



# BCM2835 ARM Peripherals

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## 1 Introduction

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### 1.1 Overview

BCM2835 contains the following peripherals which may safely be accessed by the ARM:

- Timers
- Interrupt controller
- GPIO
- USB
- PCM / I2S
- DMA controller
- I2C master
- I2C / SPI slave
- SPI0, SPI1, SPI2
- PWM
- UART0, UART1

The purpose of this datasheet is to provide documentation for these peripherals in sufficient detail to allow a developer to port an operating system to BCM2835.

There are a number of peripherals which are intended to be controlled by the GPU. These are omitted from this datasheet. Accessing these peripherals from the ARM is not recommended.

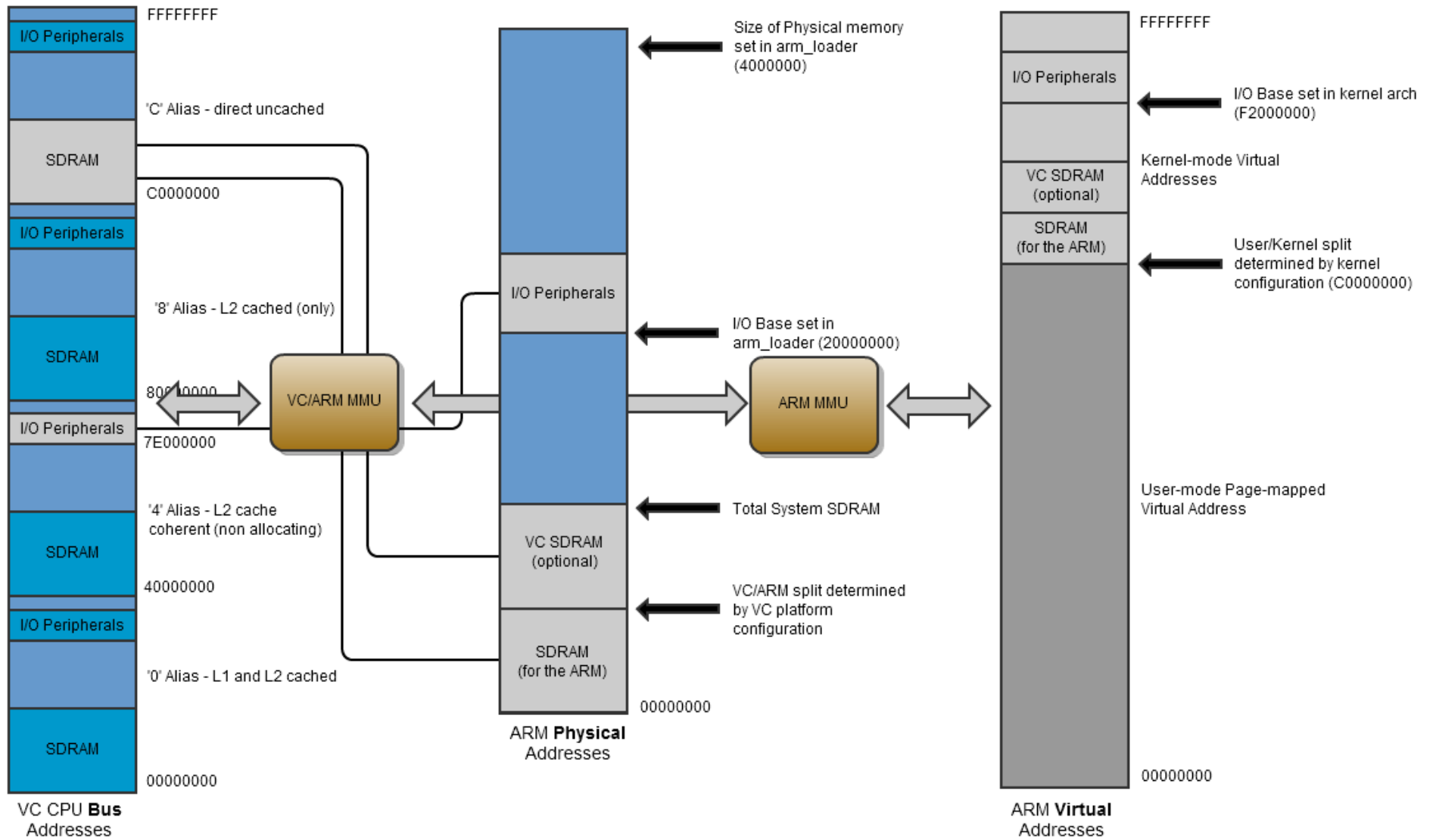
### 1.2 Address map

#### 1.2.1 Diagrammatic overview

In addition to the ARM's MMU, BCM2835 includes a second coarse-grained MMU for mapping ARM physical addresses onto system bus addresses. This diagram shows the main address spaces of interest:



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Addresses in ARM Linux are:

- issued as virtual addresses by the ARM core, then
- mapped into a physical address by the ARM MMU, then
- mapped into a bus address by the ARM mapping MMU, and finally
- used to select the appropriate peripheral or location in RAM.

## 1.2.2 ARM virtual addresses (standard Linux kernel only)

As is standard practice, the standard BCM2835 Linux kernel provides a contiguous mapping over the whole of available RAM at the top of memory. The kernel is configured for a 1GB/3GB split between kernel and user-space memory.

The split between ARM and GPU memory is selected by installing one of the supplied `start*.elf` files as `start.elf` in the FAT32 boot partition of the SD card. The minimum amount of memory which can be given to the GPU is 32MB, but that will restrict the multimedia performance; for example, 32MB does not provide enough buffering for the GPU to do 1080p30 video decoding.

Virtual addresses in kernel mode will range between `0xC0000000` and `0xEFFFFFFF`.

Virtual addresses in user mode (i.e. seen by processes running in ARM Linux) will range between `0x00000000` and `0xBFFFFFFF`.

Peripherals (at physical address `0x20000000` on) are mapped into the kernel virtual address space starting at address `0xF2000000`. Thus a peripheral advertised here at bus address `0x7Ennnnnn` is available in the ARM kernel at virtual address `0xF2nnnnnn`.

## 1.2.3 ARM physical addresses

Physical addresses start at `0x00000000` for RAM.

- The ARM section of the RAM starts at `0x00000000`.
- The VideoCore section of the RAM is mapped in only if the system is configured to support a memory mapped display (this is the common case).

The VideoCore MMU maps the ARM physical address space to the bus address space seen by VideoCore (and VideoCore peripherals). The bus addresses for RAM are set up to map onto the uncached<sup>1</sup> bus address range on the VideoCore starting at `0xC0000000`.

Physical addresses range from `0x20000000` to `0x20FFFFFF` for peripherals. The bus addresses for peripherals are set up to map onto the peripheral bus address range starting at `0x7E000000`. Thus a peripheral advertised here at bus address `0x7Ennnnnn` is available at physical address `0x20nnnnnn`.

## 1.2.4 Bus addresses

**The peripheral addresses specified in this document are bus addresses.** Software directly accessing peripherals must translate these addresses into physical or virtual addresses, as described above. Software accessing peripherals using the DMA engines must use bus addresses.

<sup>1</sup> BCM2835 provides a 128KB system L2 cache, which is used primarily by the GPU. Accesses to memory are routed either via or around the L2 cache depending on senior two bits of the bus address.



Software accessing RAM directly must use physical addresses (based at 0x00000000). Software accessing RAM using the DMA engines must use bus addresses (based at 0xC0000000).

## 1.3 Peripheral access precautions for correct memory ordering

The BCM2835 system uses an AMBA AXI-compatible interface structure. In order to keep the system complexity low and data throughput high, the BCM2835 AXI system does not always return read data in-order<sup>2</sup>. The GPU has special logic to cope with data arriving out-of-order; however the ARM core does not contain such logic. Therefore some precautions must be taken when using the ARM to access peripherals.

Accesses to the same peripheral will always arrive and return in-order. It is only when switching from one peripheral to another that data can arrive out-of-order. The simplest way to make sure that data is processed in-order is to place a memory barrier instruction at critical positions in the code. You should place:

- A memory write barrier before the first write to a peripheral.
- A memory read barrier after the last read of a peripheral.

It is **not** required to put a memory barrier instruction after **each** read or write access. Only at those places in the code where it is possible that a peripheral read or write may be followed by a read or write of a **different** peripheral. This is normally at the entry and exit points of the peripheral service code.

As interrupts can appear anywhere in the code so you should safeguard those. If an interrupt routine reads from a peripheral the routine should start with a memory read barrier. If an interrupt routine writes to a peripheral the routine should end with a memory write barrier.

---

<sup>2</sup>Normally a processor assumes that if it executes two read operations the data will arrive in order. So a read from location X followed by a read from location Y should return the data of location X first, followed by the data of location Y. Data arriving out of order can have disastrous consequences. For example:

```
a_status = *pointer_to_peripheral_a;  
b_status = *pointer_to_peripheral_b;
```

Without precautions the values ending up in the variables a\_status and b\_status can be swapped around.

It is theoretical possible for writes to go 'wrong' but that is far more difficult to achieve. The AXI system makes sure the data always arrives in-order at its intended destination. So:

```
*pointer_to_peripheral_a = value_a;  
*pointer_to_peripheral_b = value_b;
```

will always give the expected result. The only time write data can arrive out-of-order is if two different peripherals are connected to the same external equipment.



## 2 Auxiliaries: UART1 & SPI1, SPI2

### 2.1 Overview

The Device has three Auxiliary peripherals: One mini UART and two SPI masters. These three peripheral are grouped together as they share the same area in the peripheral register map and they share a common interrupt. Also all three are controlled by the auxiliary enable register.

Auxiliary peripherals Register Map (offset = 0x7E21 5000)			
Address	Register Name <sup>3</sup>	Description	Size
0x7E21 5000	AUX_IRQ	Auxiliary Interrupt status	3
0x7E21 5004	AUX_ENABLES	Auxiliary enables	3
0x7E21 5040	AUX_MU_IO_REG	Mini Uart I/O Data	8
0x7E21 5044	AUX_MU_IER_REG	Mini Uart Interrupt Enable	8
0x7E21 5048	AUX_MU_IIR_REG	Mini Uart Interrupt Identify	8
0x7E21 504C	AUX_MU_LCR_REG	Mini Uart Line Control	8
0x7E21 5050	AUX_MU_MCR_REG	Mini Uart Modem Control	8
0x7E21 5054	AUX_MU_LSR_REG	Mini Uart Line Status	8
0x7E21 5058	AUX_MU_MSR_REG	Mini Uart Modem Status	8
0x7E21 505C	AUX_MU_SCRATCH	Mini Uart Scratch	8
0x7E21 5060	AUX_MU_CNTL_REG	Mini Uart Extra Control	8
0x7E21 5064	AUX_MU_STAT_REG	Mini Uart Extra Status	32
0x7E21 5068	AUX_MU_BAUD_REG	Mini Uart Baudrate	16
0x7E21 5080	AUX_SPI0_CNTL0_REG	SPI 1 Control register 0	32
0x7E21 5084	AUX_SPI0_CNTL1_REG	SPI 1 Control register 1	8
0x7E21 5088	AUX_SPI0_STAT_REG	SPI 1 Status	32
0x7E21 5090	AUX_SPI0_IO_REG	SPI 1 Data	32
0x7E21 5094	AUX_SPI0_PEEK_REG	SPI 1 Peek	16
0x7E21 50C0	AUX_SPI1_CNTL0_REG	SPI 2 Control register 0	32
0x7E21 50C4	AUX_SPI1_CNTL1_REG	SPI 2 Control register 1	8

<sup>3</sup> These register names are identical to the defines in the AUX\_IO header file. For programming purposes these names should be used wherever possible.





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0x7E21 50C8	AUX_SPI1_STAT_REG	SPI 2 Status	32
0x7E21 50D0	AUX_SPI1_IO_REG	SPI 2 Data	32
0x7E21 50D4	AUX_SPI1_PEEK_REG	SPI 2 Peek	16

### 2.1.1 AUX registers

There are two Auxiliary registers which control all three devices. One is the interrupt status register, the second is the Auxiliary enable register. The Auxiliary IRQ status register can help to hierarchically determine the source of an interrupt.

#### AUXIRQ Register (0x7E21 5000)

**SYNOPSIS** The AUXIRQ register is used to check any pending interrupts which may be asserted by the three Auxiliary sub blocks.

Bit(s)	Field Name	Description	Type	Reset
31:3		Reserved, write zero, read as don't care		
2	SPI 2 IRQ	If set the SPI 2 module has an interrupt pending.	R	0
1	SPI 1 IRQ	If set the SPI1 module has an interrupt pending.	R	0
0	Mini UART IRQ	If set the mini UART has an interrupt pending.	R	0

#### AUXENB Register (0x7E21 5004)

**SYNOPSIS** The AUXENB register is used to enable the three modules; UART, SPI1, SPI2.

Bit(s)	Field Name	Description	Type	Reset
31:3		Reserved, write zero, read as don't care		
2	SPI2 enable	If set the SPI 2 module is enabled. If clear the SPI 2 module is disabled. That also disables any SPI 2 module register access	R/W	0
1	SPI 1 enable	If set the SPI 1 module is enabled. If clear the SPI 1 module is disabled. That also disables any SPI 1 module register access	R/W	0
0	Mini UART enable	If set the mini UART is enabled. The UART will immediately start receiving data, especially if the UART1_RX line is <i>low</i> . If clear the mini UART is disabled. That also disables any mini UART register access	R/W	0



If the enable bits are clear you will have no access to a peripheral. You can not even read or write the registers!

GPIO pins should be set up first the before enabling the UART. The UART core is build to emulate 16550 behaviour. So when it is enabled any data at the inputs will immediately be received . If the UART1\_RX line is low (because the GPIO pins have not been set-up yet) that will be seen as a start bit and the UART will start receiving 0x00-characters.

Valid stops bits are not required for the UART. (See also Implementation details). Hence any bit status is acceptable as stop bit and is only used so there is clean timing start for the next bit.

Looking after a reset: the baudrate will be zero and the system clock will be 250 MHz. So only 2.5 µseconds suffice to fill the receive FIFO. The result will be that the FIFO is full and overflowing in no time flat.

## 2.2 Mini UART

The mini UART is a secondary low throughput<sup>4</sup> UART intended to be used as a console. It needs to be enabled before it can be used. It is also recommended that the correct GPIO function mode is selected before enabling the mini Uart.

The mini Uart has the following features:

- 7 or 8 bit operation.
- 1 start and 1 stop bit.
- No parities.
- Break generation.
- 8 symbols deep FIFOs for receive and transmit.
- SW controlled RTS, SW readable CTS.
- Auto flow control with programmable FIFO level.
- 16550 *like* registers.
- Baudrate derived from system clock.

This is a mini UART and it does NOT have the following capabilities:

- Break detection
- Framing errors detection.
- Parity bit
- Receive Time-out interrupt
- DCD, DSR, DTR or RI signals.

The implemented UART is not a 16650 compatible UART However as far as possible the first 8 control and status registers are laid out like a 16550 UART. Al 16550 register bits which are not supported can be written but will be ignored and read back as 0. All control bits for simple UART receive/transmit operations are available.

---

<sup>4</sup> The UART itself has no throughput limitations in fact it can run up to 32 Mega baud. But doing so requires significant CPU involvement as it has shallow FIFOs and no DMA support.



