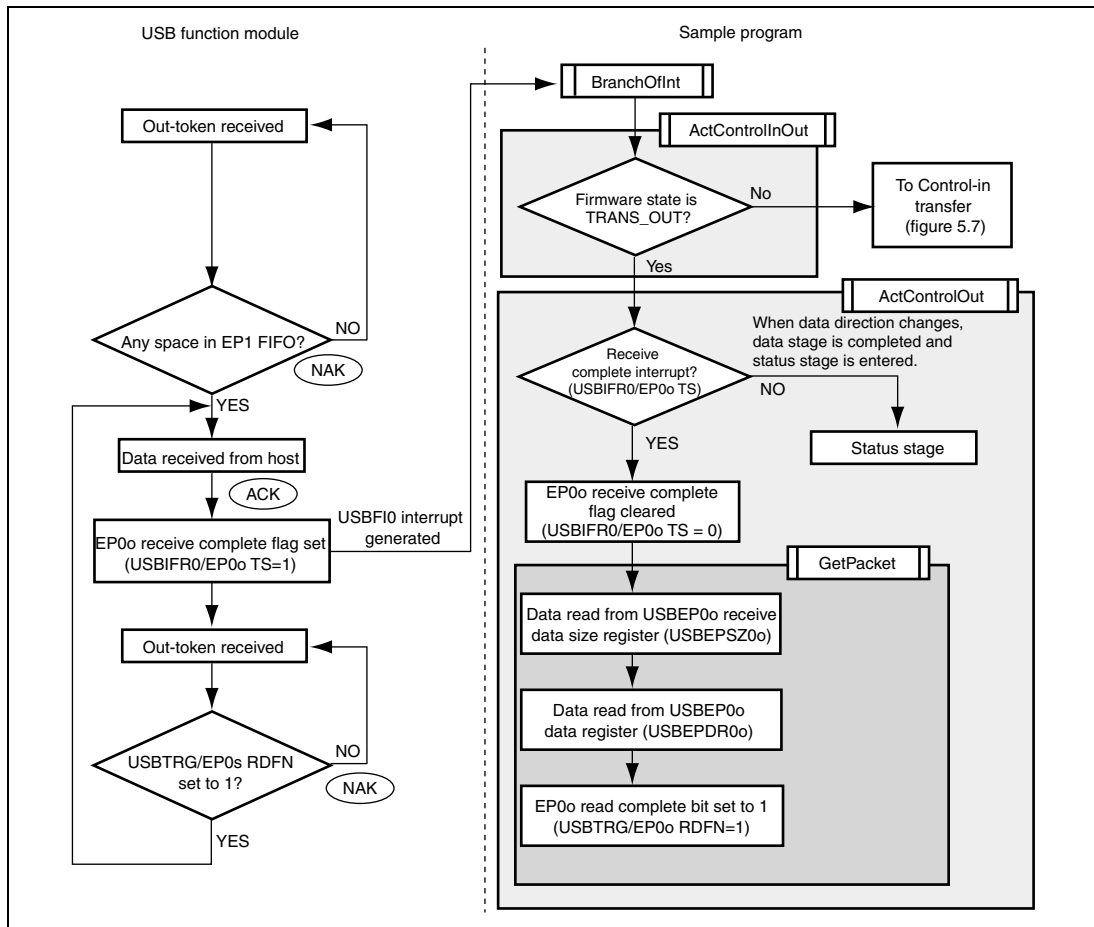


Figure 5.8 Data Stage (Control-Out Transfer)

5.4.3 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.

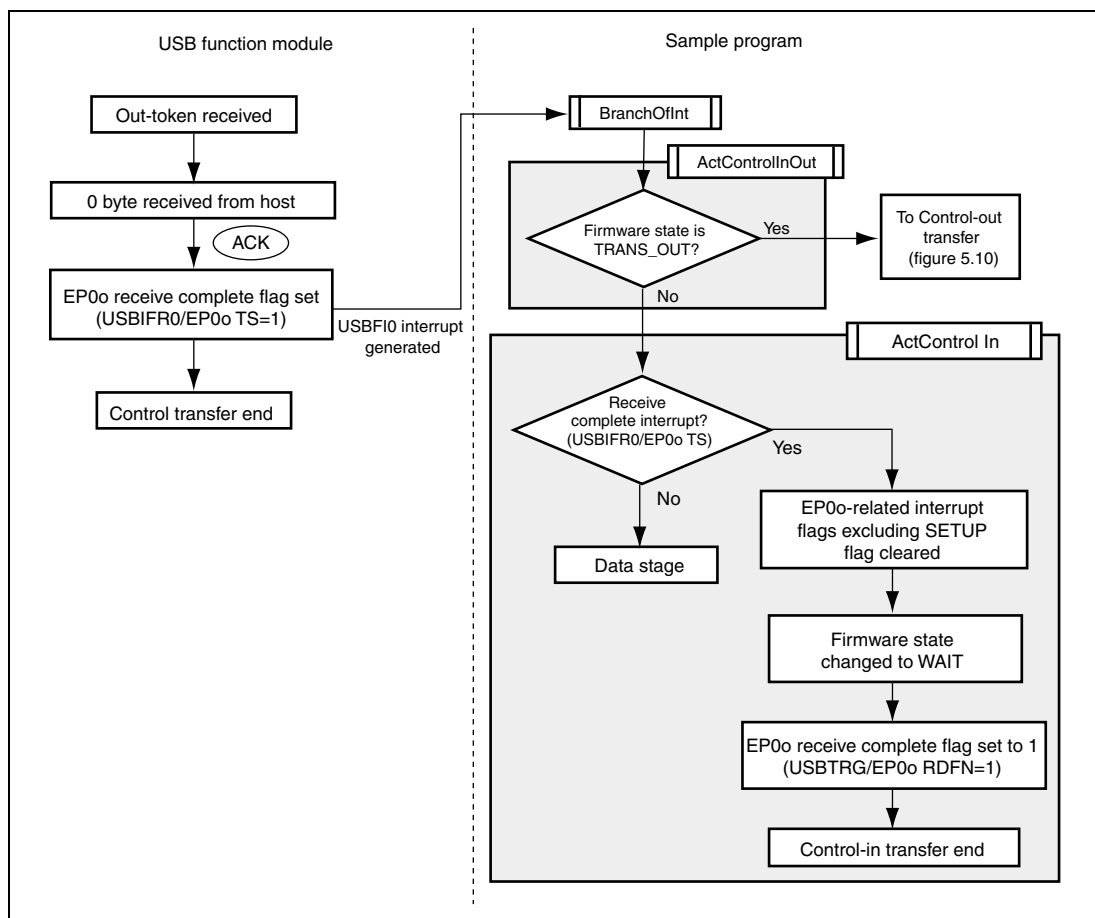


Figure 5.9 Status Stage (Control-In Transfer)

