FAT32 IP Core for SATA

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Features

- Simple user interface
- Operating with DG SATA Host IP Core
- Implement FAT32 file system management without CPU usage
- Maximum write speed up to 520 MB/s and read speed up to 560 MB/s
- Support disk capacity: 64 MB – 2 TB disk
- Support three commands, i.e. Format, Write file, and Read file
- Support seven file sizes, i.e. 32MB, 64MB, 128MB, 256MB, 512MB, 1024MB, 2048MB
- Reference design available on ArriaV GX Starter board with AB12-HSMCRAID, and Arria10 GX/Arria10 SoC development baord with AB09-FMCRAID

Core Facts

Provided with Core	
Documentation	User Guide, Design Guide
Design File Formats	Encrypted hdl File
Instantiation Templates	VHDL
Reference Designs & Application Notes	QuartusII Project, See Reference Design Manual
Additional Items	Demo on ArriaVGX/Arria10 SoC/Arria10 GX Development Kit
Support	
Support Provided by Design Gateway Co., Ltd.	

Table 1: Example Implementation Statistics

Family	Example Device	Fmax (MHz)	Logic utilization (ALMs)	Registers[1]	Pin	Block Memory bit	Design Tools
ArriaV GX	5AGXFB3H4F35C4	263	665	1,085	-	41,984	QuartusII 16.0
Arria10 SX	10AS066N3F40E2SG	384	699	1,082	-	41,984	QuartusII 16.0

Notes:
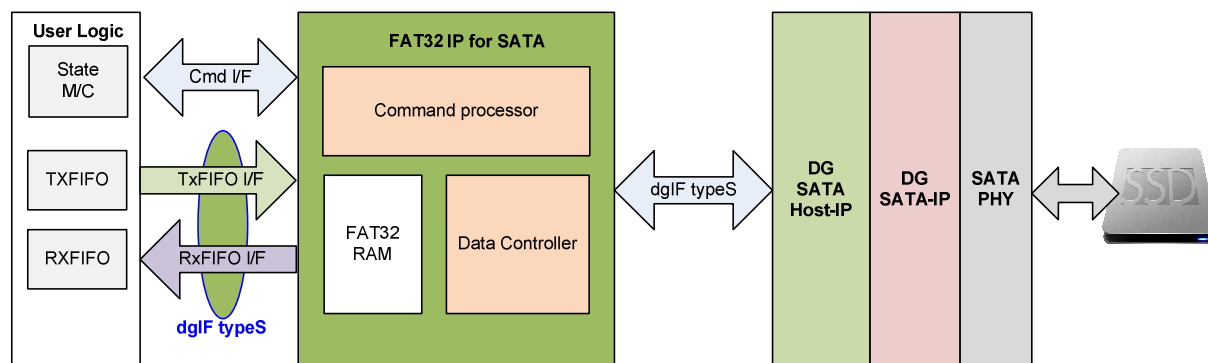1) Actual logic resource dependent on percentage of unrelated logic

Figure 1: FAT32 IP Block Diagram

Applications

FAT32 IP Core for SATA operating with SATA Host-IP core suite (DG SATA Host-IP and DG SATA-IP) and SATA PHY is an ideal to access SATA device with FAT32 File system management without using both CPU and external memory. It can transfer data as a file in FAT32 format as fast as raw data transfer. The data transfer speed can be raised up to the maximum limit of SATA device by using FAT32 IP Core combined with SATA Host IP Core suite. The IP is recommended for application which requires very high-speed data recording system and the data can be processed directly by the operating system that can access FAT32 format.

General Description

FAT32 IP Core for SATA is designed to transfer data as FAT32 file system to SATA device. by interfacing between user logic and SATA Host IP Core suite. User can transfer data to SATA device as a file in FAT32 file system standard instead of raw data. In general system, data format in SATA device when using SATA Host IP Core suite is raw data. When user connects SATA device to other systems, it needs to use special software to access as raw data. FAT32 file system is well known and general use in many systems, so user can read data from SATA device without special software.

FAT32 IP Core for SATA supports three commands, i.e. Format, Write file, and Read file. FAT32 IP Core can work with varieties of disk capacity from 64 MB – 2 TB with only one partition, stored data as a file with adjustable file size from 32MB - 2GB per file. Once a disk is writtten, file size cannont be changed until it is formatted.

User interface of FAT32 IP Core for SATA has two groups, i.e. control and data. Control interface is almost similar to dgIF typeS, but physical address and length are replaced by file number and numbers of file. Data interface of FAT32 IP Core is dgIF typeS interface.