## 2.2.1 Mini UART implementation details.

The UART1\_CTS and UART1\_RX inputs are synchronised and will take 2 system clock cycles before they are processed.

The module does not check for any framing errors. After receiving a start bit and 8 (or 7) data bits the receiver waits for one half bit time and then starts scanning for the next start bit. The mini UART does *not* check if the stop bit is high or wait for the stop bit to appear. As a result of this a UART1\_RX input line which is continuously low (a break condition or an error in connection or GPIO setup) causes the receiver to continuously receive 0x00 symbols.

The mini UART uses 8-times oversampling. The Baudrate can be calculated from:

$$baudrate = \frac{system\_clock\_freq}{8 * (baudrate\_reg + 1)}$$

If the system clock is 250 MHz and the baud register is zero the baudrate is 31.25 Mega baud. (25 Mbits/sec or 3.125 Mbytes/sec). The lowest baudrate with a 250 MHz system clock is 476 Baud.

When writing to the data register only the LS 8 bits are taken. All other bits are ignored. When reading from the data register only the LS 8 bits are valid. All other bits are zero.

## 2.2.2 Mini UART register details.

### AUX\_MU\_IO\_REG Register (0x7E21 5040)

**SYNOPSIS** The AUX\_MU\_IO\_REG register is primary used to write data to and read data from the UART FIFOs.  
If the DLAB bit in the line control register is set this register gives access to the LS 8 bits of the baud rate. (Note: there is easier access to the baud rate register)

Bit(s)	Field Name	Description	Type	Reset
31:8		Reserved, write zero, read as don't care		
7:0	LS 8 bits Baudrate read/write, DLAB=1	Access to the LS 8 bits of the 16-bit baudrate register. (Only If bit 7 of the line control register (DLAB bit) is set)	R/W	0
7:0	Transmit data write, DLAB=0	Data written is put in the transmit FIFO (Provided it is not full) (Only If bit 7 of the line control register (DLAB bit) is clear)	W	0
7:0	Receive data read, DLAB=0	Data read is taken from the receive FIFO (Provided it is not empty) (Only If bit 7 of the line control register (DLAB bit) is clear)	R	0



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## AUX\_MU\_IIR\_REG Register (0x7E21 5044)

**SYNOPSIS** The AUX\_MU\_IER\_REG register is primary used to enable interrupts  
If the DLAB bit in the line control register is set this register gives access to the MS 8 bits of the baud rate. (Note: there is easier access to the baud rate register)

Bit(s)	Field Name	Description	Type	Reset
31:8		Reserved, write zero, read as don't care		
7:0	MS 8 bits Baudrate read/write, DLAB=1	Access to the MS 8 bits of the 16-bit baudrate register. (Only If bit 7 of the line control register (DLAB bit) is set)	R/w	0
7:2		Reserved, write zero, read as don't care <i>Some of these bits have functions in a 16550 compatible UART but are ignored here</i>		
1	Enable receive interrupt (DLAB=0)	If this bit is set the interrupt line is asserted whenever the receive FIFO holds at least 1 byte. If this bit is clear no receive interrupts are generated.	R	0
0	Enable transmit interrupt (DLAB=0)	If this bit is set the interrupt line is asserted whenever the transmit FIFO is empty. If this bit is clear no transmit interrupts are generated.	R	0



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## AUX\_MU\_IER\_REG Register (0x7E21 5048)

**SYNOPSIS** The AUX\_MU\_IIR\_REG register shows the interrupt status.  
It also has two FIFO enable status bits and (when writing) FIFO clear bits.

Bit(s)	Field Name	Description	Type	Reset
31:8		Reserved, write zero, read as don't care		
7:6	FIFO enables	Both bits always read as 1 as the FIFOs are always enabled	R	11
5:4	-	Always read as zero	R	00
3	-	Always read as zero as the mini UART has no timeout function	R	0
2:1	READ: Interrupt ID bits WRITE: FIFO clear bits	On read this register shows the interrupt ID bit 00 : No interrupts 01 : Transmit holding register empty 10 : Receiver holds valid byte 11 : <Not possible> On write: Writing with bit 1 set will clear the receive FIFO Writing with bit 2 set will clear the transmit FIFO	R/W	00
0	Interrupt pending	This bit is clear whenever an interrupt is pending	R	1



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### AUX\_MU\_LCR\_REG Register (0x7E21 504C)

**SYNOPSIS** The AUX\_MU\_LCR\_REG register controls the line data format and gives access to the baudrate register

Bit(s)	Field Name	Description	Type	Reset
31:8		Reserved, write zero, read as don't care		
7	DLAB access	If set the first to Mini UART register give access the the Baudrate register. During operation this bit must be cleared.	R/W	0
6	Break	If set high the UART1_TX line is pulled low continuously. If held for at least 12 bits times that will indicate a break condition.	R/W	0
5:1		Reserved, write zero, read as don't care <i>Some of these bits have functions in a 16550 compatible UART but are ignored here</i>		0
0	data size	If clear the UART works in 7-bit mode If set the UART works in 8-bit mode	R/W	0

### AUX\_MU\_MCR\_REG Register (0x7E21 5050)

**SYNOPSIS** The AUX\_MU\_MCR\_REG register controls the 'modem' signals.

Bit(s)	Field Name	Description	Type	Reset
31:8		Reserved, write zero, read as don't care		
7:2		Reserved, write zero, read as don't care <i>Some of these bits have functions in a 16550 compatible UART but are ignored here</i>		0
1	RTS	If clear the UART1_RTS line is high If set the UART1_RTS line is low This bit is ignored if the RTS is used for auto-flow control. See the Mini Uart Extra Control register description)	R/W	0
0		Reserved, write zero, read as don't care <i>This bit has a function in a 16550 compatible UART but is ignored here</i>		0



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## AUX\_MU\_LSR\_REG Register (0x7E21 5054)

**SYNOPSIS** The AUX\_MU\_LSR\_REG register shows the data status.

Bit(s)	Field Name	Description	Type	Reset
31:8		Reserved, write zero, read as don't care		
7		Reserved, write zero, read as don't care <i>This bit has a function in a 16550 compatible UART but is ignored here</i>		0
6	Transmitter idle	This bit is set if the transmit FIFO is empty and the transmitter is idle. (Finished shifting out the last bit).	R	1
5	Transmitter empty	This bit is set if the transmit FIFO can accept at least one byte.	R	0
4:2		Reserved, write zero, read as don't care <i>Some of these bits have functions in a 16550 compatible UART but are ignored here</i>		0
1	Receiver Overrun	This bit is set if there was a receiver overrun. That is: one or more characters arrived whilst the receive FIFO was full. The newly arrived characters have been discarded. This bit is cleared each time this register is read. To do a non-destructive read of this overrun bit use the Mini Uart Extra Status register.	R/C	0
0	Data ready	This bit is set if the receive FIFO holds at least 1 symbol.	R	0

## AUX\_MU\_MSR\_REG Register (0x7E21 5058)

**SYNOPSIS** The AUX\_MU\_MSR\_REG register shows the 'modem' status.

Bit(s)	Field Name	Description	Type	Reset
31:8		Reserved, write zero, read as don't care		
7:6		Reserved, write zero, read as don't care <i>Some of these bits have functions in a 16550 compatible UART but are ignored here</i>		0
5	CTS status	This bit is the inverse of the UART1_CTS input Thus : If set the UART1_CTS pin is low If clear the UART1_CTS pin is high	R	1
3:0		Reserved, write zero, read as don't care <i>Some of these bits have functions in a 16550 compatible UART but are ignored here</i>		0



## AUX\_MU\_SCRATCH Register (0x7E21 505C)

**SYNOPSIS** The AUX\_MU\_SCRATCH is a single byte storage.

Bit(s)	Field Name	Description	Type	Reset
31:8		Reserved, write zero, read as don't care		
7:0	Scratch	One whole byte extra on top of the 134217728 provided by the SDC	R/W	0

## AUX\_MU\_CNTL\_REG Register (0x7E21 5060)

**SYNOPSIS** The AUX\_MU\_CNTL\_REG provides access to some extra useful and nice features not found on a normal 16550 UART .

Bit(s)	Field Name	Description	Type	Reset
31:8		Reserved, write zero, read as don't care		
7	CTS assert level	This bit allows one to invert the CTS auto flow operation polarity. If set the CTS auto flow assert level is low* If clear the CTS auto flow assert level is high*	R/W	0
6	RTS assert level	This bit allows one to invert the RTS auto flow operation polarity. If set the RTS auto flow assert level is low* If clear the RTS auto flow assert level is high*	R/W	0
5:4	RTS AUTO flow level	These two bits specify at what receiver FIFO level the RTS line is de-asserted in auto-flow mode. 00 : De-assert RTS when the receive FIFO has 3 empty spaces left. 01 : De-assert RTS when the receive FIFO has 2 empty spaces left. 10 : De-assert RTS when the receive FIFO has 1 empty space left. 11 : De-assert RTS when the receive FIFO has 4 empty spaces left.	R/W	0
3	Enable transmit Auto flow-control using CTS	If this bit is set the transmitter will stop if the CTS line is de-asserted. If this bit is clear the transmitter will ignore the status of the CTS line	R/W	0





2	Enable receive Auto flow-control using RTS	If this bit is set the RTS line will de-assert if the receive FIFO reaches it 'auto flow' level. In fact the RTS line will behave as an RTR ( <i>Ready To Receive</i> ) line. If this bit is clear the RTS line is controlled by the AUX_MU_MCR_REG register bit 1.	R/W	0
1	Transmitter enable	If this bit is set the mini UART transmitter is enabled. If this bit is clear the mini UART transmitter is disabled	R/W	1
0	Receiver enable	If this bit is set the mini UART receiver is enabled. If this bit is clear the mini UART receiver is disabled	R/W	1

### Receiver enable

If this bit is set no new symbols will be accepted by the receiver. Any symbols in progress of reception will be finished.

### Transmitter enable

If this bit is set no new symbols will be send the transmitter. Any symbols in progress of transmission will be finished.

### Auto flow control

Automatic flow control can be enabled independent for the receiver and the transmitter.

CTS auto flow control impacts the transmitter only. The transmitter will not send out new symbols when the CTS line is de-asserted. Any symbols in progress of transmission when the CTS line becomes de-asserted will be finished.

RTS auto flow control impacts the receiver only. In fact the name RTS for the control line is incorrect and should be RTR (Ready to Receive). The receiver will de-asserted the RTS (RTR) line when its receive FIFO has a number of empty spaces left. Normally 3 empty spaces should be enough.

If looping back a mini UART using full auto flow control the logic is fast enough to allow the RTS auto flow level of '10' (De-assert RTS when the receive FIFO has 1 empty space left).

### Auto flow polarity

To offer full flexibility the polarity of the CTS and RTS (RTR) lines can be programmed. This should allow the mini UART to interface with any existing hardware flow control available.



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## AUX\_MU\_STAT\_REG Register (0x7E21 5064)

**SYNOPSIS** The AUX\_MU\_STAT\_REG provides a lot of useful information about the internal status of the mini UART not found on a normal 16550 UART.

Bit(s)	Field Name	Description	Type	Reset
31:28		Reserved, write zero, read as don't care		
27:24	Transmit FIFO fill level	These bits shows how many symbols are stored in the transmit FIFO The value is in the range 0-8	R	0
23:20		Reserved, write zero, read as don't care		
19:16	Receive FIFO fill level	These bits shows how many symbols are stored in the receive FIFO The value is in the range 0-8	R	0
15:10		Reserved, write zero, read as don't care		
9	Transmitter done	This bit is set if the transmitter is idle and the transmit FIFO is empty. It is a logic AND of bits 2 and 8	R	1
8	Transmit FIFO is empty	If this bit is set the transmitter FIFO is empty. Thus it can accept 8 symbols.	R	1
7	CTS line	This bit shows the status of the UART1_CTS line.	R	0
6	RTS status	This bit shows the status of the UART1_RTS line.	R	0
5	Transmit FIFO is full	This is the inverse of bit 1	R	0
4	Receiver overrun	This bit is set if there was a receiver overrun. That is: one or more characters arrived whilst the receive FIFO was full. The newly arrived characters have been discarded. This bit is cleared each time the AUX_MU_LSR_REG register is read.	R	0
3	Transmitter is idle	If this bit is set the transmitter is idle. If this bit is clear the transmitter is idle.	R	1
2	Receiver is idle	If this bit is set the receiver is idle. If this bit is clear the receiver is busy. This bit can change unless the receiver is disabled	R	1
1	Space available	If this bit is set the mini UART transmitter FIFO can accept at least one more symbol. If this bit is clear the mini UART transmitter FIFO is full	R	0



## BCM2835 ARM Peripherals

0	Symbol available	If this bit is set the mini UART receive FIFO contains at least 1 symbol If this bit is clear the mini UART receiver FIFO is empty	R	0
---	------------------	---	---	---

### Receiver is idle

This bit is only useful if the receiver is disabled. The normal use is to disable the receiver. Then check (or wait) until the bit is set. Now you can be sure that no new symbols will arrive. (e.g. now you can change the baudrate...)

### Transmitter is idle

This bit tells if the transmitter is idle. Note that the bit will set only for a short time if the transmit FIFO contains data. Normally you want to use bit 9: Transmitter done.

### RTS status

This bit is useful only in receive Auto flow-control mode as it shows the status of the RTS line.

### AUX\_MU\_BAUD Register (0x7E21 5068)

**SYNOPSIS** The AUX\_MU\_BAUD register allows direct access to the 16-bit wide baudrate counter.

Bit(s)	Field Name	Description	Type	Reset
31:16		Reserved, write zero, read as don't care		
15:0	Baudrate	mini UART baudrate counter	R/W	0

This is the same register as is accessed using the LABD bit and the first two register, but much easier to access.

## 2.3 Universal SPI Master (2x)

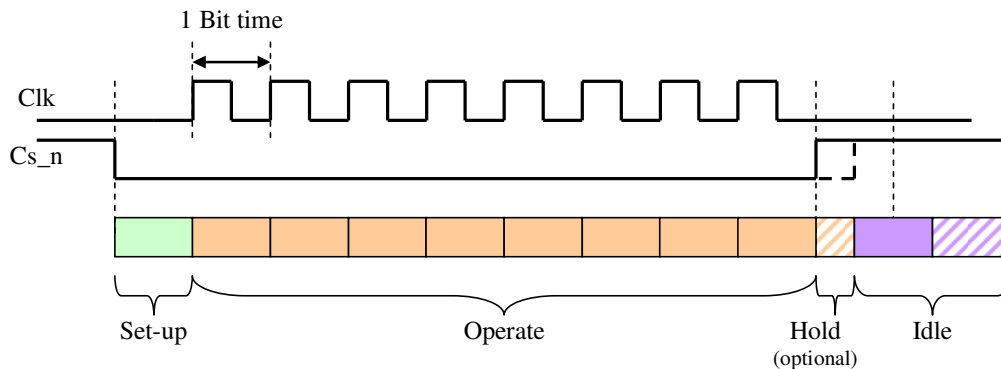
The two universal SPI masters are secondary low throughput<sup>5</sup> SPI interfaces. Like the UART the devices need to be enabled before they can be used. Each SPI master has the following features:

- Single beat bit length between 1 and 32 bits.
- Single beat variable bit length between 1 and 24 bits
- Multi beat infinite bit length.
- 3 independent chip selects per master.
- 4 entries 32-bit wide transmit and receive FIFOs.
- Data out on rising or falling clock edge.
- Data in on rising or falling clock edge.
- Clock inversion (Idle high or idle low).
- Wide clocking range.
- Programmable data out hold time.
- Shift in/out MS or LS bit first

A major issue with an SPI interface is that there is no SPI standard in any form. Because the SPI interface has been around for a long time some pseudo-standard rules have appeared mostly when interfacing with memory devices. The universal SPI master has been developed to work even with the most 'non-standard' SPI devices.