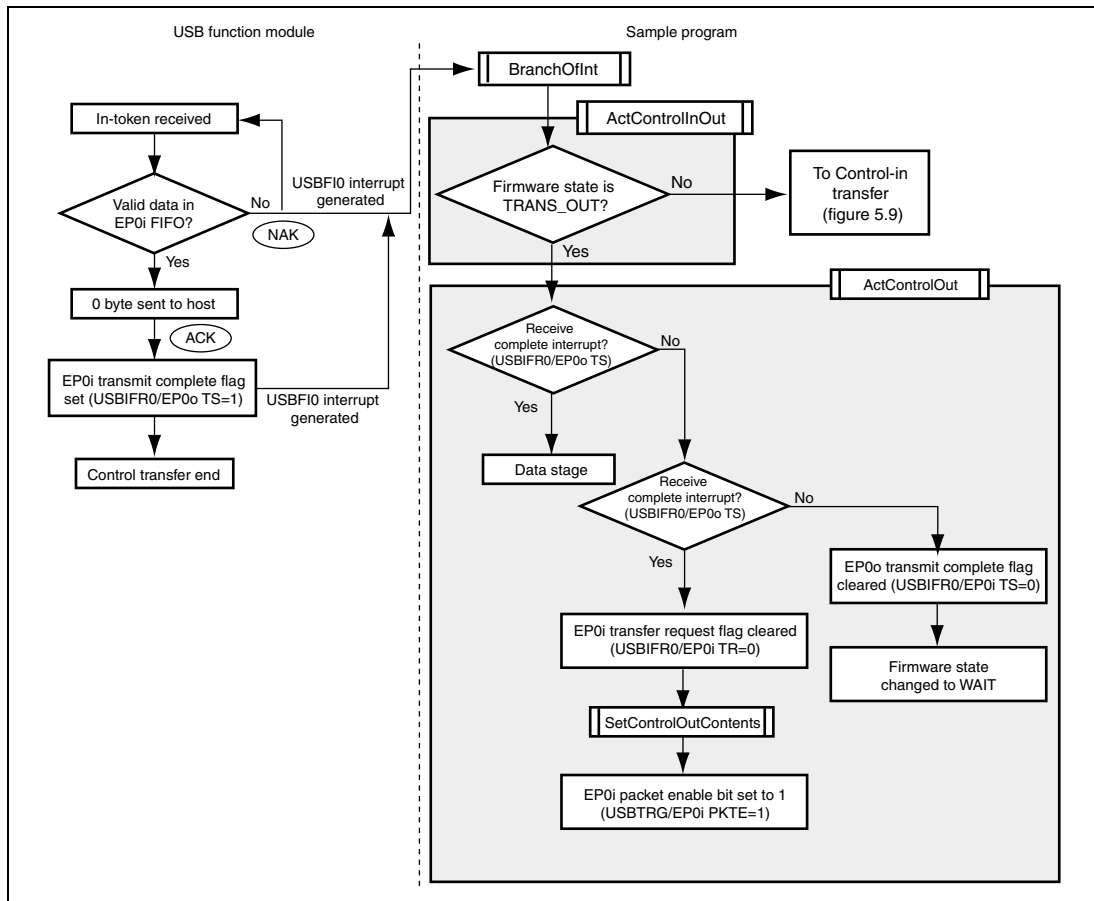


Figure 5.10 Status Stage (Control-Out Transfer)

5.5 Bulk Transfers

In bulk transfers, bits 4 to 6 of the interrupt flag register are used. Bulk transfers can also be divided into two types according to the direction of data transmission (figure 5.11).

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.

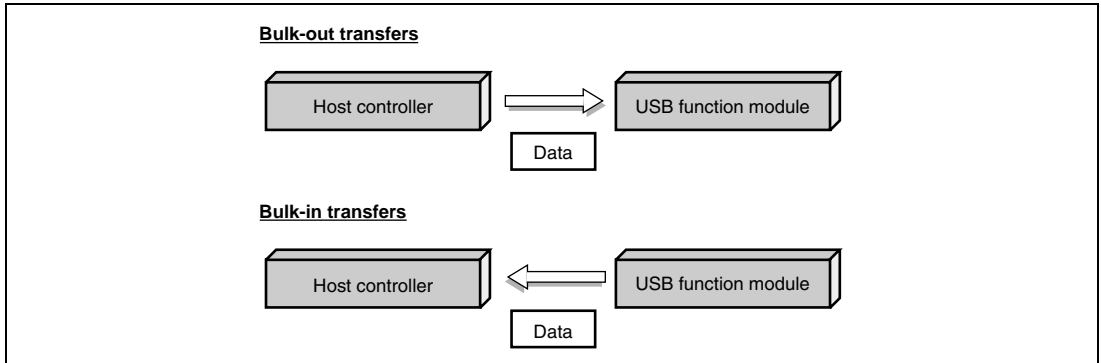


Figure 5.11 Bulk Transfers

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 5.12): 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 sent 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 5.12). The appropriate variables must be loaded 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.

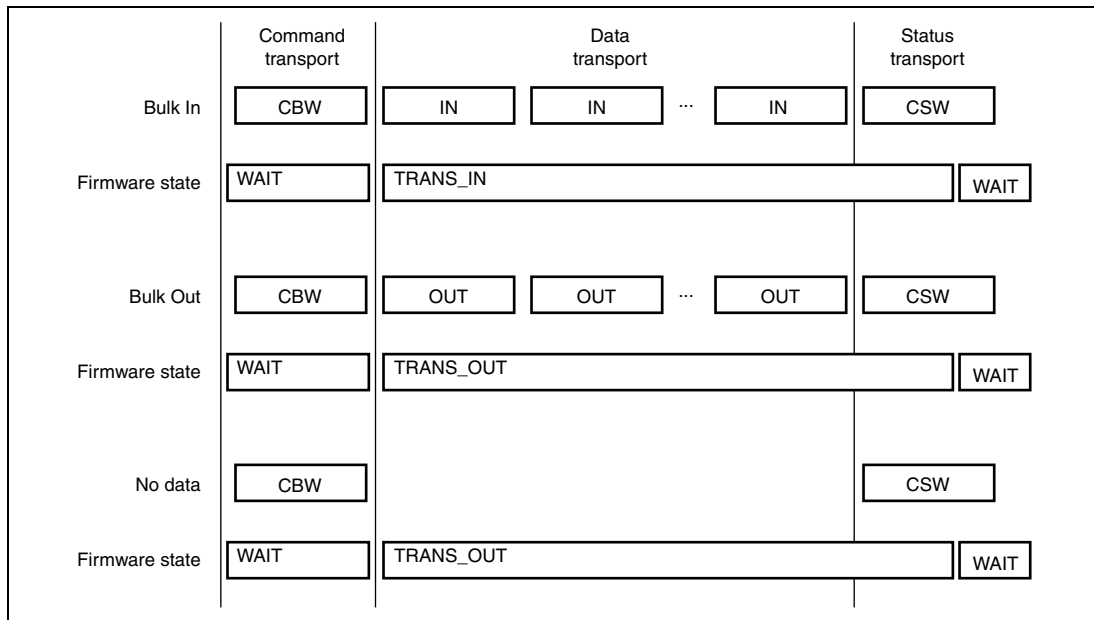


Figure 5.12 Various Stages in Bulk-Only Transport

5.5.1 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 5.13 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.

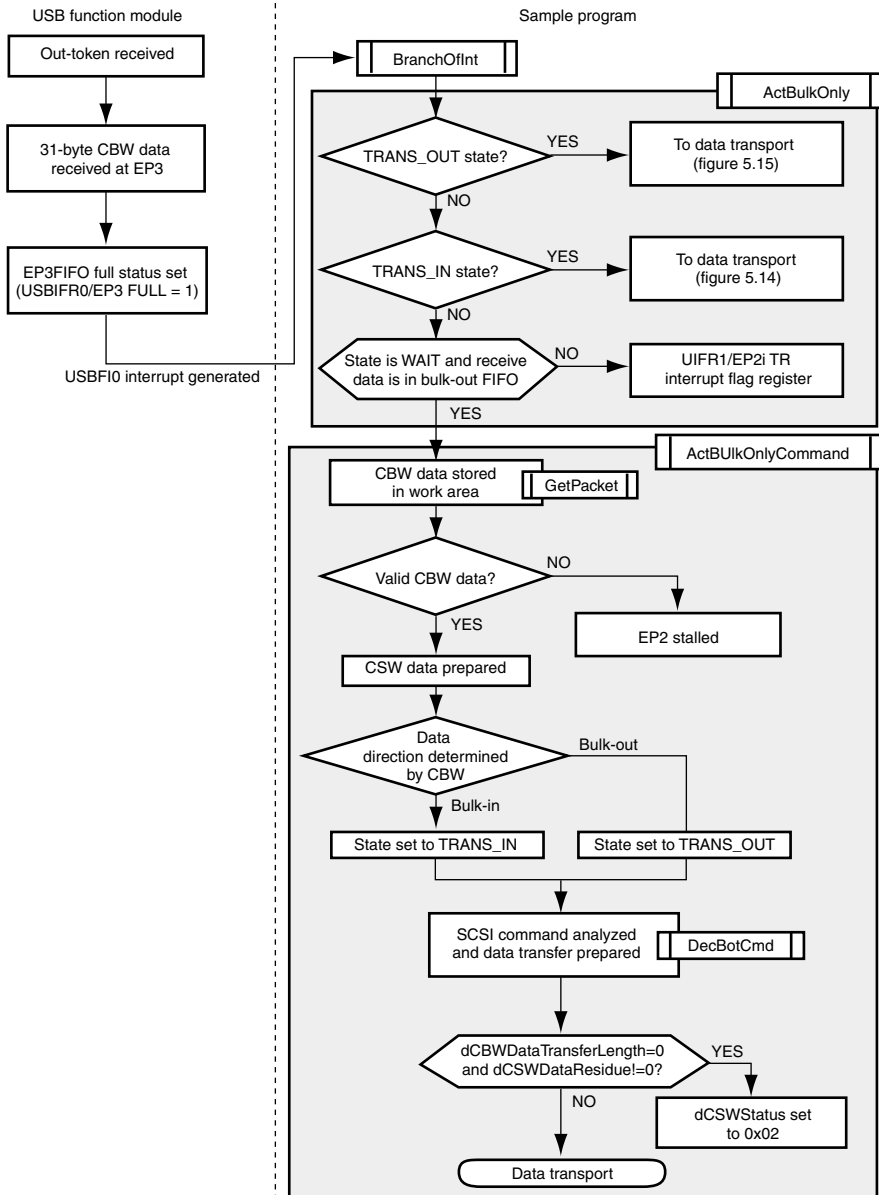


Figure 5.13 Command Transport

5.5.2 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 5.14 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.