Clock domain for FAT32 IP Core for SATA is same as SATA Host IP's user clock.
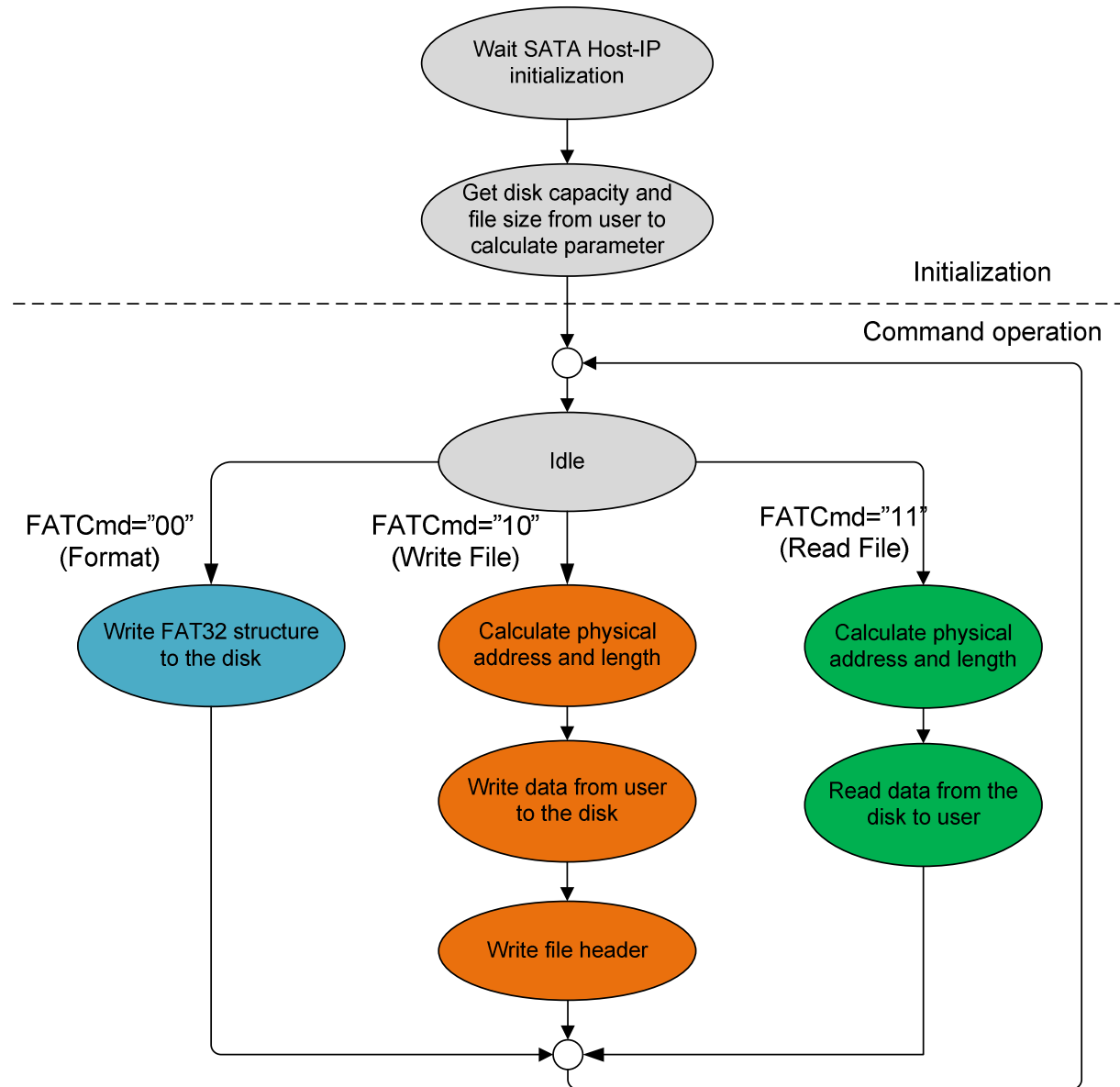
Functional Description

Figure 2: FAT32 IP for SATA Operation

The sequence of FAT32 IP Core for SATA operation is as follows:
1) IP waits SATA Host-IP to complete SATA device initialization.
2) IP sends Identify device command to SATA Host-IP to get disk capacity. File size input from user and disk capacity are used to calculate FAT32 parameters. After that, IP is ready to wait command from user. Three commands can be selected, i.e. Format, Write file, and Read file.
3) a. Format command is required to set up file system in the disk and clean up the disk. If file size parameter is changed, the maximum numbers of file in the disk will be changed. So, Format commmand is required when file size is changed.
In Format command, the IP writes FAT32 file structure such as Master Boot Record and root directory to the disk.

b. When user select Write command, the 1st file name and numbers of file input from user are received to calculate the start physical address and total length to write the disk by user data. Data from user is transferred to the disk continuously until end of transfer. After that, the IP writes file header to complete file operation.