### 2.3.1 SPI implementation details

The following diagram shows a typical SPI access cycle. In this case we have 8 SPI clocks.



One bit time before any clock edge changes the CS<sub>n</sub> will go low. This makes sure that the MOSI signal has a full bit-time of set-up against any changing clock edges.

The operation normally ends after the last clock cycle. Note that at the end there is one half-bit time where the clock does not change but which still is part of the operation cycle.

There is an option to add a half bit cycle hold time. This makes sure that any MISO data has at least a full SPI bit time to arrive. (Without this hold time, data clocked out of the SPI device on the last clock edge would have only half a bit time to arrive).

<sup>5</sup> Again the SPIs themselves have no throughput limitations in fact they can run with an SPI clock of 125 MHz. But doing so requires significant CPU involvement as they have shallow FIFOs and no DMA support.



Last there is a guarantee of at least a full bit time where the spi chip select is high. A longer CS\_n high period can be programmed for another 1-7 cycles.

The SPI clock frequency is:

$$SPIx\_CLK = \frac{system\_clock\_freq}{2 * (speed\_field + 1)}$$

If the system clock is 250 MHz and the speed field is zero the SPI clock frequency is 125 MHz. The practical SPI clock will be lower as the I/O pads can not transmit or receive signals at such high speed. The lowest SPI clock frequency with a 250 MHz system clock is 30.5 KHz.

The hardware has an option to add hold time to the MOSI signal against the SPI clk. This is again done using the system clock. So a 250 MHz system clock will add hold times in units of 4 ns. Hold times of 0, 1, 4 and 7 system clock cycles can be used. (So at 250MHz an additional hold time of 0, 4, 16 and 28 ns can be achieved). The hold time is *additional* to the normal output timing as specified in the data sheet.

### 2.3.2 Interrupts

The SPI block has two interrupts: TX FIFO is empty, SPI is Idle.

TX FIFO is empty:

This interrupt will be asserted as soon as the last entry has been read from the transmit FIFO. At that time the interface will still be busy shifting out that data. This also implies that the receive FIFO will not yet contain the last received data. It is possible at that time to fill the TX FIFO again and read the receive FIFO entries which have been received. Note that there is no "receive FIFO full" interrupt as the number of entries received is always equal to the number of entries transmitted.

SPI is IDLE:

This interrupt will be asserted when the transmit FIFO is empty and the SPI block has finished all actions (including the CS-high time) By this time the receive FIFO will have all received data as well.

### 2.3.3 Long bit streams

The SPI module works in bursts of maximum 32 bits. Some SPI devices require data which is longer the 32 bits. To do this the user must make use of the two different data TX addresses: Tx data written to one address cause the CS to remain asserted. Tx data written to the other address cause the CS to be de-asserted at the end of the transmit cycle. So in order to exchange 96 bits you do the following:

Write the first two data words to one address, then write the third word to the other address.



## 2.3.4 SPI register details.

### AUXSPI0/1\_CNTLO Register (0x7E21 5080,0x7E21 50C0)

**SYNOPSIS** The AUXSPIx\_CNTLO register control many features of the SPI interfaces.

Bit(s)	Field Name	Description	Type	Reset
31:20	Speed	Sets the SPI clock speed. spi clk freq = system_clock_freq/2*(speed+1)	R/W	0
19:17	chip selects	The pattern output on the CS pins when active.	R/W	111
16	post-input mode	If set the SPI input works in post input mode. For details see text further down	R/W	0
15	Variable CS	If 1 the SPI takes the CS pattern and the data from the TX fifo If 0 the SPI takes the CS pattern from bits 17-19 of this register Set this bit only if also bit 14 (variable width) is set	R/W	0
14	Variable width	If 1 the SPI takes the shift length and the data from the TX fifo If 0 the SPI takes the shift length from bits 0-5 of this register	R/W	0
13:12	DOUT Hold time	Controls the extra DOUT hold time in system clock cycles. 00 : No extra hold time 01 : 1 system clock extra hold time 10 : 4 system clocks extra hold time 11 : 7 system clocks extra hold time	R/W	0
11	Enable	Enables the SPI interface. Whilst disabled the FIFOs can still be written to or read from This bit should be 1 during normal operation.	R/W	0
10	In rising	If 1 data is clocked in on the rising edge of the SPI clock If 0 data is clocked in on the falling edge of the SPI clock	R/W	0
9	Clear FIFOs	If 1 the receive and transmit FIFOs are held in reset (and thus flushed.) This bit should be 0 during normal operation.	R/W	0

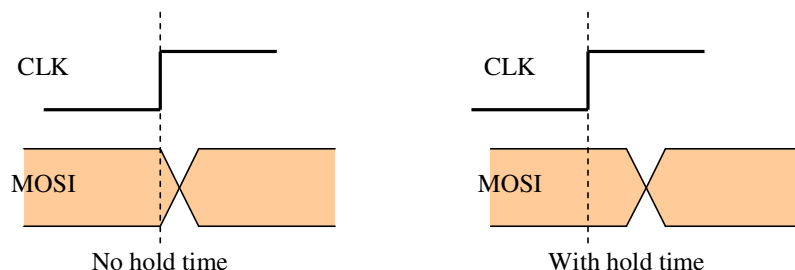
8	Out rising	If 1 data is clocked out on the rising edge of the SPI clock If 0 data is clocked out on the falling edge of the SPI clock	R/W	0
7	Invert SPI CLK	If 1 the 'idle' clock line state is high. If 0 the 'idle' clock line state is low.	R/W	0
6	Shift out MS bit first	If 1 the data is shifted out starting with the MS bit. (bit 15 or bit 11) If 0 the data is shifted out starting with the LS bit. (bit 0)	R/W	0
5:0	Shift length	Specifies the number of bits to shift This field is ignored when using 'variable shift' mode	R/W	0

### Invert SPI CLK

Changing this bit will immediately change the polarity of the SPI clock output. It is recommended not to do this when also the CS is active as the connected devices will see this as a clock change.

### DOUT hold time

Because the interface runs on fast silicon the MOSI hold time against the clock will be very short. This can cause considerable problems on SPI slaves. To make it easier for the slave to see the data the hold time of the MOSI out against the SPI clock out is programmable.



### Variable width

In this mode the shift length is taken from the transmit FIFO. The transmit data bits 28:24 are used as shift length and the data bits 23:0 are the actual transmit data. If the option 'shift MS out first' is selected the first bit shifted out will be bit 23. The receive data will arrive as normal.

### Variable CS

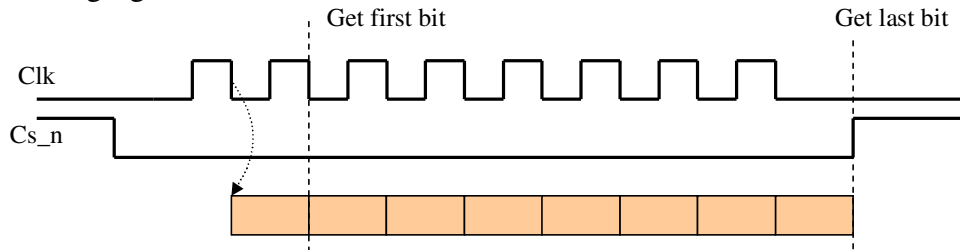
This mode is used together with the variable width mode. In this mode the CS pattern is taken from the transmit FIFO. The transmit data bits 31:29 are used as CS and the data bits 23:0 are the actual transmit data. This allows the CPU to write to different SPI devices without having to change the CS bits. However the data length is limited to 24 bits.

### Post-input mode

Some rare SPI devices output data on the falling clock edge which then has to be picked up on the next falling clock edge. There are two problems with this:

1. The very first falling clock edge there is no valid data arriving.
2. After the last clock edge there is one more 'dangling' bit to pick up.

The post-input mode is specifically to deal with this sort of data. If the post-input mode bit is set, the data arriving at the first falling clock edge is ignored. Then after the last falling clock edge the CS remain asserted and after a full bit time the last data bit is picked up. The following figure shows this behaviour:



In this mode the CS will go high 1 full SPI clock cycle after the last clock edge. This guarantees a full SPI clock cycle time for the data to settle and arrive at the MISO input.

## AUXSPI0/1\_CNTL1 Register (0x7E21 5084,0x7E21 50C4)

**SYNOPSIS** The AUXSPIx\_CNTL1 registers control more features of the SPI interfaces.

Bit(s)	Field Name	Description	Type	Reset
31:18	-	Reserved, write zero, read as don't care		
10:8	CS high time	Additional SPI clock cycles where the CS is high.	R/W	0
7	TX empty IRQ	If 1 the interrupt line is high when the transmit FIFO is empty	R/W	0
6	Done IRQ	If 1 the interrupt line is high when the interface is idle	R/W	0
5:2	-	Reserved, write zero, read as don't care		
1	Shift in MS bit first	If 1 the data is shifted in starting with the MS bit. (bit 15) If 0 the data is shifted in starting with the LS bit. (bit 0)	R/W	0
0	Keep input	If 1 the receiver shift register is NOT cleared. Thus new data is concatenated to old data. If 0 the receiver shift register is cleared before each transaction.	R/W	0

### Keep input

Setting the 'Keep input' bit will make that the input shift register is not cleared between transactions. However the contents of the shift register is still written to the receive FIFO at the end of each transaction. E.g. if you receive two 8 bit values 0x81 followed by 0x46 the receive FIFO will contain: 0x0081 in the first entry and 0x8146 in the second entry. This mode may save CPU time concatenating bits (4 bits followed by 12 bits).





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## CS high time

The SPI CS will always be high for at least 1 SPI clock cycle. Some SPI devices need more time to process the data. This field will set a longer CS-high time. So the actual CS high time is (CS\_high\_time + 1) (In SPI clock cycles).

## Interrupts

The SPI block has two interrupts: TX FIFO is empty, SPI is Idle.

### TX FIFO is empty:

This interrupt will be asserted as soon as the last entry has been read from the transmit FIFO. At that time the interface will still be busy shifting out that data. This also implies that the receive FIFO will not yet contain the last received data.

It is possible at that time to fill the TX FIFO again and read the receive FIFO entries which have been received. There is a RX FIFO level field which tells exactly how many words are in the receive FIFO. In general at that time the receive FIFO should contain the number of Tx items minus one (the last one still being received). Note that there is no "receive FIFO full" interrupt or "receive FIFO overflow" flag as the number of entries received can never be more than the number of entries transmitted.

### AUX is IDLE:

This interrupt will be asserted when the module has finished all activities, including waiting the minimum CS high time. This guarantees that any receive data will be available and 'transparent' changes can be made to the configuration register (e.g. inverting the SPI clock polarity).

## AUXSPI0/1\_STAT Register (0x7E21 5088,0x7E21 50C8)

**SYNOPSIS** The AUXSPIx\_STAT registers show the status of the SPI interfaces.

Bit(s)	Field Name	Description	Type	Reset
31:24	TX FIFO level	The number of data units in the transmit data FIFO	R/W	0
23:12	RX FIFO level	The number of data units in the receive data FIFO.	R/W	0
11:5	-	Reserved, write zero, read as don't care		
4	TX Full	If 1 the transmit FIFO is full If 0 the transmit FIFO can accept at least 1 data unit.	R/W	0
3	TX Empty	If 1 the transmit FIFO is empty If 0 the transmit FIFO holds at least 1 data unit.	R/W	0
2	RX Empty	If 1 the receiver FIFO is empty If 0 the receiver FIFO holds at least 1 data unit.	R/W	0
6	Busy	Indicates the module is busy transferring data.	R/W	0
5:0	Bit count	The number of bits still to be processed. Starts with 'shift-length' and counts down.	R/W	0



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## Busy

This status bit indicates if the module is busy. It will be clear when the TX FIFO is empty and the module has finished all activities, including waiting the minimum CS high time.

### AUXSPI0/1\_PEEK Register (0x7E21 508C,0x7E21 50CC)

**SYNOPSIS** The AUXSPIx\_PEEK registers show received data of the SPI interfaces.

Bit(s)	Field Name	Description	Type	Reset
31:16	-	Reserved, write zero, read as don't care		
15:0	Data	Reads from this address will show the top entry from the receive FIFO, but the data is not taken from the FIFO. This provides a means of inspecting the data but not removing it from the FIFO.	RO	0

### AUXSPI0/1\_IO Register (0x7E21 50A0-0x7E21 50AC 0x7E21 50E0-0x7E21 50EC)

**SYNOPSIS** The AUXSPIx\_IO registers are the primary data port of the SPI interfaces  
These four addresses all write to the same FIFO.

**Writing to any of these addresses causes the SPI CS\_n pins to be de-asserted at the end of the access**

Bit(s)	Field Name	Description	Type	Reset
31:16	-	Reserved, write zero, read as don't care		
15:0	Data	Writes to this address range end up in the transmit FIFO. Data is lost when writing whilst the transmit FIFO is full. Reads from this address will take the top entry from the receive FIFO. Reading whilst the receive FIFO is will return the last data received.	R/W	0



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### AUXSPI0/1\_TXHOLD Register

(0x7E21 50B0-0x7E21 50BC

0x7E21 50F0-0x7E21 50FC)

**SYNOPSIS** The AUXSPIx\_TXHOLD registers are the extended CS port of the SPI interfaces. These four addresses all write to the same FIFO.

**Writing to these addresses causes the SPI CS\_n pins to remain asserted at the end of the access**

Bit(s)	Field Name	Description	Type	Reset
31:16	-	Reserved, write zero, read as don't care		
15:0	Data	Writes to this address range end up in the transmit FIFO. Data is lost when writing whilst the transmit FIFO is full. Reads from this address will take the top entry from the receive FIFO. Reading whilst the receive FIFO is will return the last data received.	R/W	0



## 3 BSC

### 3.1 Introduction

The Broadcom Serial Controller (BSC) controller is a master, fast-mode (400Kb/s) BSC controller. The Broadcom Serial Control bus is a proprietary bus compliant with the Philips® I2C bus/interface version 2.1 January 2000.

- I<sup>2</sup>C single master only operation (supports clock stretching wait states)
- Both 7-bit and 10-bit addressing is supported.
  - Timing completely software controllable via registers

### 3.2 Register View

The BSC controller has eight memory-mapped registers. All accesses are assumed to be 32-bit. Note that the BSC2 master is used dedicated with the HDMI interface and should not be accessed by user programs.

There are three BSC masters inside BCM. The register addresses starts from

- BSC0: 0x7E20\_5000
- BSC1: 0x7E80\_4000
- BSC2 : 0x7E80\_5000

The table below shows the address of I<sup>2</sup>C interface where the address is an offset from one of the three base addresses listed above.