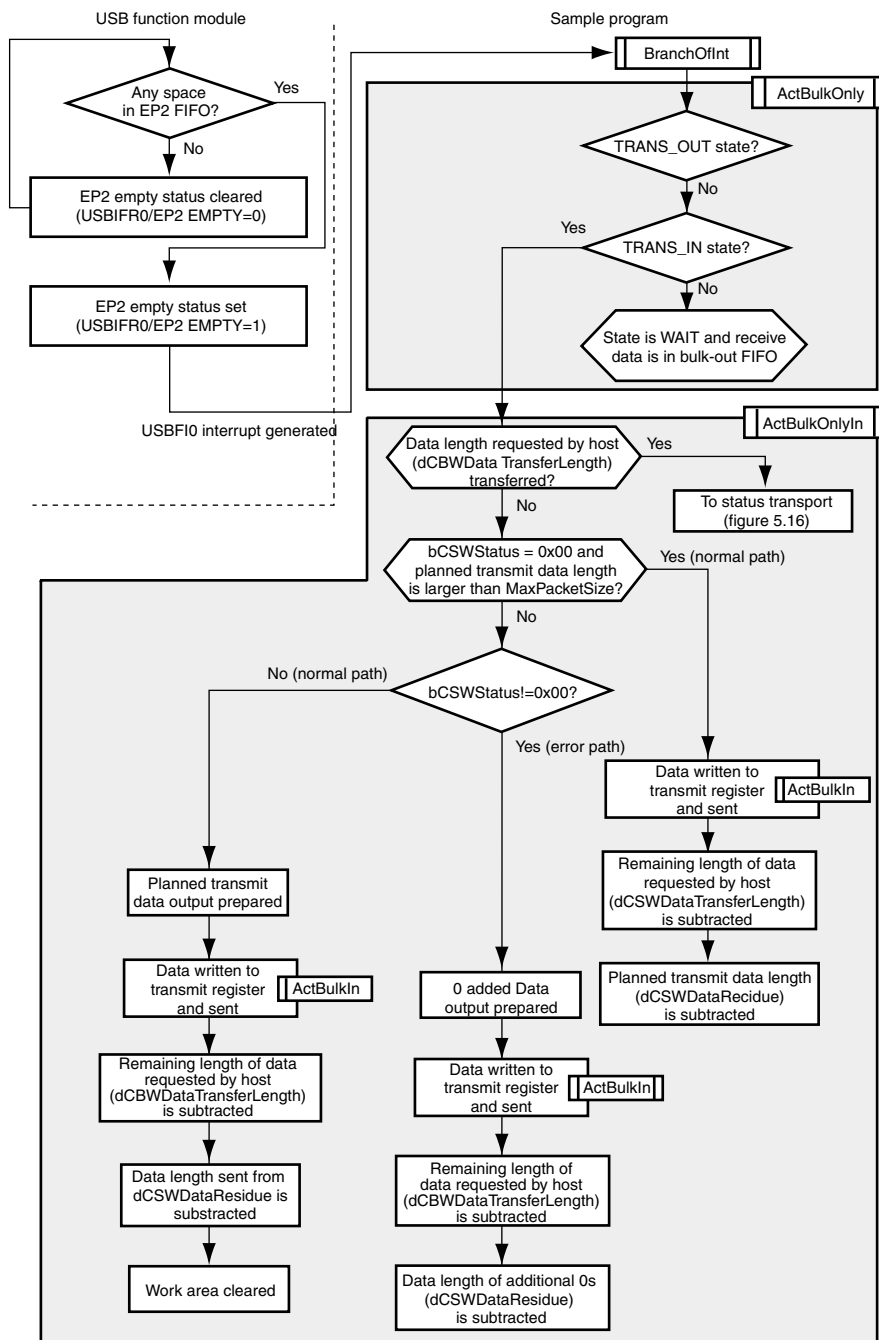


Figure 5.14 Data Transport (Bulk-In Transport)

Figure 5.15 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.

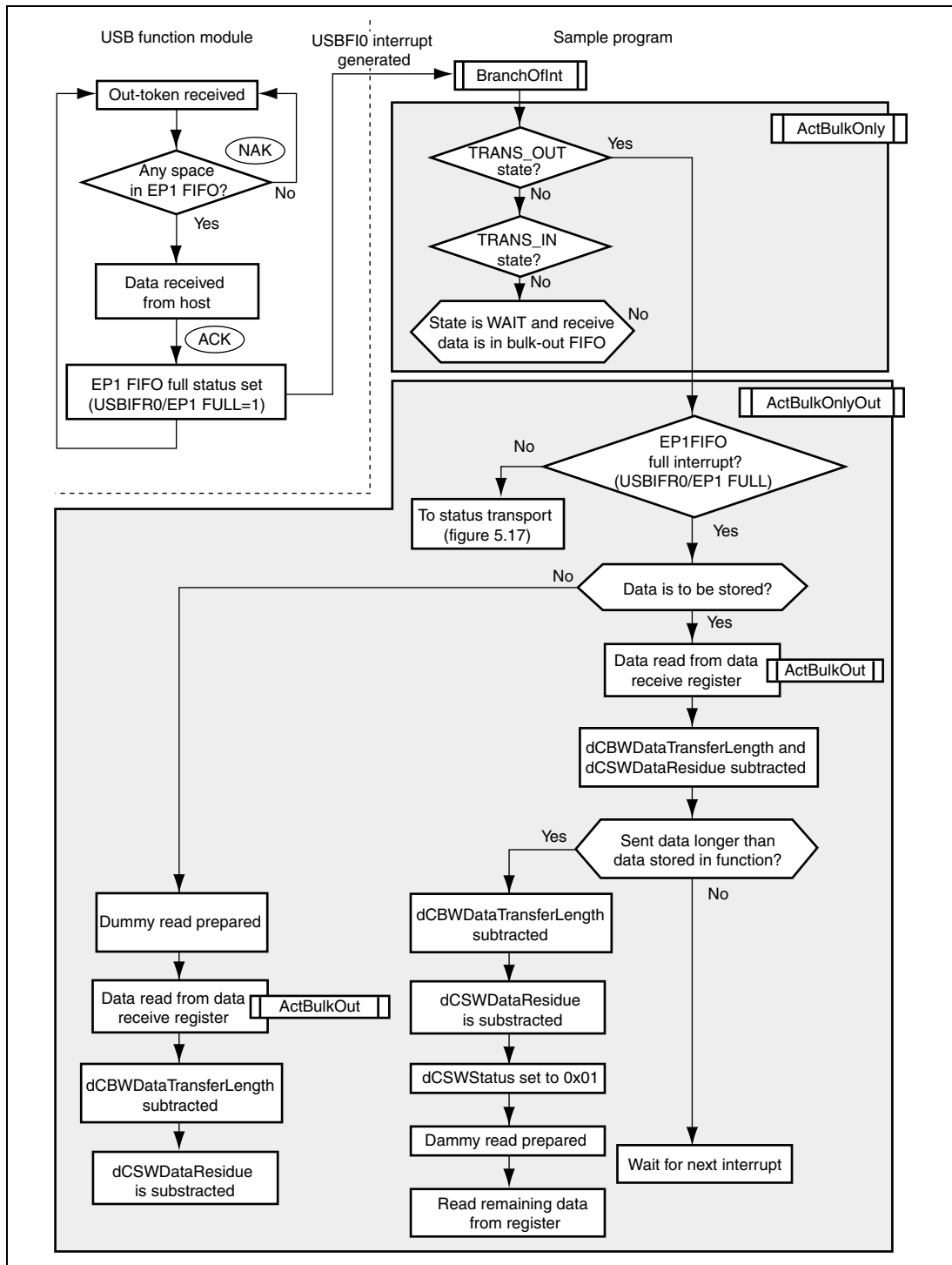


Figure 5.15 Data Transport (Bulk-Out Transport)

5.5.3 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 5.16 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.