Note:
1. File header is filled to the disk in the final step. If system is powered down before the header is filled, the new file will be lost and will not found in the disk.
2. The is no protection if the input from user is out-of-range.

c. Similar to Write command, the 1st process of Read command is to calculate start physical address and total length to read the disk from user input. Data from SATA device is transferred to user until end of transfer.

FAT32 IP for SATA

As shown in Figure 1, there are three submodules inside the IP, i.e. Command processor, Data Controller, and FAT32 RAM. Command processor receives command interface from user logic, converts the inputs to internal parameter and sends the command to DG SATA Host IP. Data controller is designed to transfer data between FIFOs in user logic to DG SATA Host IP. Data sending to DG SATA Host IP has two types, i.e. user data and file system data. Most of File system data are stored in FAT32 RAM. More details of each submodules are described as follows.

● **Command processor**

This module includes state machine to control the IP operation to follow the sequence in **Error! Reference source not found.**. There are many calculation units in this block to calculate FAT32 parameters and the physical address of system area in FAT32 file system from user inputs and disk capacity. The command interface of user logic and DG SATA Host-IP are connected to this block. Also, it calculates the parameter inputs and generates control signals to Data controller.

● **FAT32 RAM**

This RAM is designed by simple dual port RAM.The size is 1024x32-bit. FAT32 file system data is stored in this RAM.

- **FAT32 Data Controller**

  This module is desigend to control data flow between user logic and DG SATA Host IP. To create file in the disk, three data sources are transferred to DG SATA Host-IP, i.e. user data from TxFIFO in user logic, FAT32 file system data from FAT32 RAM, and FAT32 parameters from internal registers.

DG SATA Host-IP and DG SATA-IP

Details of DG SATA Host IP and DG SATA-IP are described in the datasheet and can be downloaded from our website.

http://www.dgway.com/products/IP/SATA-IP/Altera/dg_sata_host_ip_datasheet_alt_en.pdf

http://www.dgway.com/products/IP/SATA-IP/Altera/dg_sata_ip_datasheet_altera5_en.pdf

User Logic

Simple logic which can be designed by using small state machine to send command, file number, and file size. Two FIFOs are used to connect with data interface of FAT32 IP for SATA. One is used for Write command and another is used for Read command.

Core I/O Signals

Descriptions of all signal I/O are provided in Table 2.

Table 2: Core I/O Signals

Signal	Dir	Description
System signal		
RstB	In	Synchronous reset signal. Active low. Deassert to '1' when Clk signal is stable.
Clk	In	User clock. Must use the same clock as SATA Host-IP. (At least 150 MHz for SATA3 or at least 75 MHz for SATA2)
FSize[2:0]	In	File size: "000" : 32MB, "001" : 64MB, "010" : 128MB, "011" : 256MB, "100" : 512MB, "101" : 1024MB, "110" : 2048MB, "111": Reserved Note: 1) 1 MB is 1024x1024 byte 2) FSize must not be changed when there are available file in the disk. When FSize value is changed, user logic must send Format command to the IP.
FDateY[6:0]	In	Year in created date, count from 1980 (For example, FDateY=37 is year 2017). This input is used in write file command. The value must be stable during write operation.
FDateM[3:0]	In	Month in created date. Valid from 1-12 (1=Jan, 2= Feb, …). This input is used in write file command. The value must be stable during write operation.
FDateD[4:0]	In	Day in created date. Valid from 1-31. This input is used in write file command. The value must be stable during write operation.
FTimeH[4:0]	In	Hour in created time. Valid from 0-23. This input is used in write file command. The value must be stable during write operation.
FTimeM[5:0]	In	Minute in created time. Valid from 0-59. This input is used in write file command. The value must be stable during write operation.
FTImeS[4:0]	In	x2 sec in created time. Valid from 0-29 (1=2, 2=4, …). This input is used in write file command. The value must be stable during write operation.
User Interface (Command)		
UserCmd[1:0]	In	User Command. "00": Format command, "01" Reserved, "10": Write file, "11": Read file.
UserFName[15:0]	In	The 1st file name to write/read file (0= FILE0000.BIN, 1=FILE0001.BIN, …). Valid form 0 to TotalFCap - 1.
UserFLen[15:0]	In	Total files transfer in the request. Valid from 1 to (TotalFCap – UserFName).
UserReq	In	Request the new command. Can be asserted only when the IP is Idle (UserBusy='0'). Asserted with valid value on UserCmd, UserFName, and UserFLen signals.
UserBusy	Out	IP Busy status. New request will not be allowed if this signal is asserted to '1'.
TotalFCap[15:0]	Out	Maximum numbers of file which the disk can store. This value is updated after FAT32-IP completes initialization process.
UserError	Out	Direct mapped to SATAError siganl. Please see more details in SATA Host-IP datasheet.
UserErrorType[31:0]	Out	Direct mapped to SATAErrorType siganl. Please see more details in SATA Host-IP datasheet.
TesPin[63:0]	Out	Reserved to be IP test point.