I2C Address Map			
Address Offset	Register Name	Description	Size
0x0	<a href="#">C</a>	Control	32
0x4	<a href="#">S</a>	Status	32
0x8	<a href="#">DLEN</a>	Data Length	32
0xc	<a href="#">A</a>	Slave Address	32
0x10	<a href="#">FIFO</a>	Data FIFO	32
0x14	<a href="#">DIV</a>	Clock Divider	32
0x18	<a href="#">DEL</a>	Data Delay	32



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0x1c	<a href="#">CLKT</a>	Clock Stretch Timeout	32
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## C Register

**Synopsis** The control register is used to enable interrupts, clear the FIFO, define a read or write operation and start a transfer.

The READ field specifies the type of transfer.

The CLEAR field is used to clear the FIFO. Writing to this field is a one-shot operation which will always read back as zero. The CLEAR bit can set at the same time as the start transfer bit, and will result in the FIFO being cleared just prior to the start of transfer. Note that clearing the FIFO during a transfer will result in the transfer being aborted.

The ST field starts a new BSC transfer. This has a one shot action, and so the bit will always read back as 0 .

The INTD field enables interrupts at the end of a transfer the DONE condition. The interrupt remains active until the DONE condition is cleared by writing a 1 to the I2CS.DONE field. Writing a 0 to the INTD field disables interrupts on DONE.

The INTT field enables interrupts whenever the FIFO is or more empty and needs writing (i.e. during a write transfer) - the TXW condition. The interrupt remains active until the TXW condition is cleared by writing sufficient data to the FIFO to complete the transfer. Writing a 0 to the INTT field disables interrupts on TXW.

The INTR field enables interrupts whenever the FIFO is or more full and needs reading (i.e. during a read transfer) - the RXR condition. The interrupt remains active until the RXW condition is cleared by reading sufficient data from the RX FIFO. Writing a 0 to the INTR field disables interrupts on RXR.

The I2CEN field enables BSC operations. If this bit is 0 then transfers will not be performed. All register accesses are still permitted however.

Bit(s)	Field Name	Description	Type	Reset
31:16		<b>Reserved</b> - Write as 0, read as don't care		
15	I2CEN	<u>I2C Enable</u> 0 = BSC controller is disabled 1 = BSC controller is enabled	RW	0x0
14:11		<b>Reserved</b> - Write as 0, read as don't care		
10	INTR	<u>INTR Interrupt on RX</u> 0 = Don t generate interrupts on RXR condition. 1 = Generate interrupt while RXR = 1.	RW	0x0
9	INTT	<u>INTT Interrupt on TX</u> 0 = Don t generate interrupts on TXW condition. 1 = Generate interrupt while TXW = 1.	RW	0x0



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8	INTD	<u>INTD Interrupt on DONE</u> 0 = Don t generate interrupts on DONE condition. 1 = Generate interrupt while DONE = 1.	RW	0x0
7	ST	<u>ST Start Transfer</u> 0 = No action. 1 = Start a new transfer. One shot operation. Read back as 0.	RW	0x0
6		<b>Reserved</b> - Write as 0, read as don't care		
5:4	CLEAR	<u>CLEAR FIFO Clear</u> 00 = No action. x1 = Clear FIFO. One shot operation. 1x = Clear FIFO. One shot operation. If CLEAR and ST are both set in the same operation, the FIFO is cleared before the new frame is started. Read back as 0. Note: 2 bits are used to maintain compatibility to previous version.	RW	0x0
3:1		<b>Reserved</b> - Write as 0, read as don't care		
0	READ	<u>READ Read Transfer</u> 0 = Write Packet Transfer. 1 = Read Packet Transfer.	RW	0x0

**S Register**



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**Synopsis** The status register is used to record activity status, errors and interrupt requests. The TA field indicates the activity status of the BSC controller. This read-only field returns a 1 when the controller is in the middle of a transfer and a 0 when idle. The DONE field is set when the transfer completes. The DONE condition can be used with I2CC.INTD to generate an interrupt on transfer completion. The DONE field is reset by writing a 1, writing a 0 to the field has no effect. The read-only TXW bit is set during a write transfer and the FIFO is less than full and needs writing. Writing sufficient data (i.e. enough data to either fill the FIFO more than full or complete the transfer) to the FIFO will clear the field. When the I2CC.INTT control bit is set, the TXW condition can be used to generate an interrupt to write more data to the FIFO to complete the current transfer. If the I2C controller runs out of data to send, it will wait for more data to be written into the FIFO. The read-only RXR field is set during a read transfer and the FIFO is or more full and needs reading. Reading sufficient data to bring the depth below will clear the field. When I2CC.INTR control bit is set, the RXR condition can be used to generate an interrupt to read data from the FIFO before it becomes full. In the event that the FIFO does become full, all I2C operations will stall until data is removed from the FIFO. The read-only TXD field is set when the FIFO has space for at least one byte of data. TXD is clear when the FIFO is full. The TXD field can be used to check that the FIFO can accept data before any is written. Any writes to a full TX FIFO will be ignored. The read-only RXD field is set when the FIFO contains at least one byte of data. RXD is cleared when the FIFO becomes empty. The RXD field can be used to check that the FIFO contains data before reading. Reading from an empty FIFO will return invalid data. The read-only TXE field is set when the FIFO is empty. No further data will be transmitted until more data is written to the FIFO. The read-only RXF field is set when the FIFO is full. No more clocks will be generated until space is available in the FIFO to receive more data. The ERR field is set when the slave fails to acknowledge either its address or a data byte written to it. The ERR field is reset by writing a 1, writing a 0 to the field has no effect. The CLKT field is set when the slave holds the SCL signal high for too long (clock stretching). The CLKT field is reset by writing a 1, writing a 0 to the field has no effect.

Bit(s)	Field Name	Description	Type	Reset
31:10		<b>Reserved</b> - Write as 0, read as don't care		
9	CLKT	<u>CLKT Clock Stretch Timeout</u> 0 = No errors detected. 1 = Slave has held the SCL signal low (clock stretching) for longer and that specified in the I2CCLKT register Cleared by writing 1 to the field.	RW	0x0
8	ERR	<u>ERR ACK Error</u> 0 = No errors detected. 1 = Slave has not acknowledged its address. Cleared by writing 1 to the field.	RW	0x0
7	RXF	<u>RXF - FIFO Full</u> 0 = FIFO is not full. 1 = FIFO is full. If a read is underway, no further serial data will be received until data is read from FIFO.	RO	0x0



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6	TXE	<u>TXE - FIFO Empty</u> 0 = FIFO is not empty. 1 = FIFO is empty. If a write is underway, no further serial data can be transmitted until data is written to the FIFO.	RO	0x1
5	RXD	<u>RXD - FIFO contains Data</u> 0 = FIFO is empty. 1 = FIFO contains at least 1 byte. Cleared by reading sufficient data from FIFO.	RO	0x0
4	TXD	<u>TXD - FIFO can accept Data</u> 0 = FIFO is full. The FIFO cannot accept more data. 1 = FIFO has space for at least 1 byte.	RO	0x1
3	RXR	<u>RXR - FIFO needs Reading ( full)</u> 0 = FIFO is less than full and a read is underway. 1 = FIFO is or more full and a read is underway. Cleared by reading sufficient data from the FIFO.	RO	0x0
2	TXW	<u>TXW - FIFO needs Writing ( full)</u> 0 = FIFO is at least full and a write is underway (or sufficient data to send). 1 = FIFO is less than full and a write is underway. Cleared by writing sufficient data to the FIFO.	RO	0x0
1	DONE	<u>DONE Transfer Done</u> 0 = Transfer not completed. 1 = Transfer complete. Cleared by writing 1 to the field.	RW	0x0
0	TA	<u>TA Transfer Active</u> 0 = Transfer not active. 1 = Transfer active.	RO	0x0

## DLEN Register

**Synopsis** The data length register defines the number of bytes of data to transmit or receive in the I2C transfer. Reading the register gives the number of bytes remaining in the current transfer.

The DLEN field specifies the number of bytes to be transmitted/received. Reading the DLEN field when a transfer is in progress (TA = 1) returns the number of bytes still to be transmitted or received. Reading the DLEN field when the transfer has just completed (DONE = 1) returns zero as there are no more bytes to transmit or receive. Finally, reading the DLEN field when TA = 0 and DONE = 0 returns the last value written. The DLEN field can be left over multiple transfers.

Bit(s)	Field Name	Description	Type	Reset
31:16		<i>Reserved - Write as 0, read as don't care</i>		





# BCM2835 ARM Peripherals

15:0	DLEN	<u>Data Length.</u> Writing to DLEN specifies the number of bytes to be transmitted/received. Reading from DLEN when TA = 1 or DONE = 1, returns the number of bytes still to be transmitted or received. Reading from DLEN when TA = 0 and DONE = 0, returns the last DLEN value written. DLEN can be left over multiple packets.	RW	0x0
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## A Register

**Synopsis** The slave address register specifies the slave address and cycle type. The address register can be left across multiple transfers  
 The ADDR field specifies the slave address of the I2C device.

Bit(s)	Field Name	Description	Type	Reset
31:7		<i>Reserved - Write as 0, read as don't care</i>		
6:0	ADDR	<u>Slave Address.</u>	RW	0x0

## FIFO Register

**Synopsis** The Data FIFO register is used to access the FIFO. Write cycles to this address place data in the 16-byte FIFO, ready to transmit on the BSC bus. Read cycles access data received from the bus.  
 Data writes to a full FIFO will be ignored and data reads from an empty FIFO will result in invalid data. The FIFO can be cleared using the I2CC.CLEAR field.  
 The DATA field specifies the data to be transmitted or received.

Bit(s)	Field Name	Description	Type	Reset
31:8		<i>Reserved - Write as 0, read as don't care</i>		
7:0	DATA	<u>Writes to the register write transmit data to the FIFO. Reads from register reads received data from the FIFO.</u>	RW	0x0

## DIV Register



# BCM2835 ARM Peripherals

**Synopsis** The clock divider register is used to define the clock speed of the BSC peripheral. The CDIV field specifies the core clock divider used by the BSC.

Bit(s)	Field Name	Description	Type	Reset
31:16		<i>Reserved - Write as 0, read as don't care</i>		
15:0	CDIV	<u>Clock Divider</u> SCL = core clock / CDIV Where core_clk is nominally 150 MHz. If CDIV is set to 0, the divisor is 32768. CDIV is always rounded down to an even number. The default value should result in a 100 kHz I2C clock frequency.	RW	0x5dc

## DEL Register

**Synopsis** The data delay register provides fine control over the sampling/launch point of the data. The REDL field specifies the number core clocks to wait after the rising edge before sampling the incoming data. The FEDL field specifies the number core clocks to wait after the falling edge before outputting the next data bit. Note: Care must be taken in choosing values for FEDL and REDL as it is possible to cause the BSC master to malfunction by setting values of CDIV/2 or greater. Therefore the delay values should always be set to less than CDIV/2.

Bit(s)	Field Name	Description	Type	Reset
31:16	FEDL	<u>FEDL Falling Edge Delay</u> Number of core clock cycles to wait after the falling edge of SCL before outputting next bit of data.	RW	0x30
15:0	REDL	<u>REDL Rising Edge Delay</u> Number of core clock cycles to wait after the rising edge of SCL before reading the next bit of data.	RW	0x30

## CLKT Register



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**Synopsis** The clock stretch timeout register provides a timeout on how long the master waits for the slave to stretch the clock before deciding that the slave has hung. The TOUT field specifies the number I2C SCL clocks to wait after releasing SCL high and finding that the SCL is still low before deciding that the slave is not responding and moving the I2C machine forward. When a timeout occurs, the I2CS.CLKT bit is set. Writing 0x0 to TOUT will result in the Clock Stretch Timeout being disabled.

Bit(s)	Field Name	Description	Type	Reset
31:16		<i>Reserved - Write as 0, read as don't care</i>		
15:0	TOUT	<u>TOUT Clock Stretch Timeout Value</u> Number of SCL clock cycles to wait after the rising edge of SCL before deciding that the slave is not responding.	RW	0x40

## 3.3 10 Bit Addressing

10 Bit addressing is an extension to the standard 7-bit addressing mode. This section describes in detail how to read/write using 10-bit addressing with this I2C controller.

10-bit addressing is compatible with, and can be combined with, 7 bit addressing. Using 10 bits for addressing exploits the reserved combination 1111 0xx for the first byte following a START (S) or REPEATED START (Sr) condition.

The 10 bit slave address is formed from the first two bytes following a S or Sr condition.

The first seven bits of the first byte are the combination 11110XX of which the last two bits (XX) are the two *most significant* bits of the 10-bit address. The eighth bit of the first byte is the R/W bit. If the R/W bit is '0' (write) then the following byte contains the remaining 8 bits of the 10-bit address. If the R/W bit is '1' then the next byte contains data transmitted from the slave to the master.

### Writing

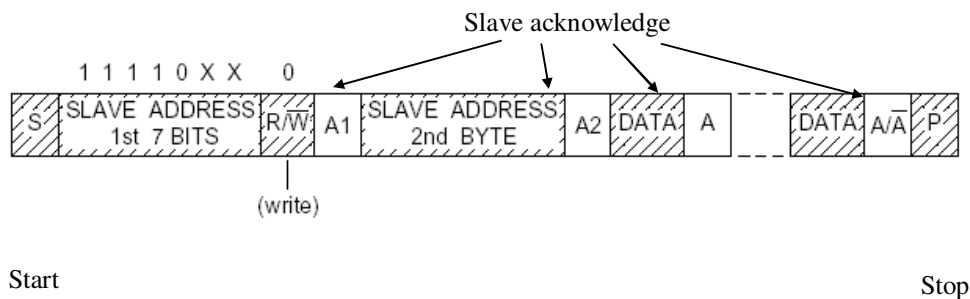


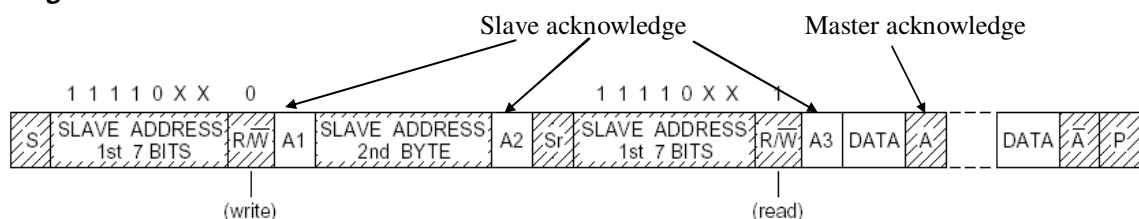
Figure 3-1 Write to a slave with 10 bit address

Figure 3-1 shows a write to a slave with a 10-bit address, to perform this using the controller one must do the following:

Assuming we are in the 'stop' state: (and the FIFO is empty)

1. Write the number of data bytes to written (plus one) to the I2CDLEN register.
2. Write 'XXXXXXXX' to the FIFO where 'XXXXXXXX' are the least 8 significant bits of the 10-bit slave address.
3. Write other data to be transmitted to the FIFO.
4. Write '11110XX' to Slave Address Register where 'XX' are the two most significant bits of the 10-bit address. Set I2CC.READ = 0 and I2CC.ST = 1, this will start a write transfer.