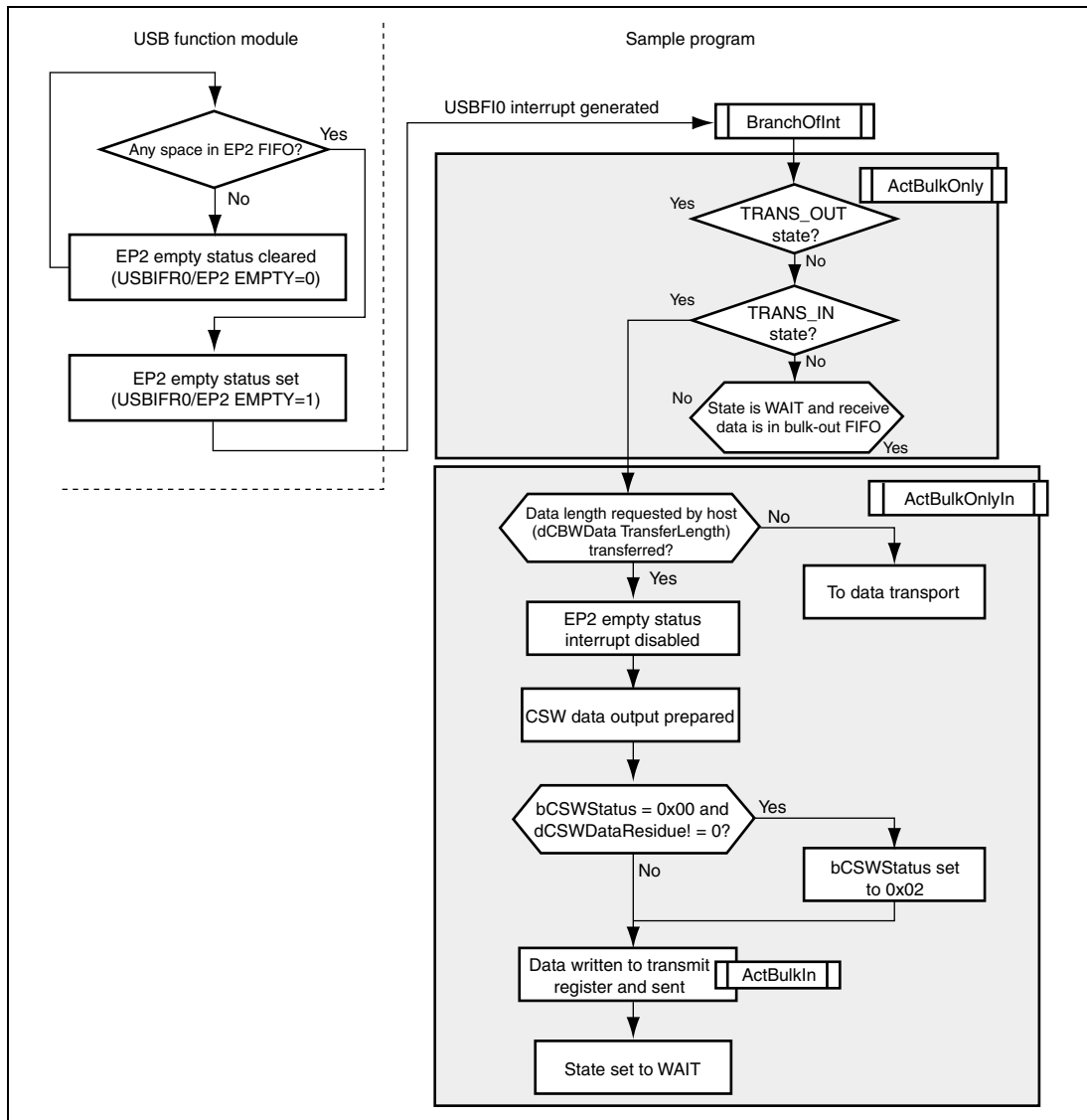


Figure 5.16 Status Transport (Data Transport Bulk-In Transport)

Figure 5.17 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).