Signal	Dir	Description
User Interface (Data)		
UserFifoWrCnt[15:0]	In	Write data counter of received FIFO. Used to check full status. If total FIFO size is less than 16-bit, please fill '1' to upper bit. UserFifoWrEn will be asserted when UserFifoWrCnt[15:3] is not equal to all 1.
UserFifoWrEn	Out	Write data valid of received FIFO.
UserFifoWrData[31:0]	Out	Write data bus of received FIFO. Synchronous to UserFifoWrEn.
UserFifoRdCnt[15:0]	In	Read data counter of transmit FIFO. Used to check data available size in FIFO. If total FIFO size is less than 16-bit, please fill '0' to upper bit. This signal is unused for this IP.
UserFifoEmpty	In	FIFO empty flag of transmit FIFO to check data available status.
UserFifoRdEn	Out	Read valid of transmit FIFO.
UserFifoRdData[31:0]	In	Read data returned from transmit FIFO. Valid after UserFifoRdEn asserted about one clock period.
SATA Host-IP User Interface (Connect to dgIF typeS of SATA Host-IP) (Please see more details from SATA Host-IP datasheet)		
SATACmd[1:0]	Out	Connect to UserCmd of SATA Host-IP
SATAAddr[47:0]	Out	Connect to UserAddr of SATA Host-IP
SATALen[47:0]	Out	Connect to UserLen of SATA Host-IP
SATAReq	Out	Connect to UserReq of SATA Host-IP
SATABusy	In	Connect to UserBusy of SATA Host-IP
SATALBASize[47:0]	In	Connect to LBASize of SATA Host-IP
SATAError	In	Connect to UserError of SATA Host-IP
SATAErrorType[31:0]	In	Connect to UserErrorType of SATA Host-IP
SATAFifoWrCnt[15:0]	Out	Connect to UserFifoWrCnt of SATA Host-IP
SATAFifoWrEn	In	Connect to UserFifoWrEn of SATA Host-IP
SATAFifoWrData[31:0]	In	Connect to UserFifoWrData of SATA Host-IP
SATAFifoRdCnt[15:0]	Out	Connect to UserFifoRdCnt of SATA Host-IP
SATAFifoEmpty	Out	Connect to UserFifoEmpty of SATA Host-IP
SATAFifoRdEn	In	Connect to UserFifoRdEn of SATA Host-IP
SATAFifoRdData[31:0]	Out	Connect to UserFifoRdData of SATA Host-IP

Timing Diagram

Initialization

After RstB is deasserted, UserBusy flag is set to '1'. After the initialization process is completed, UserBusy is deasserted to '0'. The IP is ready to receive new command and TotalFCap signal is valid as shown in Figure 3.
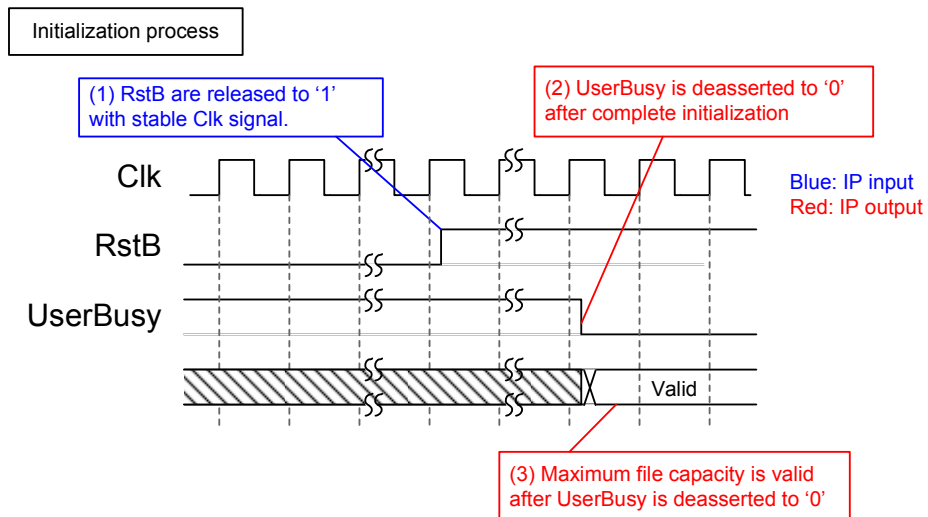