### Reading



**Figure 3-2 Read from slave with 10 bit address**

Figure 3-2 shows how a read from a slave with a 10-bit address is performed. Following is the procedure for performing a read using the controller:

1. Write 1 to the I2CDLEN register.
2. Write 'XXXXXXXX' to the FIFO where 'XXXXXXXX' are the least 8 significant bits of the 10-bit slave address.
3. Write '11110XX' to the Slave Address Register where 'XX' are the two most significant bits of the 10-bit address. Set I2CC.READ = 0 and I2CC.ST = 1, this will start a write transfer.
4. Poll the I2CS.TA bit, waiting for the transfer has started.
5. Write the number of data bytes to read to the I2CDLEN register.
6. Set I2CC.READ = 1 and I2CC.ST = 1, this will send the repeat start bit, new slave address and R/W bit (which is '1') initiating the read.

## 4 DMA Controller

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### 4.1 Overview

The majority of hardware pipelines and peripherals within the BCM2835 are bus masters, enabling them to efficiently satisfy their own data requirements. This reduces the requirements of the DMA controller to block-to-block memory transfers and supporting some of the simpler peripherals. In addition, the DMA controller provides a *read only* prefetch mode to allow data to be brought into the L2 cache in anticipation of its later use.

Beware that the DMA controller is directly connected to the peripherals. Thus the DMA controller must be set-up to use the Physical (hardware) addresses of the peripherals.

The BCM2835 DMA Controller provides a total of 16 DMA channels. Each channel operates independently from the others and is internally arbitrated onto one of the 3 system busses. This means that the amount of bandwidth that a DMA channel may consume can be controlled by the arbiter settings.

Each DMA channel operates by loading a *Control Block* (CB) data structure from memory into internal registers. The *Control Block* defines the required DMA operation. Each *Control Block* can point to a further *Control Block* to be loaded and executed once the operation described in the current *Control Block* has completed. In this way a linked list of *Control Blocks* can be constructed in order to execute a sequence of DMA operations without software intervention.

The DMA supports AXI read bursts to ensure efficient external SDRAM use. The DMA control block contains a burst parameter which indicates the required burst size of certain memory transfers. In general the DMA doesn't do write bursts, although wide writes will be done in 2 beat bursts if possible.

Memory-to-Peripheral transfers can be paced by a *Data Request* (DREQ) signal which is generated by the peripheral. The DREQ signal is level sensitive and controls the DMA by gating its AXI bus requests.

A peripheral can also provide a *Panic* signal alongside the DREQ to indicate that there is an imminent danger of FIFO underflow or overflow or similar critical situation. The *Panic* is used to select the AXI apriority level which is then passed out onto the AXI bus so that it can be used to influence arbitration in the rest of the system.

The allocation of peripherals to DMA channels is programmable.

The DMA can deal with byte aligned transfers and will minimise bus traffic by buffering and packing misaligned accesses.

Each DMA channel can be fully disabled via a top level power register to save power.



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## 4.2 DMA Controller Registers

The DMA Controller is comprised of several identical DMA Channels depending upon the required configuration. Each individual DMA channel has an identical register map (although LITE channels have less functionality and hence less registers).

DMA Channel 0 is located at the address of 0x7E007000, Channel 1 at 0x7E007100, Channel 2 at 0x7E007200 and so on. Thus adjacent DMA Channels are offset by 0x100.

DMA Channel 15 however, is physically removed from the other DMA Channels and so has a different address base of 0x7EE05000.

DMA Channel Offsets	
DMA Channels 0 – 14 Register Set Offsets from DMA0_BASE	
0x000	<i>DMA Channel 0 Register Set</i>
0x100	<i>DMA Channel 1 Register Set</i>
0x200	<i>DMA Channel 2 Register Set</i>
0x300	<i>DMA Channel 3 Register Set</i>
0x400	<i>DMA Channel 4 Register Set</i>
0x500	<i>DMA Channel 5 Register Set</i>
0x600	<i>DMA Channel 6 Register Set</i>
0x700	<i>DMA Channel 7 Register Set</i>
0x800	<i>DMA Channel 8 Register Set</i>
0x900	<i>DMA Channel 9 Register Set</i>
0xa00	<i>DMA Channel 10 Register Set</i>
0xb00	<i>DMA Channel 11 Register Set</i>
0xc00	<i>DMA Channel 12 Register Set</i>
0xd00	<i>DMA Channel 13 Register Set</i>
0xe00	<i>DMA Channel 14 Register Set</i>
DMA Channel 15 Register Set Offset from DMA15_BASE	
0x000	<i>DMA Channel 15 Register Set</i>

**Table 4-1 – DMA Controller Register Address Map**

## 4.2.1 DMA Channel Register Address Map

Each DMA channel has an identical register map, only the base address of each channel is different.

There is a global enable register at the top of the Address map that can disable each DMA for powersaving.

Only three registers in each channels register set are directly writeable (CS, CONBLK\_AD and DEBUG). The other registers (TI, SOURCE\_AD, DEST\_AD, TXFR\_LEN, STRIDE & NEXTCONBK), are automatically loaded from a *Control Block* data structure held in external memory.

### 4.2.1.1 Control Block Data Structure

Control Blocks (CB) are 8 words (256 bits) in length and must start at a 256-bit aligned address. The format of the CB data structure in memory, is shown below.

Each 32 bit word of the control block is automatically loaded into the corresponding 32 bit DMA control block register at the start of a DMA transfer. The descriptions of these registers also defines the corresponding bit locations in the CB data structure in memory.

32-bit Word Offset	Description	Associated Read-Only Register
0	Transfer Information	TI
1	Source Address	SOURCE_AD
2	Destination Address	DEST_AD
3	Transfer Length	TXFR_LEN
4	2D Mode Stride	STRIDE
5	Next Control Block Address	NEXTCONBK
6-7	<i>Reserved – set to zero.</i>	N/A

**Table 4-2 – DMA Control Block Definition**

The DMA is started by writing the address of a CB structure into the CONBLK\_AD register and then setting the ACTIVE bit. The DMA will fetch the CB from the address set in the SCB\_ADDR field of this reg and it will load it into the *read-only* registers described below. It will then begin a DMA transfer according to the information in the CB.

When it has completed the current DMA transfer (length => 0) the DMA will update the CONBLK\_AD register with the contents of the NEXTCONBK register, fetch a new CB from that address, and start the whole procedure once again.

The DMA will stop (and clear the ACTIVE bit) when it has completed a DMA transfer and the NEXTCONBK register is set to 0x0000\_0000. It will load this value into the CONBLK\_AD reg and then stop.





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Most of the control block registers cannot be written to directly as they loaded automatically from memory. They can be read to provide status information, and to indicate the progress of the current DMA transfer. The value loaded into the NEXTCONBK register can be overwritten so that the linked list of Control Block data structures can be dynamically altered. However it is only safe to do this when the DMA is paused.

## 4.2.1.2 Register Map

DMA Address Map			
Address Offset	Register Name	Description	Size
0x0	<a href="#">0_CS</a>	DMA Channel 0 Control and Status	32
0x4	<a href="#">0_CONBLK_AD</a>	DMA Channel 0 Control Block Address	32
0x8	<a href="#">0_TI</a>	DMA Channel 0 CB Word 0 (Transfer Information)	32
0xc	<a href="#">0_SOURCE_AD</a>	DMA Channel 0 CB Word 1 (Source Address)	32
0x10	<a href="#">0_DEST_AD</a>	DMA Channel 0 CB Word 2 (Destination Address)	32
0x14	<a href="#">0_TXFR_LEN</a>	DMA Channel 0 CB Word 3 (Transfer Length)	32
0x18	<a href="#">0_STRIDE</a>	DMA Channel 0 CB Word 4 (2D Stride)	32
0x1c	<a href="#">0_NEXTCONBK</a>	DMA Channel 0 CB Word 5 (Next CB Address)	32
0x20	<a href="#">0_DEBUG</a>	DMA Channel 0 Debug	32
0x100	<a href="#">1_CS</a>	DMA Channel 1 Control and Status	32
0x104	<a href="#">1_CONBLK_AD</a>	DMA Channel 1 Control Block Address	32
0x108	<a href="#">1_TI</a>	DMA Channel 1 CB Word 0 (Transfer Information)	32
0x10c	<a href="#">1_SOURCE_AD</a>	DMA Channel 1 CB Word 1 (Source Address)	32
0x110	<a href="#">1_DEST_AD</a>	DMA Channel 1 CB Word 2 (Destination Address)	32
0x114	<a href="#">1_TXFR_LEN</a>	DMA Channel 1 CB Word 3 (Transfer Length)	32



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0x118	<a href="#">1 STRIDE</a>	DMA Channel 1 CB Word 4 (2D Stride)	32
0x11c	<a href="#">1 NEXTCONBK</a>	DMA Channel 1 CB Word 5 (Next CB Address)	32
0x120	<a href="#">1 DEBUG</a>	DMA Channel 1 Debug	32
0x200	<a href="#">2 CS</a>	DMA Channel 2 Control and Status	32
0x204	<a href="#">2 CONBLK_AD</a>	DMA Channel 2 Control Block Address	32
0x208	<a href="#">2 TI</a>	DMA Channel 2 CB Word 0 (Transfer Information)	32
0x20c	<a href="#">2 SOURCE_AD</a>	DMA Channel 2 CB Word 1 (Source Address)	32
0x210	<a href="#">2 DEST_AD</a>	DMA Channel 2 CB Word 2 (Destination Address)	32
0x214	<a href="#">2 TXFR_LEN</a>	DMA Channel 2 CB Word 3 (Transfer Length)	32
0x218	<a href="#">2 STRIDE</a>	DMA Channel 2 CB Word 4 (2D Stride)	32
0x21c	<a href="#">2 NEXTCONBK</a>	DMA Channel 2 CB Word 5 (Next CB Address)	32
0x220	<a href="#">2 DEBUG</a>	DMA Channel 2 Debug	32
0x300	<a href="#">3 CS</a>	DMA Channel 3 Control and Status	32
0x304	<a href="#">3 CONBLK_AD</a>	DMA Channel 3 Control Block Address	32
0x308	<a href="#">3 TI</a>	DMA Channel 3 CB Word 0 (Transfer Information)	32
0x30c	<a href="#">3 SOURCE_AD</a>	DMA Channel 3 CB Word 1 (Source Address)	32
0x310	<a href="#">3 DEST_AD</a>	DMA Channel 3 CB Word 2 (Destination Address)	32
0x314	<a href="#">3 TXFR_LEN</a>	DMA Channel 3 CB Word 3 (Transfer Length)	32
0x318	<a href="#">3 STRIDE</a>	DMA Channel 3 CB Word 4 (2D Stride)	32
0x31c	<a href="#">3 NEXTCONBK</a>	DMA Channel 3 CB Word 5 (Next CB Address)	32
0x320	<a href="#">3 DEBUG</a>	DMA Channel 0 Debug	32



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0x400	<a href="#">4_CS</a>	DMA Channel 4 Control and Status	32
0x404	<a href="#">4_CONBLK_AD</a>	DMA Channel 4 Control Block Address	32
0x408	<a href="#">4_TI</a>	DMA Channel 4 CB Word 0 (Transfer Information)	32
0x40c	<a href="#">4_SOURCE_AD</a>	DMA Channel 4 CB Word 1 (Source Address)	32
0x410	<a href="#">4_DEST_AD</a>	DMA Channel 4 CB Word 2 (Destination Address)	32
0x414	<a href="#">4_TXFR_LEN</a>	DMA Channel 4 CB Word 3 (Transfer Length)	32
0x418	<a href="#">4_STRIDE</a>	DMA Channel 4 CB Word 4 (2D Stride)	32
0x41c	<a href="#">4_NEXTCONBK</a>	DMA Channel 4 CB Word 5 (Next CB Address)	32
0x420	<a href="#">4_DEBUG</a>	DMA Channel 0 Debug	32
0x500	<a href="#">5_CS</a>	DMA Channel 5 Control and Status	32
0x504	<a href="#">5_CONBLK_AD</a>	DMA Channel 5 Control Block Address	32
0x508	<a href="#">5_TI</a>	DMA Channel 5 CB Word 0 (Transfer Information)	32
0x50c	<a href="#">5_SOURCE_AD</a>	DMA Channel 5 CB Word 1 (Source Address)	32
0x510	<a href="#">5_DEST_AD</a>	DMA Channel 5 CB Word 2 (Destination Address)	32
0x514	<a href="#">5_TXFR_LEN</a>	DMA Channel 5 CB Word 3 (Transfer Length)	32
0x518	<a href="#">5_STRIDE</a>	DMA Channel 5 CB Word 4 (2D Stride)	32
0x51c	<a href="#">5_NEXTCONBK</a>	DMA Channel 5 CB Word 5 (Next CB Address)	32
0x520	<a href="#">5_DEBUG</a>	DMA Channel 5 Debug	32
0x600	<a href="#">6_CS</a>	DMA Channel 6 Control and Status	32
0x604	<a href="#">6_CONBLK_AD</a>	DMA Channel 6 Control Block Address	32
0x608	<a href="#">6_TI</a>	DMA Channel 6 CB Word 0 (Transfer Information)	32



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0x60c	<a href="#">6_SOURCE_AD</a>	DMA Channel 6 CB Word 1 (Source Address)	32
0x610	<a href="#">6_DEST_AD</a>	DMA Channel 6 CB Word 2 (Destination Address)	32
0x614	<a href="#">6_TXFR_LEN</a>	DMA Channel 6 CB Word 3 (Transfer Length)	32
0x618	<a href="#">6_STRIDE</a>	DMA Channel 6 CB Word 4 (2D Stride)	32
0x61c	<a href="#">6_NEXTCONBK</a>	DMA Channel 6 CB Word 5 (Next CB Address)	32
0x620	<a href="#">6_DEBUG</a>	DMA Channel 6 Debug	32
0x700	<a href="#">7_CS</a>	DMA Channel 7 Control and Status	32
0x704	<a href="#">7_CONBLK_AD</a>	DMA Channel 7 Control Block Address	32
0x708	<a href="#">7_TI</a>	DMA Channel 7 CB Word 0 (Transfer Information)	32
0x70c	<a href="#">7_SOURCE_AD</a>	DMA Channel 7 CB Word 1 (Source Address)	32
0x710	<a href="#">7_DEST_AD</a>	DMA Channel 7 CB Word 2 (Destination Address)	32
0x714	<a href="#">7_TXFR_LEN</a>	DMA Channel 7 CB Word 3 (Transfer Length)	32
0x71c	<a href="#">7_NEXTCONBK</a>	DMA Channel 7 CB Word 5 (Next CB Address)	32
0x720	<a href="#">7_DEBUG</a>	DMA Channel 7 Debug	32
0x800	<a href="#">8_CS</a>	DMA Channel 8 Control and Status	32
0x804	<a href="#">8_CONBLK_AD</a>	DMA Channel 8 Control Block Address	32
0x808	<a href="#">8_TI</a>	DMA Channel 8 CB Word 0 (Transfer Information)	32
0x80c	<a href="#">8_SOURCE_AD</a>	DMA Channel 8 CB Word 1 (Source Address)	32
0x810	<a href="#">8_DEST_AD</a>	DMA Channel 8 CB Word 2 (Destination Address)	32
0x814	<a href="#">8_TXFR_LEN</a>	DMA Channel 8 CB Word 3 (Transfer Length)	32
0x81c	<a href="#">8_NEXTCONBK</a>	DMA Channel 8 CB Word 5 (Next CB Address)	32