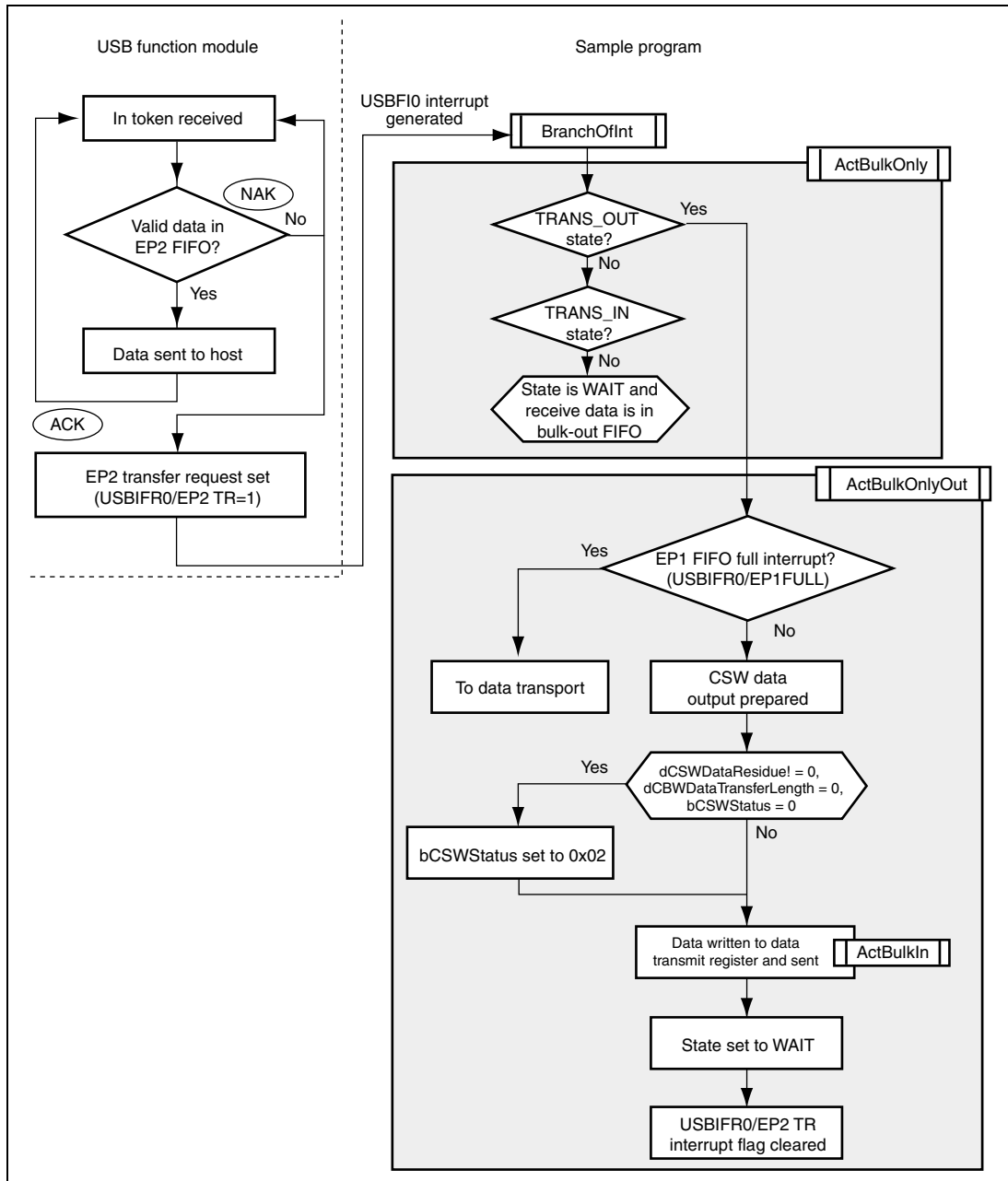


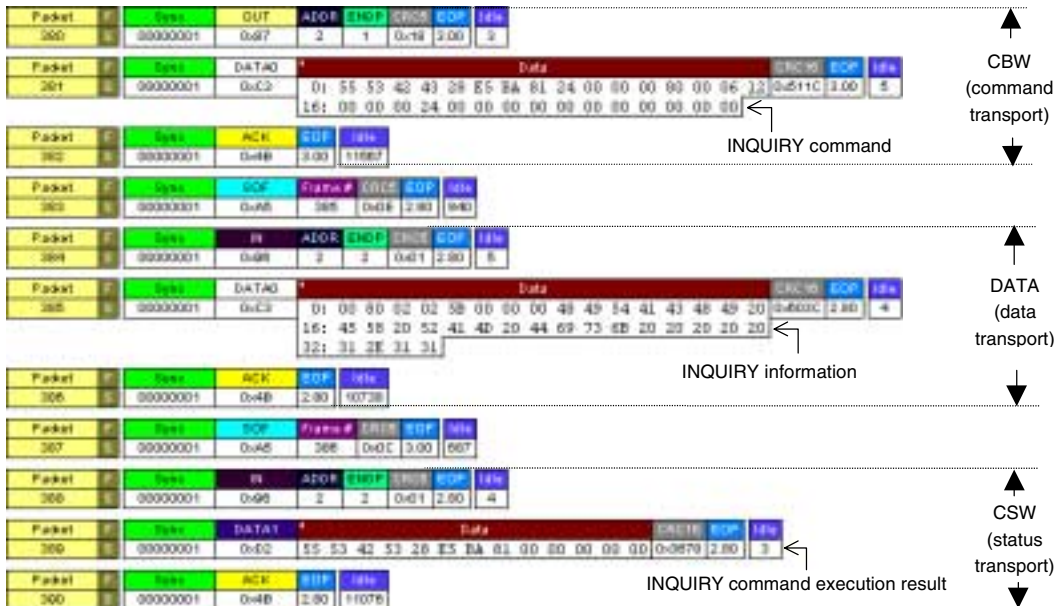
Figure 5.17 Status Transport (Data Transport Bulk-Out Transport)

Section 6 Analyzer Data

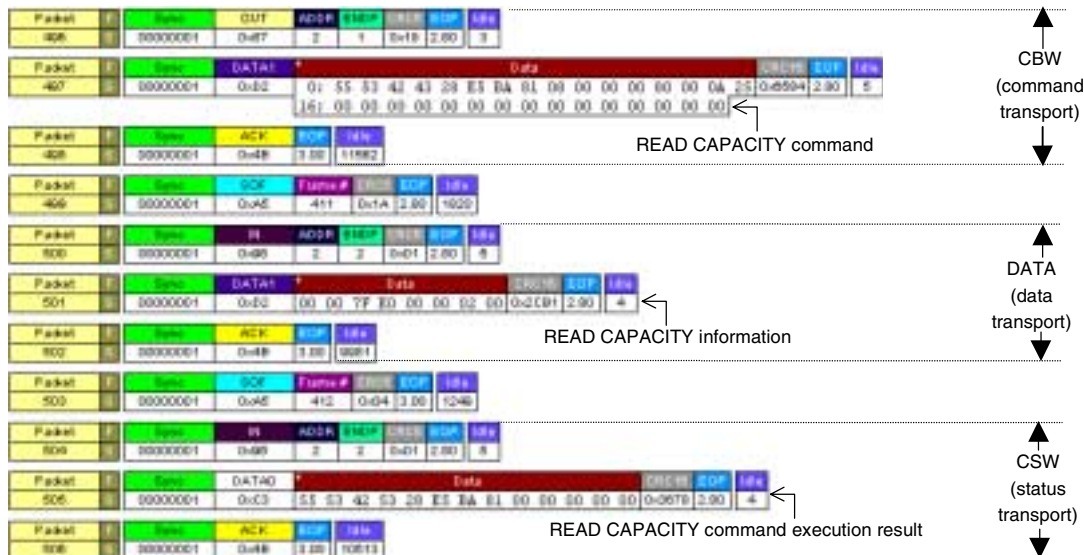
In this chapter, we look at how measurement is carried out with the USB Inspector, a USB protocol analyzer made by CATC (<http://www.catic.com>), using the USB function module in the SH7705, and at what happens to the data as it actually flows along the bus. For more detailed information on the packets, please see section 2.3.

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

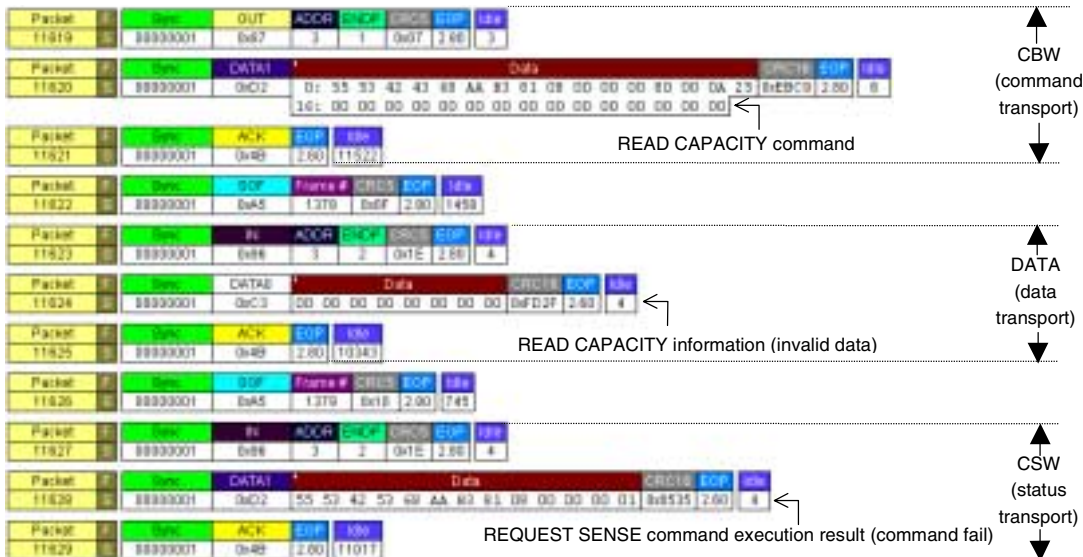
- INQUIRY command



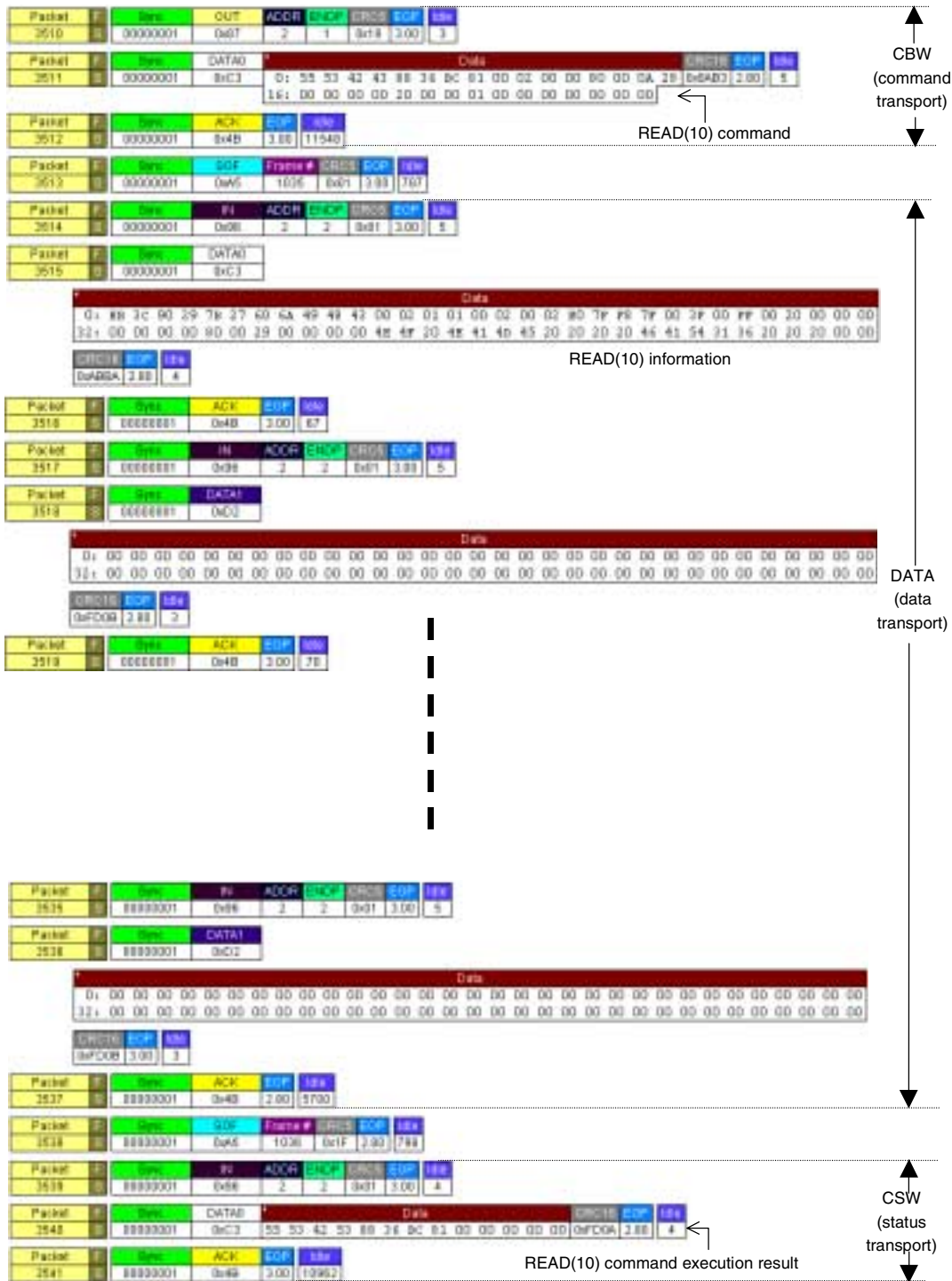
- READ CAPACITY command (Normal)