Figure 3: FAT32-IP for SATA Intialization

User Interface

User interface can be split into two groups, i.e. command interface and data interface. Timing diagram of both groups are compatible to dgIF typeS interface. The input parameters in command interface of FAT32-IP for SATA are changed from physical level to be file name and numbers of file as shown in Figure 4.

Before sending new command to the IP, UserBusy must be always monitored to confirm that IP is Idle. UserCmd, UserFName, and UserFLen must be valid and latched during asserting UserReq='1'. UserBusy changes status from '0' to '1' after start the command operation. So, UserReq can be cleared and user logic can prepare the next command to the command bus.

Note: UserFName and UserFLen input are ignored in Format command.

For data interface, transmit FIFO (TXFIFO) is read for Write file command and received FIFO (RXFIFO) is written for Read file command. Timing diagram of data interface are shown in Figure 5 and Figure 6.
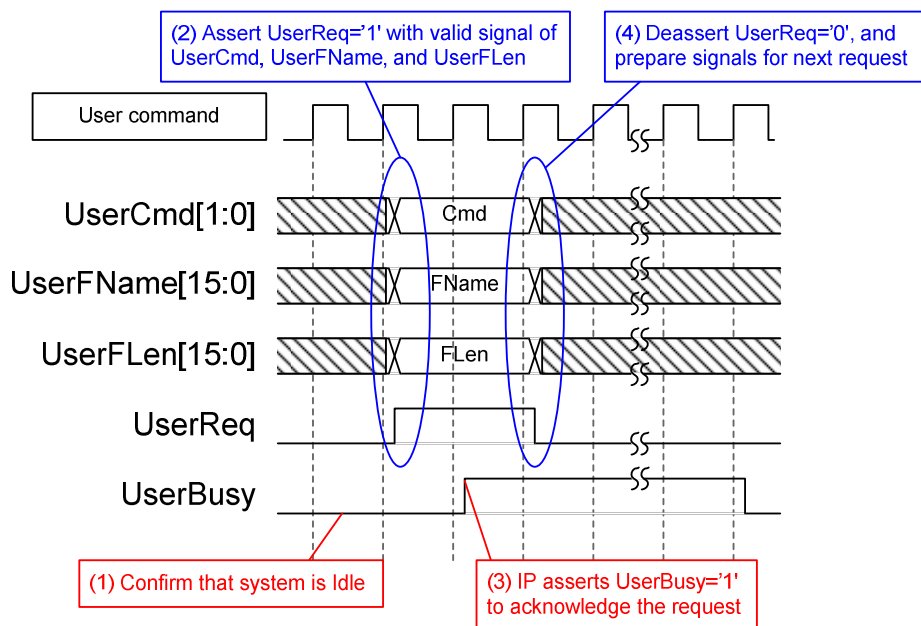

Figure 4: User Interface (Command) Timing diagram

For write command, UserFifoEmpty is monitored to check data available status of TXFIFO. When data is ready, UserFifoRdEn is asserted to forward data from TXFIFO to SATA Host-IP until total data are transferred to SATA Host-IP. Similar to typical FIFO, UserFifoRdData is valid in the next clock after UserFifoRdEn is asserted, as shown in Figure 5.
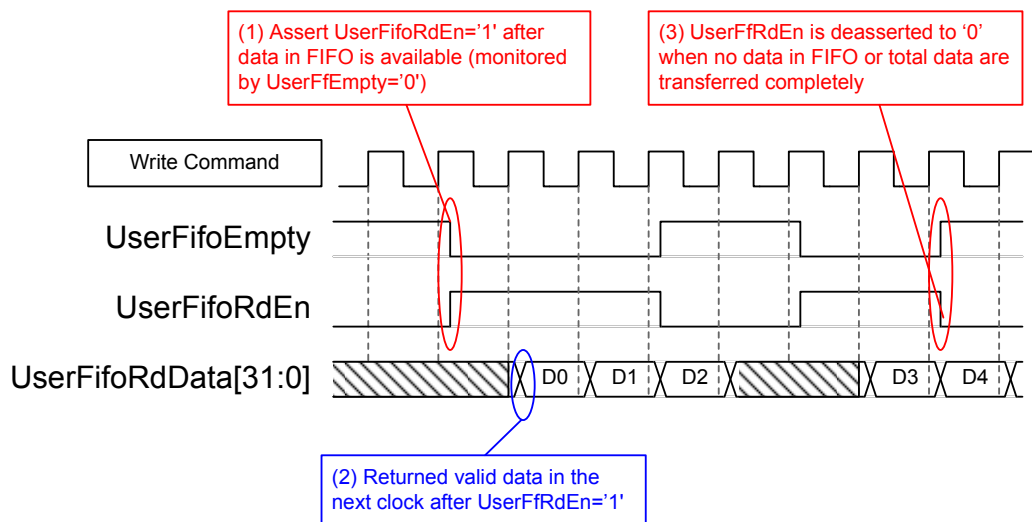