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0x820	<a href="#">8_DEBUG</a>	DMA Channel 8 Debug	32
0x900	<a href="#">9_CS</a>	DMA Channel 9 Control and Status	32
0x904	<a href="#">9_CONBLK_AD</a>	DMA Channel 9 Control Block Address	32
0x908	<a href="#">9_TI</a>	DMA Channel 9 CB Word 0 (Transfer Information)	32
0x90c	<a href="#">9_SOURCE_AD</a>	DMA Channel 9 CB Word 1 (Source Address)	32
0x910	<a href="#">9_DEST_AD</a>	DMA Channel 9 CB Word 2 (Destination Address)	32
0x914	<a href="#">9_TXFR_LEN</a>	DMA Channel 9 CB Word 3 (Transfer Length)	32
0x91c	<a href="#">9_NEXTCONBK</a>	DMA Channel 9 CB Word 5 (Next CB Address)	32
0x920	<a href="#">9_DEBUG</a>	DMA Channel 9 Debug	32
0xa00	<a href="#">10_CS</a>	DMA Channel 10 Control and Status	32
0xa04	<a href="#">10_CONBLK_AD</a>	DMA Channel 10 Control Block Address	32
0xa08	<a href="#">10_TI</a>	DMA Channel 10 CB Word 0 (Transfer Information)	32
0xa0c	<a href="#">10_SOURCE_AD</a>	DMA Channel 10 CB Word 1 (Source Address)	32
0xa10	<a href="#">10_DEST_AD</a>	DMA Channel 10 CB Word 2 (Destination Address)	32
0xa14	<a href="#">10_TXFR_LEN</a>	DMA Channel 10 CB Word 3 (Transfer Length)	32
0xa1c	<a href="#">10_NEXTCONBK</a>	DMA Channel 10 CB Word 5 (Next CB Address)	32
0xa20	<a href="#">10_DEBUG</a>	DMA Channel 10 Debug	32
0xb00	<a href="#">11_CS</a>	DMA Channel 11 Control and Status	32
0xb04	<a href="#">11_CONBLK_AD</a>	DMA Channel 11 Control Block Address	32
0xb08	<a href="#">11_TI</a>	DMA Channel 11 CB Word 0 (Transfer Information)	32
0xb0c	<a href="#">11_SOURCE_AD</a>	DMA Channel 11 CB Word 1 (Source Address)	32



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0xb10	<a href="#">11_DEST_AD</a>	DMA Channel 11 CB Word 2 (Destination Address)	32
0xb14	<a href="#">11_TXFR_LEN</a>	DMA Channel 11 CB Word 3 (Transfer Length)	32
0xb1c	<a href="#">11_NEXTCONBK</a>	DMA Channel 11 CB Word 5 (Next CB Address)	32
0xb20	<a href="#">11_DEBUG</a>	DMA Channel 11 Debug	32
0xc00	<a href="#">12_CS</a>	DMA Channel 12 Control and Status	32
0xc04	<a href="#">12_CONBLK_AD</a>	DMA Channel 12 Control Block Address	32
0xc08	<a href="#">12_TI</a>	DMA Channel 12 CB Word 0 (Transfer Information)	32
0xc0c	<a href="#">12_SOURCE_AD</a>	DMA Channel 12 CB Word 1 (Source Address)	32
0xc10	<a href="#">12_DEST_AD</a>	DMA Channel 12 CB Word 2 (Destination Address)	32
0xc14	<a href="#">12_TXFR_LEN</a>	DMA Channel 12 CB Word 3 (Transfer Length)	32
0xc1c	<a href="#">12_NEXTCONBK</a>	DMA Channel 12 CB Word 5 (Next CB Address)	32
0xc20	<a href="#">12_DEBUG</a>	DMA Channel 12 Debug	32
0xd00	<a href="#">13_CS</a>	DMA Channel 13 Control and Status	32
0xd04	<a href="#">13_CONBLK_AD</a>	DMA Channel 13 Control Block Address	32
0xd08	<a href="#">13_TI</a>	DMA Channel 13 CB Word 0 (Transfer Information)	32
0xd0c	<a href="#">13_SOURCE_AD</a>	DMA Channel 13 CB Word 1 (Source Address)	32
0xd10	<a href="#">13_DEST_AD</a>	DMA Channel 13 CB Word 2 (Destination Address)	32
0xd14	<a href="#">13_TXFR_LEN</a>	DMA Channel 13 CB Word 3 (Transfer Length)	32
0xd1c	<a href="#">13_NEXTCONBK</a>	DMA Channel 13 CB Word 5 (Next CB Address)	32
0xd20	<a href="#">13_DEBUG</a>	DMA Channel 13 Debug	32
0xe00	<a href="#">14_CS</a>	DMA Channel 14 Control and Status	32



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0xe04	<a href="#">14_CONBLK_AD</a>	DMA Channel 14 Control Block Address	32
0xe08	<a href="#">14_TI</a>	DMA Channel 14 CB Word 0 (Transfer Information)	32
0xe0c	<a href="#">14_SOURCE_AD</a>	DMA Channel 14 CB Word 1 (Source Address)	32
0xe10	<a href="#">14_DEST_AD</a>	DMA Channel 14 CB Word 2 (Destination Address)	32
0xe14	<a href="#">14_TXFR_LEN</a>	DMA Channel 14 CB Word 3 (Transfer Length)	32
0xe1c	<a href="#">14_NEXTCONBK</a>	DMA Channel 14 CB Word 5 (Next CB Address)	32
0xe20	<a href="#">14_DEBUG</a>	DMA Channel 14 Debug	32
0xfe0	<a href="#">INT_STATUS</a>	Interrupt status of each DMA channel	32
0xff0	<a href="#">ENABLE</a>	Global enable bits for each DMA channel	32

## 0\_CS 1\_CS 2\_CS 3\_CS 4\_CS 5\_CS 6\_CS 7\_CS 8\_CS 9\_CS 10\_CS 11\_CS 12\_CS 13\_CS 14\_CS Register

**Synopsis** DMA Control And Status register contains the main control and status bits for this DMA channel.

Bit(s)	Field Name	Description	Type	Reset
31	RESET	<u>DMA Channel Reset</u> Writing a 1 to this bit will reset the DMA. The bit cannot be read, and will self clear.	W1SC	0x0
30	ABORT	<u>Abort DMA</u> Writing a 1 to this bit will abort the current DMA CB. The DMA will load the next CB and attempt to continue. The bit cannot be read, and will self clear.	W1SC	0x0
29	DISDEBUG	<u>Disable debug pause signal</u> When set to 1, the DMA will not stop when the debug pause signal is asserted.	RW	0x0

28	WAIT_FOR_OUTSTANDING_WRITES	<p><u>Wait for outstanding writes</u> When set to 1, the DMA will keep a tally of the AXI writes going out and the write responses coming in. At the very end of the current DMA transfer it will wait until the last outstanding write response has been received before indicating the transfer is complete. Whilst waiting it will load the next CB address (but will not fetch the CB), clear the active flag (if the next CB address = zero), and it will defer setting the END flag or the INT flag until the last outstanding write response has been received.</p> <p>In this mode, the DMA will pause if it has more than 13 outstanding writes at any one time.</p>	RW	0x0
27:24		<b>Reserved</b> - Write as 0, read as don't care		
23:20	PANIC_PRIORITY	<p><u>AXI Panic Priority Level</u> Sets the priority of panicking AXI bus transactions. This value is used when the panic bit of the selected peripheral channel is 1. Zero is the lowest priority.</p>	RW	0x0
19:16	PRIORITY	<p><u>AXI Priority Level</u> Sets the priority of normal AXI bus transactions. This value is used when the panic bit of the selected peripheral channel is zero. Zero is the lowest priority.</p>	RW	0x0
15:9		<b>Reserved</b> - Write as 0, read as don't care		
8	ERROR	<p><u>DMA Error</u> Indicates if the DMA has detected an error. The error flags are available in the debug register, and have to be cleared by writing to that register. 1 = DMA channel has an error flag set. 0 = DMA channel is ok.</p>	RO	0x0
7		<b>Reserved</b> - Write as 0, read as don't care		



6	WAITING_FOR_OUTSTANDING_WRITES	<p><u>DMA is Waiting for the Last Write to be Received</u> Indicates if the DMA is currently waiting for any outstanding writes to be received, and is not transferring data. 1 = DMA channel is waiting.</p>	RO	0x0
5	DREQ_STOPS_DMA	<p><u>DMA Paused by DREQ State</u> Indicates if the DMA is currently paused and not transferring data due to the DREQ being inactive.. 1 = DMA channel is paused. 0 = DMA channel is running.</p>	RO	0x0
4	PAUSED	<p><u>DMA Paused State</u> Indicates if the DMA is currently paused and not transferring data. This will occur if: the active bit has been cleared, if the DMA is currently executing wait cycles or if the debug_pause signal has been set by the debug block, or the number of outstanding writes has exceeded the max count. 1 = DMA channel is paused. 0 = DMA channel is running.</p>	RO	0x0
3	DREQ	<p><u>DREQ State</u> Indicates the state of the selected DREQ (Data Request) signal, ie. the DREQ selected by the PERMAP field of the transfer info. 1 = Requesting data. This will only be valid once the DMA has started and the PERMAP field has been loaded from the CB. It will remain valid, indicating the selected DREQ signal, until a new CB is loaded. If PERMAP is set to zero (un-paced transfer) then this bit will read back as 1. 0 = No data request.</p>	RO	0x0
2	INT	<p><u>Interrupt Status</u> This is set when the transfer for the CB ends and INTEN is set to 1. Once set it must be manually cleared down, even if the next CB has INTEN = 0. Write 1 to clear.</p>	W1C	0x0



# BCM2835 ARM Peripherals

1	END	<u>DMA End Flag</u> Set when the transfer described by the current control block is complete. Write 1 to clear.	W1C	0x0
0	ACTIVE	<u>Activate the DMA</u> This bit enables the DMA. The DMA will start if this bit is set and the CB_ADDR is non zero. The DMA transfer can be paused and resumed by clearing, then setting it again. This bit is automatically cleared at the end of the complete DMA transfer, ie. after a NEXTCONBK = 0x0000_0000 has been loaded.	RW	0x0

**0\_CONBLK\_AD 1\_CONBLK\_AD 2\_CONBLK\_AD 3\_CONBLK\_AD 4\_CONBLK\_AD 5\_CONBLK\_AD 6\_CONBLK\_AD 7\_CONBLK\_AD 8\_CONBLK\_AD 9\_CONBLK\_AD 10\_CONBLK\_AD 11\_CONBLK\_AD 12\_CONBLK\_AD 13\_CONBLK\_AD 14\_CONBLK\_AD Register**

**Synopsis** DMA Control Block Address register.

Bit(s)	Field Name	Description	Type	Reset
31:0	SCB_ADDR	<u>Control Block Address</u> This tells the DMA where to find a Control Block stored in memory. When the ACTIVE bit is set and this address is non zero, the DMA will begin its transfer by loading the contents of the addressed CB into the relevant DMA channel registers. At the end of the transfer this register will be updated with the ADDR field of the NEXTCONBK control block register. If this field is zero, the DMA will stop. Reading this register will return the address of the currently active CB (in the linked list of CB s). The address must be 256 bit aligned, so the bottom 5 bits of the address must be zero.	RW	0x0

**0\_TI 1\_TI 2\_TI 3\_TI 4\_TI 5\_TI 6\_TI Register**

**Synopsis** DMA Transfer Information.

Bit(s)	Field Name	Description	Type	Reset
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# BCM2835 ARM Peripherals

31:27		<i>Reserved - Write as 0, read as don't care</i>		
26	NO_WIDE_BURSTS	<p><u>Don't Do wide writes as a 2 beat burst</u> This prevents the DMA from issuing wide writes as 2 beat AXI bursts. This is an inefficient access mode, so the default is to use the bursts.</p>	RW	0x0
25:21	WAITS	<p><u>Add Wait Cycles</u> This slows down the DMA throughput by setting the number of dummy cycles burnt after each DMA read or write operation is completed. A value of 0 means that no wait cycles are to be added.</p>	RW	0x0
20:16	PERMAP	<p><u>Peripheral Mapping</u> Indicates the peripheral number (1-31) whose ready signal shall be used to control the rate of the transfers, and whose panic signals will be output on the DMA AXI bus. Set to 0 for a continuous un-paced transfer.</p>	RW	0x0
15:12	BURST_LENGTH	<p><u>Burst Transfer Length</u> Indicates the burst length of the DMA transfers. The DMA will attempt to transfer data as bursts of this number of words. A value of zero will produce a single transfer. Bursts are only produced for specific conditions, see main text.</p>	RW	0x0
11	SRC_IGNORE	<p><u>Ignore Reads</u> 1 = Do not perform source reads. In addition, destination writes will zero all the write strobes. This is used for fast cache fill operations. 0 = Perform source reads..</p>	RW	0x0
10	SRC_DREQ	<p><u>Control Source Reads with DREQ</u> 1 = The DREQ selected by PER_MAP will gate the source reads. 0 = DREQ has no effect.</p>	RW	0x0
9	SRC_WIDTH	<p><u>Source Transfer Width</u> 1 = Use 128-bit source read width. 0 = Use 32-bit source read width.</p>	RW	0x0
8	SRC_INC	<p><u>Source Address Increment</u> 1 = Source address increments after each read. The address will increment by 4, if S_WIDTH=0 else by 32. 0 = Source address does not change.</p>	RW	0x0



# BCM2835 ARM Peripherals

7	DEST_IGNORE	<u>Ignore Writes</u> 1 = Do not perform destination writes. 0 = Write data to destination.	RW	0x0
6	DEST_DREQ	<u>Control Destination Writes with DREQ</u> 1 = The DREQ selected by PERMAP will gate the destination writes. 0 = DREQ has no effect.	RW	0x0
5	DEST_WIDTH	<u>Destination Transfer Width</u> 1 = Use 128-bit destination write width. 0 = Use 32-bit destination write width.	RW	0x0
4	DEST_INC	<u>Destination Address Increment</u> 1 = Destination address increments after each write The address will increment by 4, if DEST_WIDTH=0 else by 32. 0 = Destination address does not change.	RW	0x0
3	WAIT_RESP	<u>Wait for a Write Response</u> When set this makes the DMA wait until it receives the AXI write response for each write. This ensures that multiple writes cannot get stacked in the AXI bus pipeline. 1= Wait for the write response to be received before proceeding. 0 = Don t wait; continue as soon as the write data is sent.	RW	0x0
2		<b>Reserved</b> - Write as 0, read as don't care		
1	TDMODE	<u>2D Mode</u> 1 = 2D mode interpret the TXFR_LEN register as YLENGTH number of transfers each of XLENGTH, and add the strides to the address after each transfer. 0 = Linear mode interpret the TXFR register as a single transfer of total length {YLENGTH ,XLENGTH}.	RW	0x0
0	INTEN	<u>Interrupt Enable</u> 1 = Generate an interrupt when the transfer described by the current Control Block completes. 0 = Do not generate an interrupt.	RW	0x0

0\_SOURCE\_AD 1\_SOURCE\_AD 2\_SOURCE\_AD 3\_SOURCE\_AD 4\_SOURCE\_AD 5\_SOURCE\_AD  
6\_SOURCE\_AD 7\_SOURCE\_AD 8\_SOURCE\_AD 9\_SOURCE\_AD 10\_SOURCE\_AD 11\_SOURCE\_AD  
12\_SOURCE\_AD 13\_SOURCE\_AD 14\_SOURCE\_AD Register



# BCM2835 ARM Peripherals

## Synopsis DMA Source Address

Bit(s)	Field Name	Description	Type	Reset
31:0	S_ADDR	<u>DMA Source Address</u> Source address for the DMA operation. Updated by the DMA engine as the transfer progresses.	RW	0x0

## 0\_DEST\_AD 1\_DEST\_AD 2\_DEST\_AD 3\_DEST\_AD 4\_DEST\_AD 5\_DEST\_AD 6\_DEST\_AD 7\_DEST\_AD 8\_DEST\_AD 9\_DEST\_AD 10\_DEST\_AD 11\_DEST\_AD 12\_DEST\_AD 13\_DEST\_AD 14\_DEST\_AD Register

## Synopsis DMA Destination Address

Bit(s)	Field Name	Description	Type	Reset
31:0	D_ADDR	<u>DMA Destination Address</u> Destination address for the DMA operation. Updated by the DMA engine as the transfer progresses.	RW	0x0

## 0\_TXFR\_LEN 1\_TXFR\_LEN 2\_TXFR\_LEN 3\_TXFR\_LEN 4\_TXFR\_LEN 5\_TXFR\_LEN 6\_TXFR\_LEN Register

**Synopsis** DMA Transfer Length. This specifies the amount of data to be transferred in bytes. In normal (non 2D) mode this specifies the amount of bytes to be transferred. In 2D mode it is interpreted as an X and a Y length, and the DMA will perform Y transfers, each of length X bytes and add the strides onto the addresses after each X leg of the transfer. The length register is updated by the DMA engine as the transfer progresses, so it will indicate the data left to transfer.