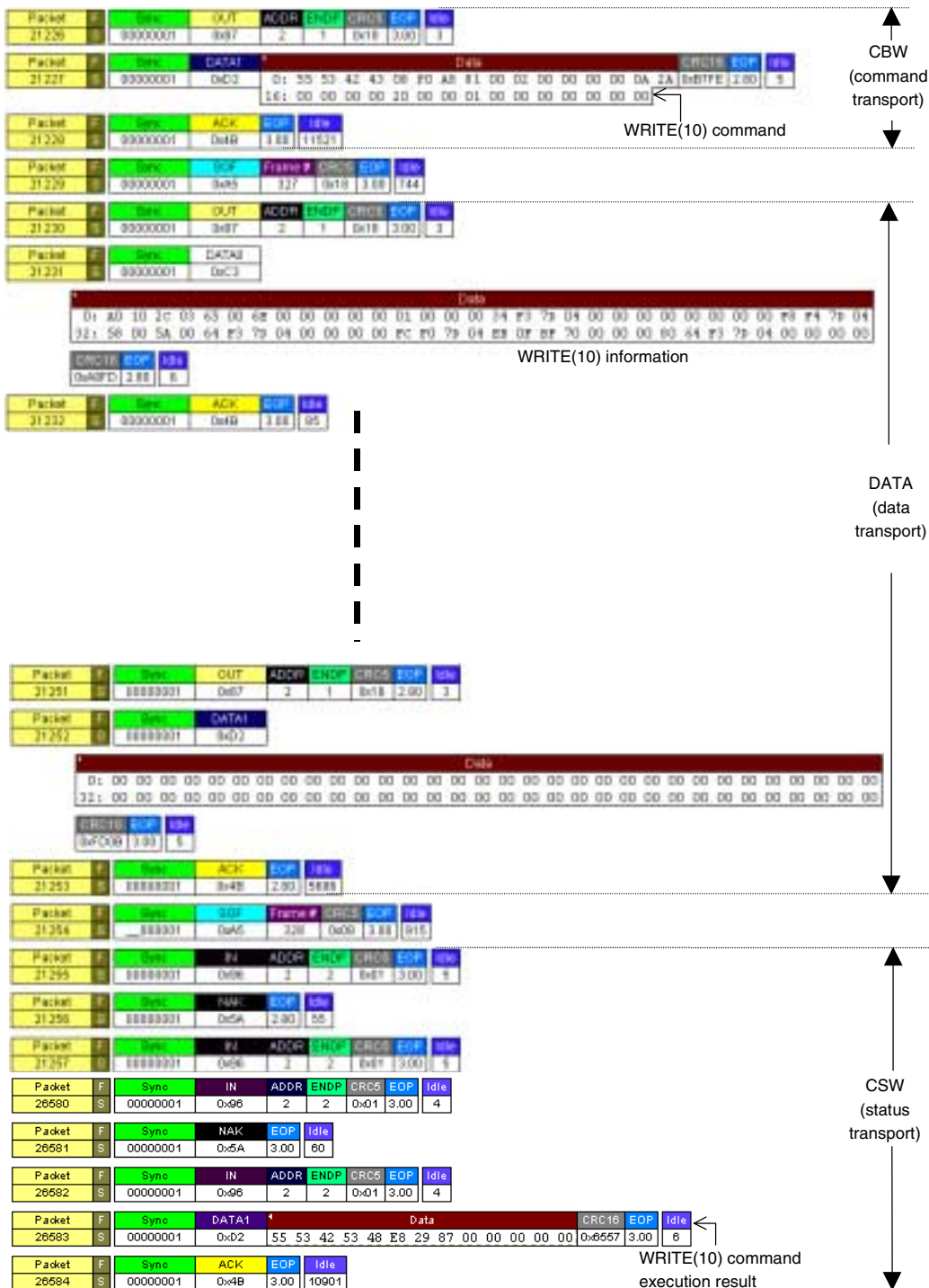
- READ CAPACITY command (When the medium is removed)