Figure 5: TX FIFO Interface for Write command

For read command, UserFifoWrEn is asserted with the valid value of UserFifoWrData to store data to RXFIFO until total data are transferred to user logic. UserFifoWrCnt is monitored to check the remaining space in the FIFO. Data is transferred when remaining space in FIFO is more than 7. If UserFfWrCnt is more than or equal to 65528 (less than 7 words are remaining in FIFO), UserFifoWrEn will be deasserted to '0' to pause data transferring, as shown in Figure 5.
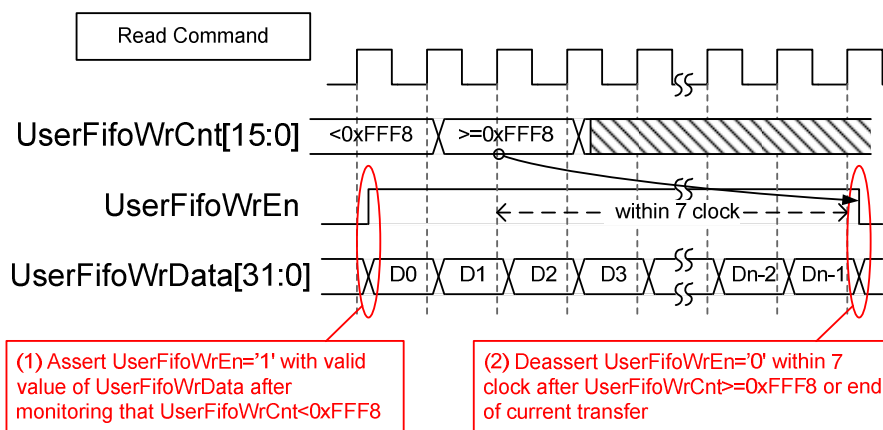

Figure 6: RX FIFO Interface for Read command

Example usage

The example sequence to use FAT32-IP for SATA to write and read data with SATA device is shown as follows.

1) Deassert RstB='1' to start system initialization. Wait until UserBusy='0'.

2) Skip to next step when the disk does not need to format. In case, the disk needs to format. Send Format command to the IP (UserCmd="00"). Wait until IP operation complete (UserBusy='0').

   Note: Format command must be sent from user logic firstly when one of following condition is matched.

   a) The disk is the new disk which is not formatted by FAT32-IP for SATA.

   b) User needs to clear data in the disk.

   c) User needs to change a file size parameter.

3) Send Write file command (UserCmd="10") or Read file command (UserCmd="11") to the disk. FSize value must not be changed after the disk is formatted.
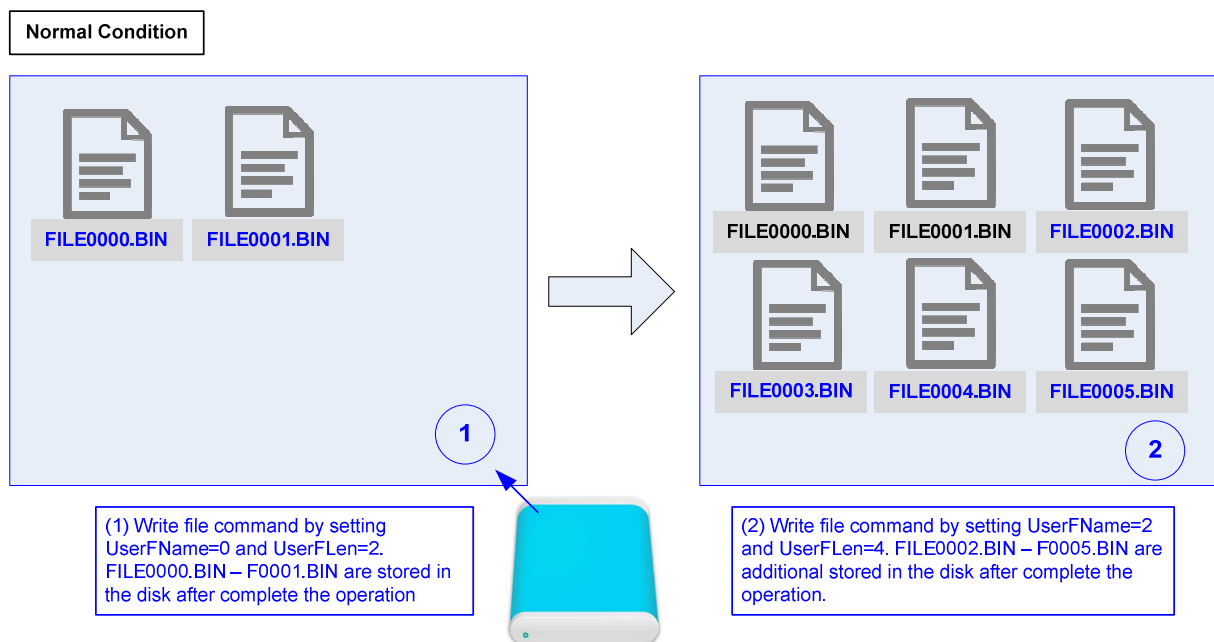
   In case of write command,