Bit(s)	Field Name	Description	Type	Reset
31:30		<i>Reserved - Write as 0, read as don't care</i>		
29:16	YLENGTH	When in 2D mode, This is the Y transfer length, indicating how many xlength transfers are performed. When in normal linear mode this becomes the top bits of the XLENGTH	RW	0x0
15:0	XLENGTH	<u>Transfer Length in bytes.</u>	RW	0x0



# BCM2835 ARM Peripherals

## 0\_STRIDE 1\_STRIDE 2\_STRIDE 3\_STRIDE 4\_STRIDE 5\_STRIDE 6\_STRIDE Register

**Synopsis** DMA 2D Stride

Bit(s)	Field Name	Description	Type	Reset
31:16	D_STRIDE	<u>Destination Stride (2D Mode)</u> Signed (2 s complement) byte increment to apply to the destination address at the end of each row in 2D mode.	RW	0x0
15:0	S_STRIDE	<u>Source Stride (2D Mode)</u> Signed (2 s complement) byte increment to apply to the source address at the end of each row in 2D mode.	RW	0x0

## 0\_NEXTCONBK 1\_NEXTCONBK 2\_NEXTCONBK 3\_NEXTCONBK 4\_NEXTCONBK 5\_NEXTCONBK 6\_NEXTCONBK 7\_NEXTCONBK 8\_NEXTCONBK 9\_NEXTCONBK 10\_NEXTCONBK 11\_NEXTCONBK 12\_NEXTCONBK 13\_NEXTCONBK 14\_NEXTCONBK Register

**Synopsis** DMA Next Control Block Address

The value loaded into this register can be overwritten so that the linked list of Control Block data structures can be altered. However it is only safe to do this when the DMA is paused. The address must be 256 bit aligned and so the bottom 5 bits cannot be set and will read back as zero.

Bit(s)	Field Name	Description	Type	Reset
31:0	ADDR	<u>Address of next CB for chained DMA operations.</u>	RW	0x0

## 0\_DEBUG 1\_DEBUG 2\_DEBUG 3\_DEBUG 4\_DEBUG 5\_DEBUG 6\_DEBUG Register

**Synopsis** DMA Debug register.

Bit(s)	Field Name	Description	Type	Reset
31:29		<i>Reserved - Write as 0, read as don't care</i>		



# BCM2835 ARM Peripherals

28	LITE	<u>DMA Lite</u> Set if the DMA is a reduced performance LITE engine.	RO	0x0
27:25	VERSION	<u>DMA Version</u> DMA version number, indicating control bit filed changes.	RO	0x2
24:16	DMA_STATE	<u>DMA State Machine State</u> Returns the value of the DMA engines state machine for this channel.	RO	0x0
15:8	DMA_ID	<u>DMA ID</u> Returns the DMA AXI ID of this DMA channel.	RO	0x0
7:4	OUTSTANDING_WRITES	<u>DMA Outstanding Writes Counter</u> Returns the number of write responses that have not yet been received. This count is reset at the start of each new DMA transfer or with a DMA reset.	RO	0x0
3		<b>Reserved</b> - Write as 0, read as don't care		
2	READ_ERROR	<u>Slave Read Response Error</u> Set if the read operation returned an error value on the read response bus. It can be cleared by writing a 1,	RW	0x0
1	FIFO_ERROR	<u>Fifo Error</u> Set if the optional read Fifo records an error condition. It can be cleared by writing a 1,	RW	0x0
0	READ_LAST_NOT_SET_ERROR	<u>Read Last Not Set Error</u> If the AXI read last signal was not set when expected, then this error bit will be set. It can be cleared by writing a 1.	RW	0x0

## 7\_TI 8\_TI 9\_TI 10\_TI 11\_TI 12\_TI 13\_TI 14\_TI Register

**Synopsis** DMA Transfer Information.

Bit(s)	Field Name	Description	Type	Reset
31:26		<b>Reserved</b> - Write as 0, read as don't care		

25:21	WAITS	<u>Add Wait Cycles</u> This slows down the DMA throughput by setting the number of dummy cycles burnt after each DMA read or write operation is completed. A value of 0 means that no wait cycles are to be added.	RW	0x0
20:16	PERMAP	<u>Peripheral Mapping</u> Indicates the peripheral number (1-31) whose ready signal shall be used to control the rate of the transfers, and whose panic signals will be output on the DMA AXI bus. Set to 0 for a continuous un-paced transfer.	RW	0x0
15:12	BURST_LENGTH	<u>Burst Transfer Length</u> Indicates the burst length of the DMA transfers. The DMA will attempt to transfer data as bursts of this number of words. A value of zero will produce a single transfer. Bursts are only produced for specific conditions, see main text.	RW	0x0
11	SRC_IGNORE		RW	0x0
10	SRC_DREQ	<u>Control Source Reads with DREQ</u> 1 = The DREQ selected by PER_MAP will gate the source reads. 0 = DREQ has no effect.	RW	0x0
9	SRC_WIDTH	<u>Source Transfer Width</u> 1 = Use 128-bit source read width. 0 = Use 32-bit source read width.	RW	0x0
8	SRC_INC	<u>Source Address Increment</u> 1 = Source address increments after each read. The address will increment by 4, if S_WIDTH=0 else by 32. 0 = Source address does not change.	RW	0x0
7	DEST_IGNORE		RW	0x0
6	DEST_DREQ	<u>Control Destination Writes with DREQ</u> 1 = The DREQ selected by PERMAP will gate the destination writes. 0 = DREQ has no effect.	RW	0x0
5	DEST_WIDTH	<u>Destination Transfer Width</u> 1 = Use 128-bit destination write width. 0 = Use 32-bit destination write width.	RW	0x0





# BCM2835 ARM Peripherals

4	DEST_INC	<u>Destination Address Increment</u> 1 = Destination address increments after each write The address will increment by 4, if DEST_WIDTH=0 else by 32. 0 = Destination address does not change.	RW	0x0
3	WAIT_RESP	<u>Wait for a Write Response</u> When set this makes the DMA wait until it receives the AXI write response for each write. This ensures that multiple writes cannot get stacked in the AXI bus pipeline. 1= Wait for the write response to be received before proceeding. 0 = Don t wait; continue as soon as the write data is sent.	RW	0x0
2:1		<b>Reserved</b> - Write as 0, read as don't care		
0	INTEN	<u>Interrupt Enable</u> 1 = Generate an interrupt when the transfer described by the current Control Block completes. 0 = Do not generate an interrupt.	RW	0x0

## 7\_TXFR\_LEN 8\_TXFR\_LEN 9\_TXFR\_LEN 10\_TXFR\_LEN 11\_TXFR\_LEN 12\_TXFR\_LEN 13\_TXFR\_LEN 14\_TXFR\_LEN Register

**Synopsis** DMA Transfer Length

Bit(s)	Field Name	Description	Type	Reset
31:16		<b>Reserved</b> - Write as 0, read as don't care		
15:0	XLENGTH	<u>Transfer Length</u> Length of transfer, in bytes. Updated by the DMA engine as the transfer progresses.	RW	0x0

## 7\_DEBUG 8\_DEBUG 9\_DEBUG 10\_DEBUG 11\_DEBUG 12\_DEBUG 13\_DEBUG 14\_DEBUG Register

**Synopsis** DMA Lite Debug register.

Bit(s)	Field Name	Description	Type	Reset
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# BCM2835 ARM Peripherals

31:29		<i>Reserved - Write as 0, read as don't care</i>		
28	LITE	<u>DMA Lite</u> Set if the DMA is a reduced performance LITE engine.	RO	0x1
27:25	VERSION	<u>DMA Version</u> DMA version number, indicating control bit filed changes.	RO	0x2
24:16	DMA_STATE	<u>DMA State Machine State</u> Returns the value of the DMA engines state machine for this channel.	RO	0x0
15:8	DMA_ID	<u>DMA ID</u> Returns the DMA AXI ID of this DMA channel.	RO	0x0
7:4	OUTSTANDING_WRITES	<u>DMA Outstanding Writes Counter</u> Returns the number of write responses that have not yet been received. This count is reset at the start of each new DMA transfer or with a DMA reset.	RO	0x0
3		<i>Reserved - Write as 0, read as don't care</i>		
2	READ_ERROR	<u>Slave Read Response Error</u> Set if the read operation returned an error value on the read response bus. It can be cleared by writing a 1,	RW	0x0
1	FIFO_ERROR	<u>Fifo Error</u> Set if the optional read Fifo records an error condition. It can be cleared by writing a 1,	RW	0x0
0	READ_LAST_NOT_SET_ERROR	<u>Read Last Not Set Error</u> If the AXI read last signal was not set when expected, then this error bit will be set. It can be cleared by writing a 1.	RW	0x0

## INT\_STATUS Register

**Synopsis** Interrupt status of each DMA engine

Bit(s)	Field Name	Description	Type	Reset
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# BCM2835 ARM Peripherals

31:16		<i>Reserved - Write as 0, read as don't care</i>		
15	INT15	<u>Interrupt status of DMA engine 15</u>	RW	0x0
14	INT14	<u>Interrupt status of DMA engine 14</u>	RW	0x0
13	INT13	<u>Interrupt status of DMA engine 13</u>	RW	0x0
12	INT12	<u>Interrupt status of DMA engine 12</u>	RW	0x0
11	INT11	<u>Interrupt status of DMA engine 11</u>	RW	0x0
10	INT10	<u>Interrupt status of DMA engine 10</u>	RW	0x0
9	INT9	<u>Interrupt status of DMA engine 9</u>	RW	0x0
8	INT8	<u>Interrupt status of DMA engine 8</u>	RW	0x0
7	INT7	<u>Interrupt status of DMA engine 7</u>	RW	0x0
6	INT6	<u>Interrupt status of DMA engine 6</u>	RW	0x0
5	INT5	<u>Interrupt status of DMA engine 5</u>	RW	0x0
4	INT4	<u>Interrupt status of DMA engine 4</u>	RW	0x0
3	INT3	<u>Interrupt status of DMA engine 3</u>	RW	0x0
2	INT2	<u>Interrupt status of DMA engine 2</u>	RW	0x0
1	INT1	<u>Interrupt status of DMA engine 1</u>	RW	0x0
0	INT0	<u>Interrupt status of DMA engine 0</u>	RW	0x0

## ENABLE Register

**Synopsis** Global enable bits for each channel

Bit(s)	Field Name	Description	Type	Reset
31:15		<i>Reserved - Write as 0, read as don't care</i>		



## BCM2835 ARM Peripherals

14	EN14	<u>enable dma engine 14</u>	RW	0x1
13	EN13	<u>enable dma engine 13</u>	RW	0x1
12	EN12	<u>enable dma engine 12</u>	RW	0x1
11	EN11	<u>enable dma engine 11</u>	RW	0x1
10	EN10	<u>enable dma engine 10</u>	RW	0x1
9	EN9	<u>enable dma engine 9</u>	RW	0x1
8	EN8	<u>enable dma engine 8</u>	RW	0x1
7	EN7	<u>enable dma engine 7</u>	RW	0x1
6	EN6	<u>enable dma engine 6</u>	RW	0x1
5	EN5	<u>enable dma engine 5</u>	RW	0x1
4	EN4	<u>enable dma engine 4</u>	RW	0x1
3	EN3	<u>enable dma engine 3</u>	RW	0x1
2	EN2	<u>enable dma engine 2</u>	RW	0x1
1	EN1	<u>enable dma engine 1</u>	RW	0x1
0	EN0	<u>enable dma engine 0</u>	RW	0x1

## 4.2.1.3 Peripheral DREQ Signals

A DREQ (Data Request) mechanism is used to pace the data flow between the DMA and a peripheral.

Each peripheral is allocated a permanent DREQ signal. Each DMA channel can select which of the DREQ signals should be used to pace the transfer by controlling the DMA reads, DMA writes or both. Note that DREQ 0 is permanently enabled and can be used if no DREQ is required.

When a DREQ signal is being used to pace the DMA reads, the DMA will wait until it has sampled DREQ high before launching a single or burst read operation. It will then wait for all the read data to be returned before re-checking the DREQ and starting the next read. Thus once a peripheral receives the read request it should remove its DREQ as soon as possible to prevent the DMA from re-sampling the same DREQ assertion.

DREQ's are not required when reading from AXI peripherals. In this case, the DMA will request data from the peripheral and the peripheral will only send the data when it is available. The DMA will not request data that it does not have room for, so no pacing of the data flow is required.

DREQ's are required when reading from APB peripherals as the AXI-to-APB bridge will not wait for an APB peripheral to be ready and will just perform the APB read regardless. Thus an APB peripheral needs to make sure that it has all of its read data ready before it drives its DREQ high.

When writing to peripherals, a DREQ is always required to pace the data. However, due to the pipelined nature of the AXI bus system, several writes may be in flight before the peripheral receives any data and withdraws its DREQ signal. Thus the peripheral must ensure that it has sufficient room in its input FIFO to accommodate the maximum amount of data that it might receive. If the peripheral is unable to do this, the DMA WAIT\_RESP mechanism can be used to ensure that only one write is in flight at any one time, however this is less efficient transfer mechanism.