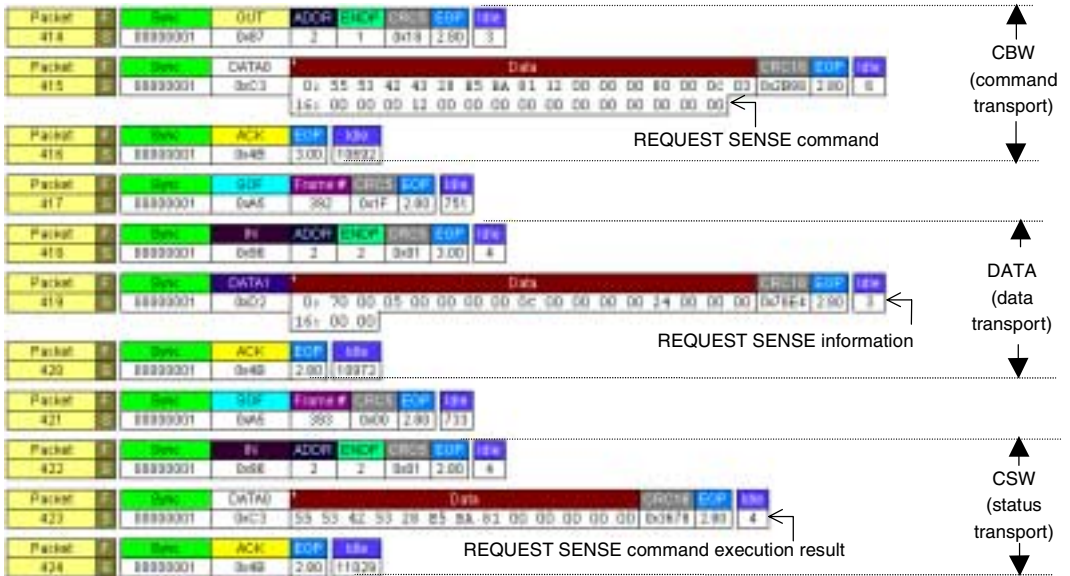
- READ (10) command



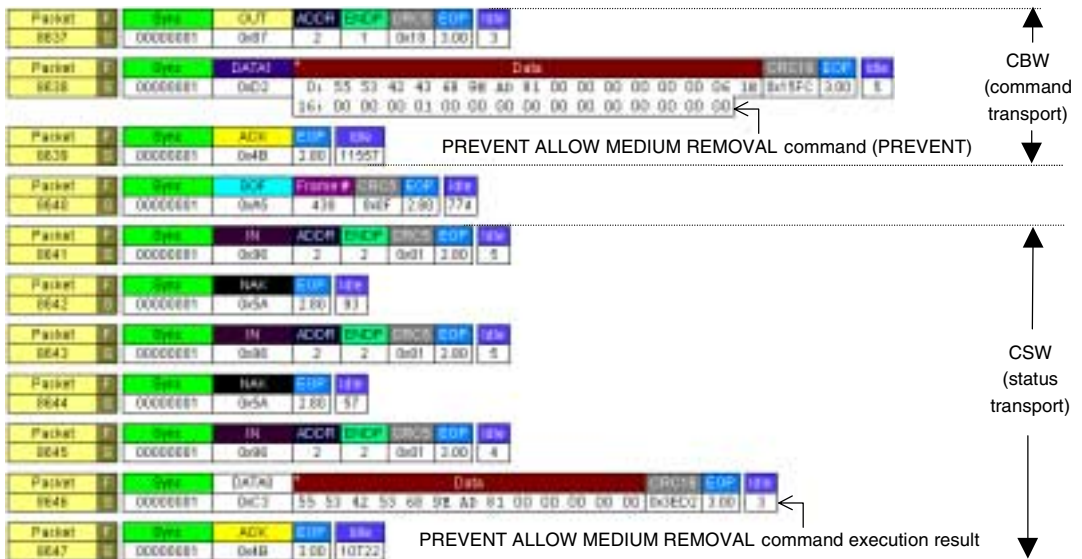
- WRITE (10) command



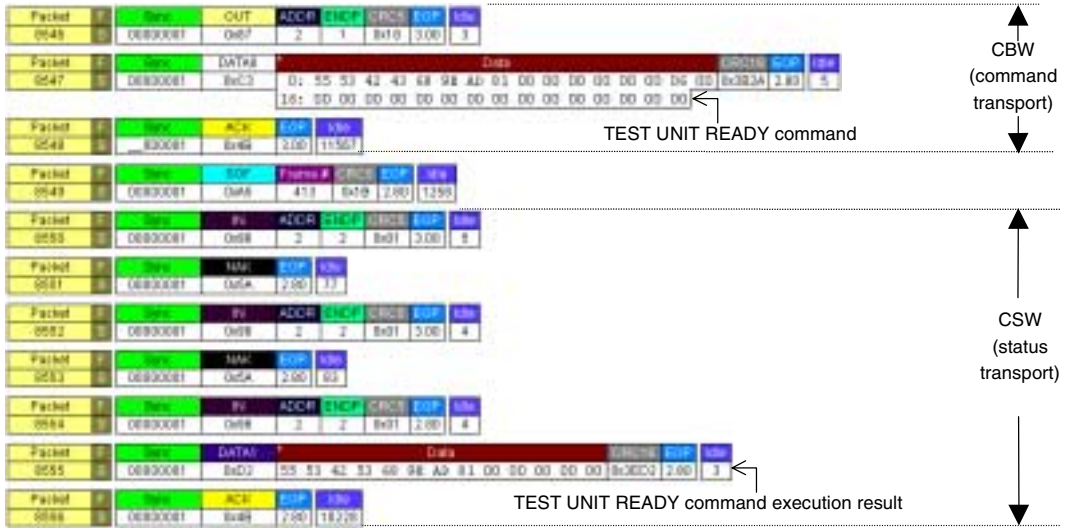
- REQUEST SENSE command



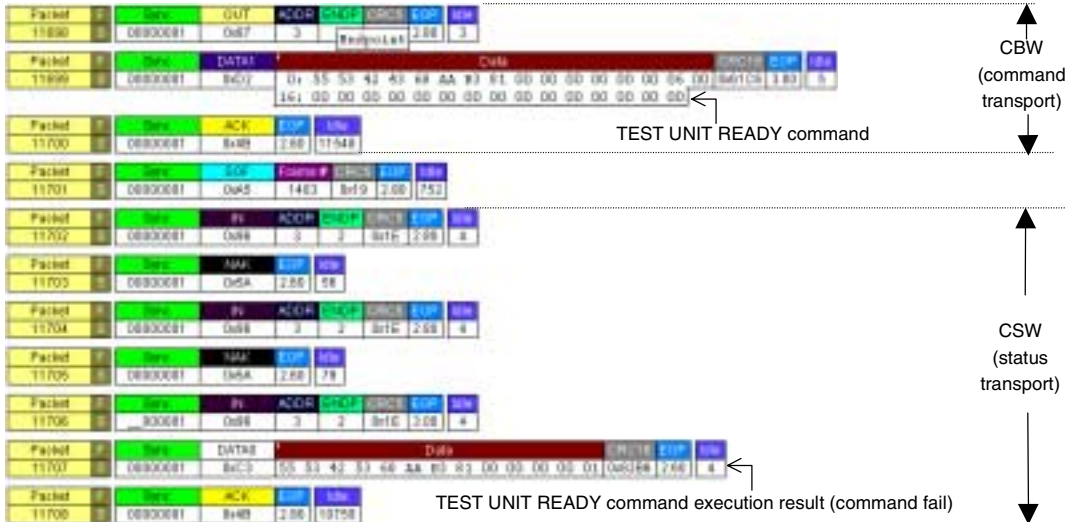
- PREVENT ALLOW MEDIUM REMOVAL command



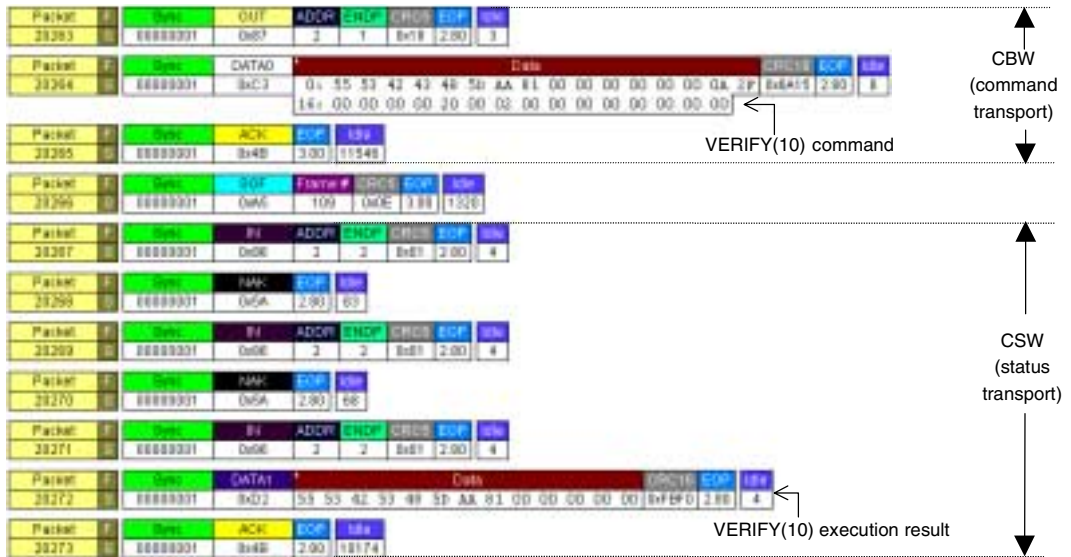
- **TEST UNIT READY** command (Normal)



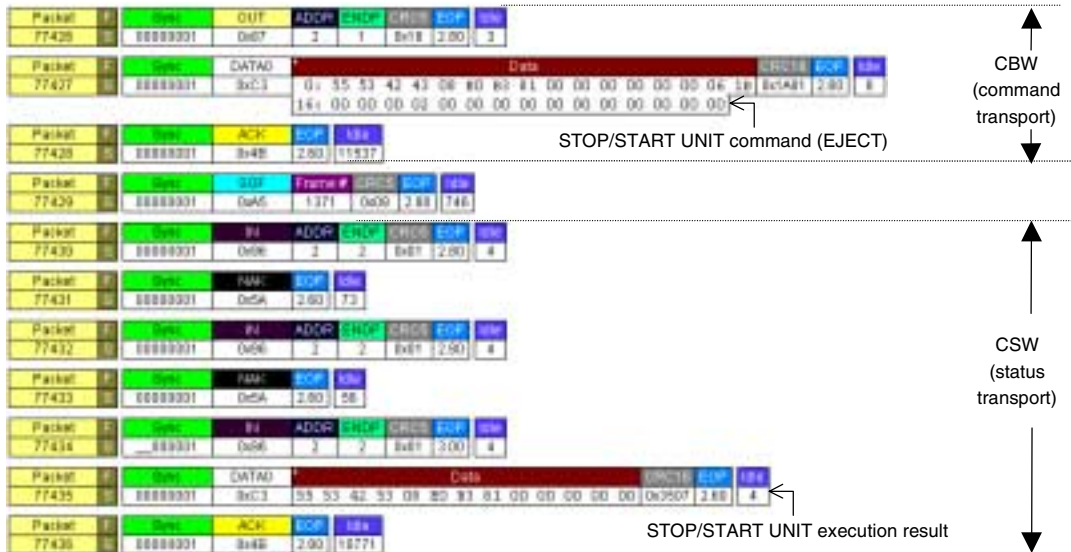
- TEST UNIT READY command (When the medium is removed)