   a) Set FDateY, FDateM, FDateD, FTimeH, FTimeM, and FTimeS to set up "Created date" and "Created time" of the file. All values must not be changed during write operation.

   b) Send Write file command with a valid UserFName and UserFLen. UserFName must be the next value from the latest file. For example, if the latest file in the disk is FILE0010.BIN, UserFName will be set to 0x000B to create FILE0011.BIN to be the 1st file in this command. UserFLen value must not be more than (TotalFCap – UserFName).

   c) Send total data to TXFIFO and the IP reads the data from TXFIFO by monitoring UserFifoEmpty='0'. Total data size is equal to UserFLen x FSize.

   d) Wait until IP operation complete (UserBusy='0').

   In case of read command,

   a) Send Read file command with valid UserFName and UserFLen. (UserFName + UserFLen) value must not be more than total number of files in the disk.

   b) Read total data from RXFIFO. The IP monitors UserFifoWrCnt[15:3] /= all 1 before sending received data to RXFIFO. Total data size is equal to UserFLen x FSize.

   c) Wait until IP operation complete (UserBusy='0').

Additional Information

1) FAT32-IP for SATA calculates FAT32 parameters which uses in all operations from user input parameters and disk capacity. File system in the disk is specially designed for using in FAT32-IP for SATA. So, the disk must not be formatted or written by other system. Only read file from the disk is allowed for other system.

2) Physical address of the disk to store user data in each file is calculated from file name and file size input from user. So FSize input from user must not change when user writes or reads the file with the disk. User needs to send Format command after user changes FSize input value. TotalFCap is updated when FSize value is changed.

3) For Write file command, UserFName input must be the next value from the latest file name, as shown in Figure 7.

Normal Condition

FILE0000.BIN   FILE0001.BIN

FILE0000.BIN   FILE0001.BIN   FILE0002.BIN

FILE0003.BIN   FILE0004.BIN   FILE0005.BIN

1

2

(1) Write file command by setting UserFName=0 and UserFLen=2. FILE0000.BIN – F0001.BIN are stored in the disk after complete the operation

(2) Write file command by setting UserFName=2 and UserFLen=4. FILE0002.BIN – F0005.BIN are additional stored in the disk after complete the operation.

Figure 7: Write file command in normal condition

If UserFName is not equal to the next value, the new file will be created with unusual status. The example of the unusual status is as follows.