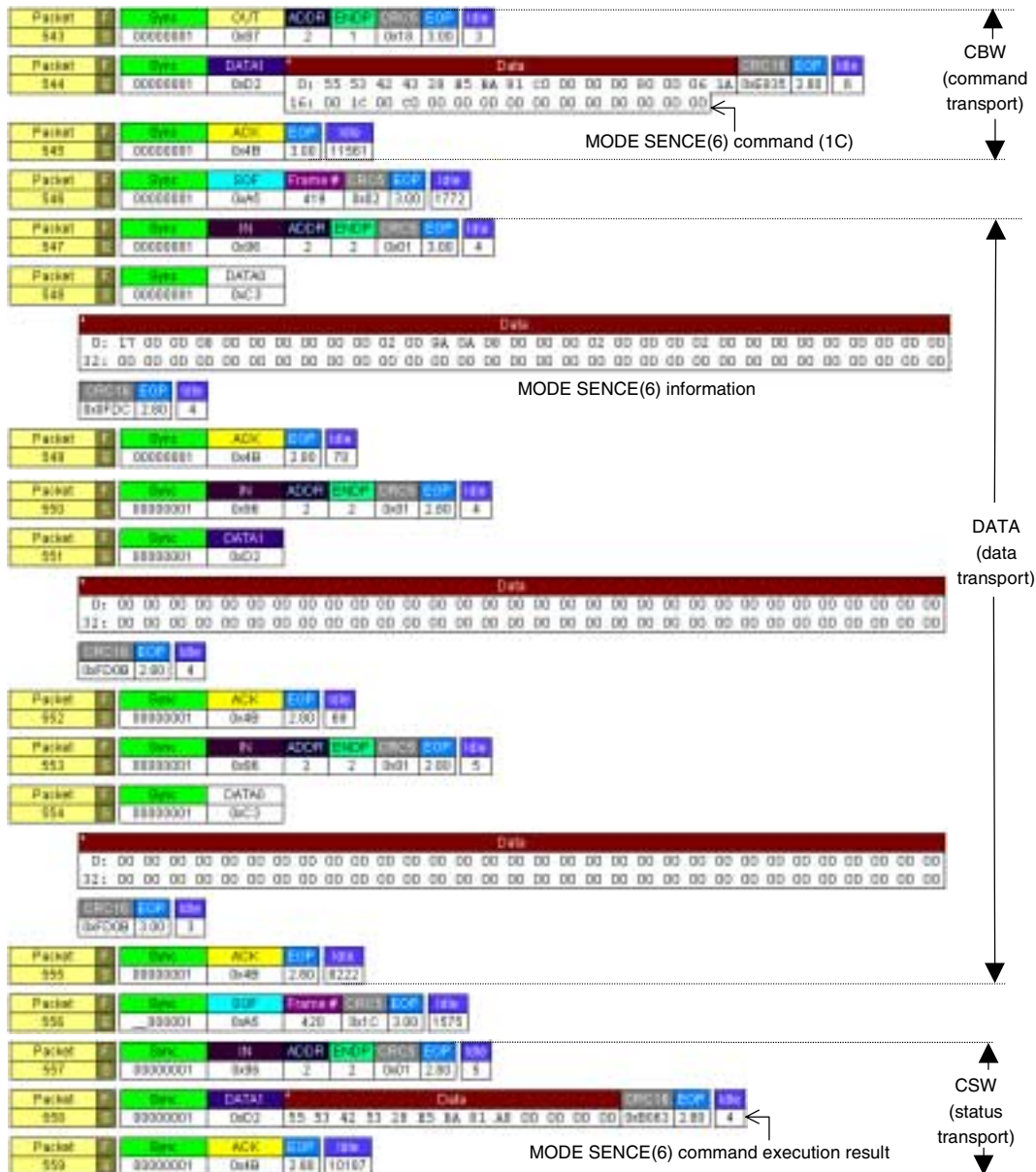
- VERIFY (10) command



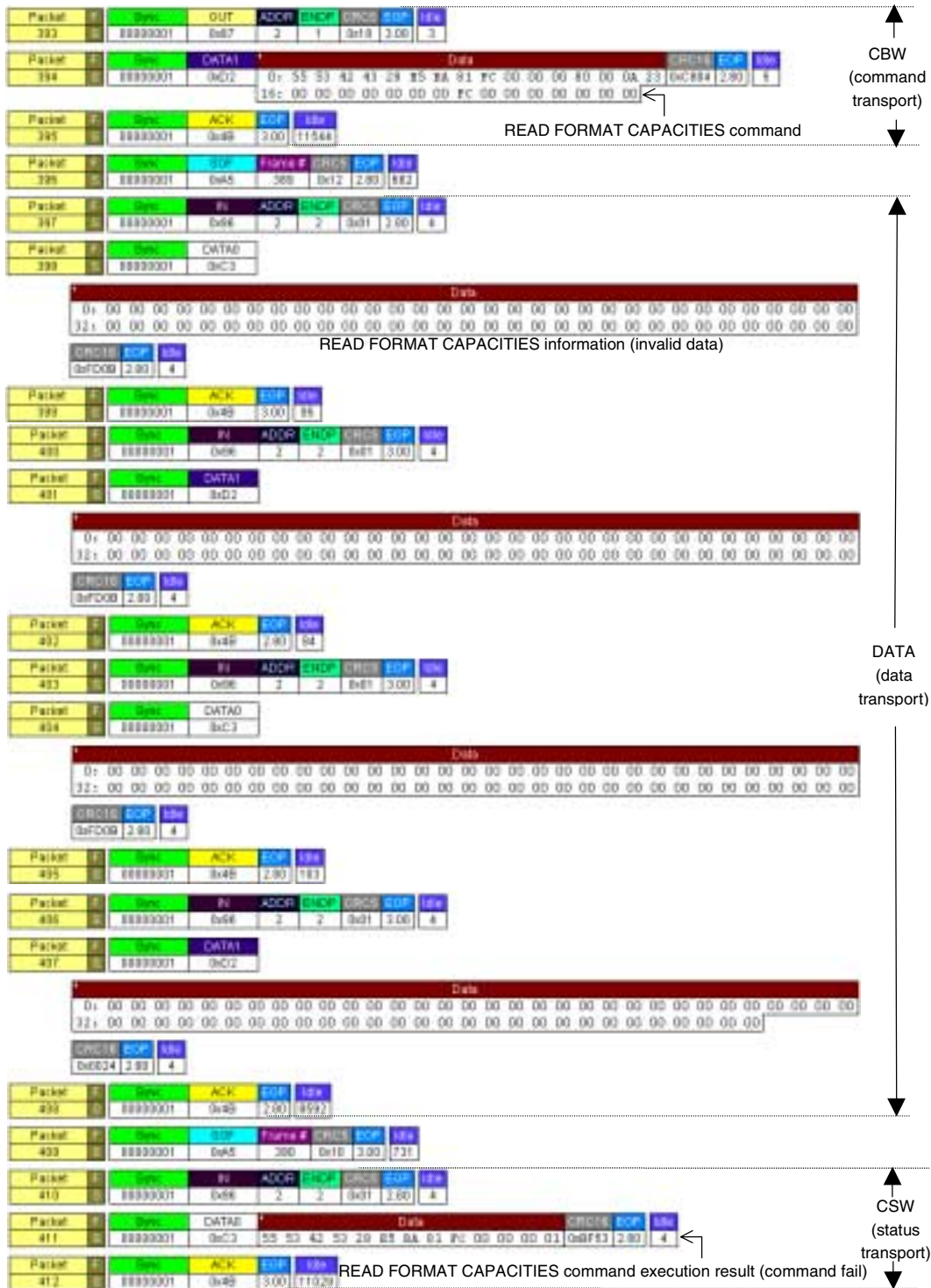
- STOP/START UNIT command



- MODE SENCE (6) command



- READ FORMAT CAPACITIES command (unsupported command)



SH7705 USB Function Module Mass Storage Class (Bulk-Only Transport) Application Note

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