a) When UserFName is more than the next value of the latest file, the dummy file which cannot be accessed is created between the latest file and the 1st new file, as shown in Figure 8.
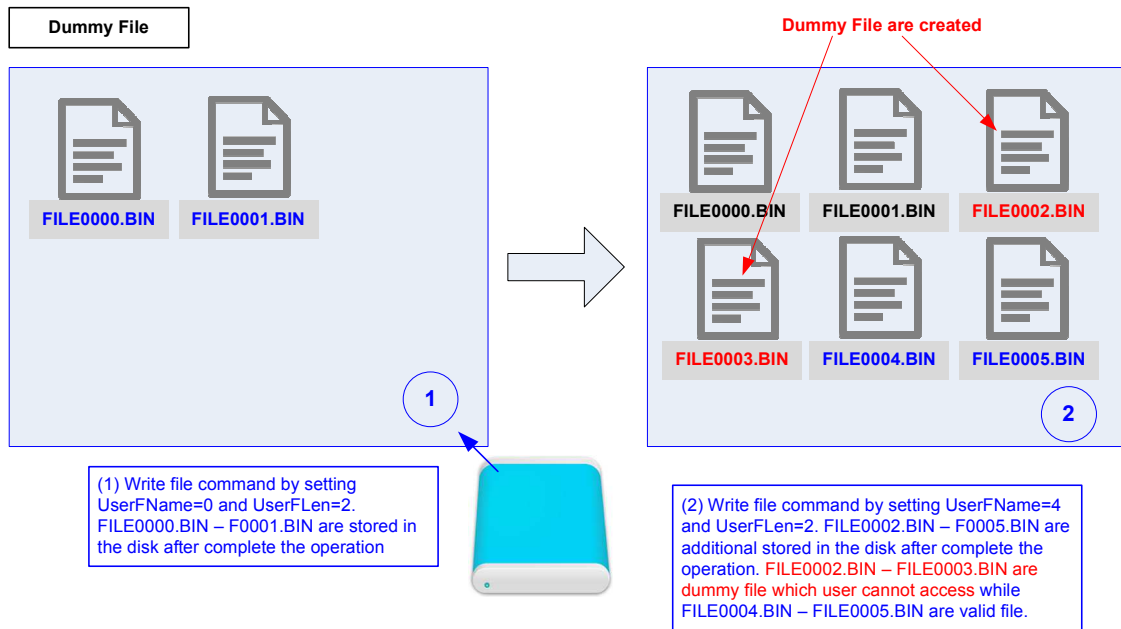
Figure 8: Write file command but UserFName is more than normal value

b) When UesrFName is less than the next value of the latest f ile, the file after the 1st new file is lost, as shown in Figure 9.
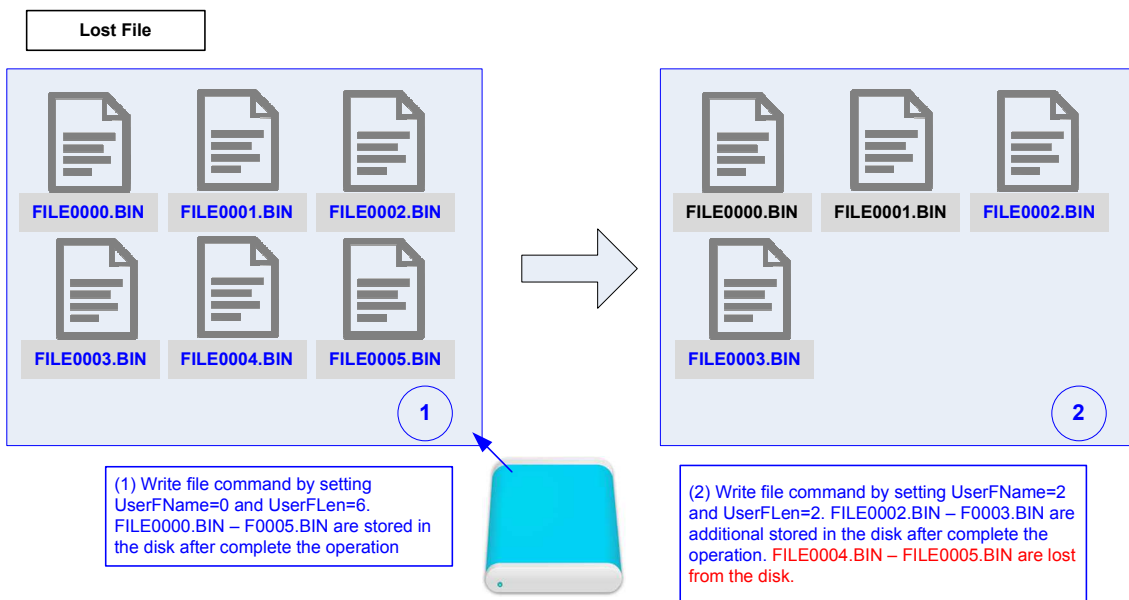
Figure 9: Write file command but UserFName is less than normal value

Verification Methods

The FAT32 IP Core for SATA functionality was verified by simulation and also proved on real board design by using ArriaV GX/Arria10 SoC/Arria10 GX development board.

Recommended Design Experience

Experience design engineers with a knowledge of QuartusII Tools should easily integrate this IP into their design.

Ordering Information

This product is available directly from Design Gateway Co., Ltd. Please contact Design Gatway Co., Ltd. for pricing and additional information about this product using the contact information on the front page of this datasheet.

Revision History

Revision	Date	Description
1.0	Sep-22-2017	New release