The mapping of peripherals to DREQ's is as follows:

DREQ	Peripheral
0	DREQ = 1 This is always on so use this channel if no DREQ is required.
1	DSI
2	PCM TX
3	PCM RX
4	SMI
5	PWM
6	SPI TX
7	SPI RX



## BCM2835 ARM Peripherals

8	BSC/SPI Slave TX
9	BSC/SPI Slave RX
10	unused
11	<i>e.MMC</i>
12	<i>UART TX</i>
13	SD HOST
14	UART RX.
15	DSI
16	SLIMBUS MCTX.
17	HDMI
18	SLIMBUS MCRX
19	SLIMBUS DC0
20	SLIMBUS DC1
21	SLIMBUS DC2
22	SLIMBUS DC3
23	SLIMBUS DC4
24	Scaler FIFO 0 & SMI *
25	Scaler FIFO 1 & SMI *
26	Scaler FIFO 2 & SMI *
27	SLIMBUS DC5
28	SLIMBUS DC6
29	SLIMBUS DC7
30	SLIMBUS DC8
31	SLIMBUS DC9

\* The SMI element of the Scaler FIFO 0 & SMI DREQs can be disabled by setting the SMI\_DISABLE bit in the DMA\_DREQ\_CONTROL register in the system arbiter control block.

## 4.3 AXI Bursts

The DMA supports bursts under specific conditions. Up to 16 beat bursts can be accommodated.

Peripheral (32 bit wide) read bursts are supported. The DMA will generate the burst if there is sufficient room in its read buffer to accommodate all the data from the burst. This limits the burst size to a maximum of 8 beats.

Read bursts in destination ignore mode (DEST\_IGNORE) are supported as there is no need for the DMA to deal with the data. This allows wide bursts of up to 16 beats to be used for efficient L2 cache fills.

DMA channel 0 and 15 are fitted with an external 128 bit 8 word read FIFO. This enables efficient memory to memory transfers to be performed. This FIFO allows the DMA to accommodate a wide read burst up to the size of the FIFO. In practice this will allow a 128 bit wide read burst of 9 as the first word back will be immediately read into the DMA engine (or a 32 bit peripheral read burst of 16 – 8 in the input buffer and 8 in the fifo). On any DMA channel, if a read burst is selected that is too large, the AXI read bus will be stalled until the DMA has written out the data. This may lead to inefficient system operation, and possibly AXI lock up if it causes a circular dependency.

In general write bursts are not supported. However to increase the efficiency of L2 cache fills, src\_ignore (SRC\_IGNORE) transfers can be specified with a write burst. In this case the DMA will issue a write burst address sequence followed by the appropriate number of zero data, zero strobe write bus cycles, which will cause the cache to pre-fetch the data. To improve the efficiency of the 128 bit wide bus architecture, and to make use of the DMAs internal 256 bit registers, the DMA will generate 128 bit wide writes as 2 beat bursts wherever possible, although this behaviour can be disabled.

## 4.4 Error Handling

If the DMA detects a Read Response error it will record the fact in the READ\_ERROR flag in the debug register. This will remain set until it is cleared by writing a 1 to it. The DMA will clear its active flag and generate an interrupt. Any outstanding read data transactions (remainder of a burst) will be honoured. This allows the operator to either restart the DMA by clearing the error bit and setting the active bit, or to abort the DMA transfer by clearing the NEXTCONBK register and restarting the DMA with the ABORT bit set.

The DMA will also record any errors from an external read FIFO. These will be latched in the FIFO\_ERROR bit in the debug register until they are cleared by writing a '1' to the bit. (note that only DMA0 and 15 have an external read fifo)

If the DMA detects that a read occurred without the AXI rlast set as expected then it will set the READ\_LAST\_NOT\_SET\_ERROR bit in the debug register. This can be cleared by writing a '1' to it.

The error bits are logically OR'd together and presented as a general ERROR bit in the CS register.

## 4.5 DMA LITE Engines

Several of the DMA engines are of the LITE design. This is a reduced specification engine designed to save space. The engine behaves in the same way as a normal DMA engine except for the following differences.

1. The internal data structure is 128 bits instead of 256 bits. This means that if you do a 128 bit wide read burst of more than 1 beat, the DMA input register will be full and the read bus will be stalled. The normal DMA engine can accept a read burst of 2 without stalling. If you do a narrow 32 bit read burst from the peripherals then the lite engine can cope with a burst of 4 as opposed to a burst of 8 for the normal engine. Note that stalling the read bus will potentially reduce the overall system performance, and may possible cause a system lockup if you end up with a conflict where the DMA cannot free the read bus as the read stall has prevented it writing out its data due to some circular system relationship.
2. The Lite engine does not support 2D transfers. The TDMODE, S\_STRIDE, D\_STRIDE and YLENGTH registers will all be removed. Setting these registers will have no effect.
3. The DMA length register is now 16 bits, limiting the maximum transferrable length to 65536 bytes.
4. Source ignore (SRC\_IGNORE) and destination ignore (DEST\_IGNORE) modes are removed.

The Lite engine will have about half the bandwidth of a normal DMA engine, and are intended for low bandwidth peripheral servicing.



## 5 External Mass Media Controller

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### ○ Introduction

The External Mass Media Controller (EMMC) is an embedded MultiMedia™ and SD™ card interface provided by Arasan™. It is compliant to the following standards:

- SD™ Host Controller Standard Specification Version 3.0 Draft 1.0
- SDIO™ card specification version 3.0
- SD™ Memory Card Specification Draft version 3.0
- SD™ Memory Card Security Specification version 1.01
- MMC™ Specification version 3.31,4.2 and 4.4

For convenience in the following text card is used as a placeholder for SD™, embedded MultiMedia and SDIO™ cards.

For detailed information about the EMMC internals please refer to the Arasan™ document [SD3.0\\_Host\\_AHB\\_eMMC4.4\\_Usersguide\\_ver5.9\\_jan11\\_10.pdf](#) but make sure to read the following chapter which lists the changes made to Arasan™'s IP.

Because the EMMC module shares pins with other functionality it must be selected in the GPIO interface. Please refer to the GPIO section for further details.

The interface to the card uses its own clock `clk_emmc` which is provided by the clock manager module. The frequency of this clock should be selected between 50 MHz and 100 MHz. Having a separate clock allows high performance access to the card even if the VideoCore runs at a reduced clock frequency. The EMMC module contains its own internal clock divider to generate the card's clock from `clk_emmc`.

Additionally can the sampling clock for the response and data from the card be delayed in up to 40 steps with a configurable delay between 200ps to 1100ps per step typically. The delay is intended to cancel the internal delay inside the card (up to 14ns) when reading. The delay per step will vary with temperature and supply voltage. Therefore it is better to use a bigger delay than necessary as there is no restriction for the maximum delay.

The EMMC module handles the handshaking process on the command and data lines and all CRC processing automatically.

Command execution is commenced by writing the command plus the appropriate flags to the `CMDTM` register after loading any required argument into the `ARG1` register. The EMMC module calculates the CRC checksum, transfers the command to the card, receives the response and checks its CRC. Once the command has executed or timed-out bit 0 of register `INTERRUPT` will be set. Please note that the `INTERRUPT` register is not self clearing, so the software has first to reset it by writing 1 before using it to detect if a command has finished.



## BCM2835 ARM Peripherals

The software is responsible for checking the status bits of the card's response in order to verify successful processing by the card.

In order to transfer data from/to the card register DATA is accessed after configuring the host and sending the according commands to the card using CMDTM. Because the EMMC module doesn't interpret the commands sent to the card it is important to configure it identical to the card setup using the CONTROL0 register. Especial care should be taken to make sure that the width of the data bus is configured identical for host and card. The card is synchronized to the data flow by switching off its clock appropriately. A handshake signal dma\_req is available for paced data transfers. Bit 1 of the INTERRUPT register can be used to determine whether a data transfer has finished. Please note that the INTERRUPT register is not self-clearing, so the software has first to reset it by writing 1 before using it to detect if a data transfer has finished.

The EMMC module restricts the maximum block size to the size of the internal data FIFO which is 1k bytes. In order to get maximum performance for data transfers it is necessary to use multiple block data transfers. In this case the EMMC module uses two FIFOs in ping-pong mode, i.e. one is used to transfer data to/from the card while the other is simultaneously accessed by DMA via the AXI bus. If the EMMC module is configured for single block transfers only one FIFO is used, so no DMA access is possible while data is transferred to/from the card and vice versa resulting in long dead times.

### ○ Registers

Contrary to Arasan™'s documentation the EMMC module registers can only be accessed as 32 bit registers, i.e. the two LSBs of the address are always zero.

The EMMC register base address is 0x7E300000

EMMC Address Map			
Address Offset	Register Name	Description	Size
0x0	<a href="#">ARG2</a>	ACMD23 Argument	32
0x4	<a href="#">BLKSIZECNT</a>	Block Size and Count	32
0x8	<a href="#">ARG1</a>	Argument	32
0xc	<a href="#">CMDTM</a>	Command and Transfer Mode	32
0x10	<a href="#">RESP0</a>	Response bits 31 : 0	32
0x14	<a href="#">RESP1</a>	Response bits 63 : 32	32



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0x18	<a href="#">RESP2</a>	Response bits 95 : 64	32
0x1c	<a href="#">RESP3</a>	Response bits 127 : 96	32
0x20	<a href="#">DATA</a>	Data	32
0x24	<a href="#">STATUS</a>	Status	32
0x28	<a href="#">CONTROL0</a>	Host Configuration bits	32
0x2c	<a href="#">CONTROL1</a>	Host Configuration bits	32
0x30	<a href="#">INTERRUPT</a>	Interrupt Flags	32
0x34	<a href="#">IRPT_MASK</a>	Interrupt Flag Enable	32
0x38	<a href="#">IRPT_EN</a>	Interrupt Generation Enable	32
0x3c	<a href="#">CONTROL2</a>	Host Configuration bits	32
0x50	<a href="#">FORCE_IRPT</a>	Force Interrupt Event	32
0x70	<a href="#">BOOT_TIMEOUT</a>	Timeout in boot mode	32
0x74	<a href="#">DBG_SEL</a>	Debug Bus Configuration	32
0x80	<a href="#">EXRDFIFO_CFG</a>	Extension FIFO Configuration	32
0x84	<a href="#">EXRDFIFO_EN</a>	Extension FIFO Enable	32
0x88	<a href="#">TUNE_STEP</a>	Delay per card clock tuning step	32
0x8c	<a href="#">TUNE_STEPS_STD</a>	Card clock tuning steps for SDR	32
0x90	<a href="#">TUNE_STEPS_DDR</a>	Card clock tuning steps for DDR	32
0xf0	<a href="#">SPI_INT_SPT</a>	SPI Interrupt Support	32
0xfc	<a href="#">SLOTISR_VER</a>	Slot Interrupt Status and Version	32

### ARG2 Register



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**Synopsis** This register contains the argument for the SD card specific command ACMD23 (SET\_WR\_BLK\_ERASE\_COUNT). ARG2 must be set before the ACMD23 command is issued using the CMDTM register.

Bit(s)	Field Name	Description	Type	Reset
31:0	ARGUMENT	<u>Argument to be issued with ACMD23</u>	RW	0x0

## BLKSIZECNT Register

**Synopsis** This register must not be accessed or modified while any data transfer between card and host is ongoing. It contains the number and size in bytes for data blocks to be transferred. Please note that the EMMC module restricts the maximum block size to the size of the internal data FIFO which is 1k bytes. BLKCNT is used to tell the host how many blocks of data are to be transferred. Once the data transfer has started and the TM\_BLKCNT\_EN bit in the CMDTM register is set the EMMC module automatically decreases the BNTCNT value as the data blocks are transferred and stops the transfer once BLKCNT reaches 0.

Bit(s)	Field Name	Description	Type	Reset
31:16	BLKCNT	<u>Number of blocks to be transferred</u>	RW	0x0
15:10		<b>Reserved</b> - Write as 0, read as don't care		
9:0	BLKSIZE	<u>Block size in bytes</u>	RW	0x0

## ARG1 Register

**Synopsis** This register contains the arguments for all commands except for the SD card specific command ACMD23 which uses ARG2. ARG1 must be set before the command is issued using the CMDTM register.

Bit(s)	Field Name	Description	Type	Reset
31:0	ARGUMENT	<u>Argument to be issued with command</u>	RW	0x0

## CMDTM Register

**Synopsis** This register is used to issue commands to the card. Besides the command it also contains flags informing the EMMC module what card response and type of data transfer to expect. Incorrect flags will result in strange behaviour.

For data transfers two modes are supported: either transferring a single block of data or several blocks of the same size. The SD card uses two different sets of commands to differentiate between them but the host needs to be additionally configured using TM\_MULTI\_BLOCK. It is important that this bit is set correct for the command sent to the card, i.e. 1 for CMD18 and CMD25 and 0 for CMD17 and CMD24. Multiple block transfer gives a better performance.

The BLKSIZECNT register is used to configure the size and number of blocks to be transferred. If bit TM\_BLKCNT\_EN of this register is set the transfer stops automatically after the number of data blocks configured in the BLKSIZECNT register has been transferred.

The TM\_AUTO\_CMD\_EN bits can be used to make the host to send automatically a command to the card telling it that the data transfer has finished once the BLKCNT bits in the BLKSIZECNT register are 0.

Bit(s)	Field Name	Description	Type	Reset
31:30		<i>Reserved - Write as 0, read as don't care</i>		
29:24	CMD_INDEX	<u>Index of the command to be issued to the card</u>	RW	0x0
23:22	CMD_TYPE	<u>Type of command to be issued to the card:</u> 00 = normal 01 = suspend (the current data transfer) 10 = resume (the last data transfer) 11 = abort (the current data transfer)	RW	0x0
21	CMD_ISDATA	<u>Command involves data transfer:</u> 0 = no data transfer command 1 = data transfer command	RW	0x0
20	CMD_IXCHK_EN	<u>Check that response has same index as command:</u> 0 = disabled 1 = enabled	RW	0x0
19	CMD_CRCCHK_EN	<u>Check the responses CRC:</u> 0 = disabled 1 = enabled	RW	0x0
18		<i>Reserved - Write as 0, read as don't care</i>		
17:16	CMD_RSPNS_TYPE	<u>Type of expected response from card:</u> 00 = no response 01 = 136 bits response 10 = 48 bits response 11 = 48 bits response using busy	RW	0x0



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15:6		<i>Reserved - Write as 0, read as don't care</i>		
5	TM_MULTI_BLOCK	<u>Type of data transfer</u> 0 = single block 1 = multiple block	RW	0x0
4	TM_DAT_DIR	<u>Direction of data transfer:</u> 0 = from host to card 1 = from card to host	RW	0x0
3:2	TM_AUTO_CMD_EN	<u>Select the command to be send after completion of a data transfer:</u> 00 = no command 01 = command CMD12 10 = command CMD23 11 = reserved	RW	0x0
1	TM_BLKCNT_EN	<u>Enable the block counter for multiple block transfers:</u> 0 = disabled 1 = enabled	RW	0x0
0		<i>Reserved - Write as 0, read as don't care</i>		

## RESP0 Register

**Synopsis** This register contains the status bits of the SD card s response. In case of commands CMD2 and CMD10 it contains CID[31:0] and in case of command CMD9 it contains CSD[31:0].  
 Note: this register is only valid once the last command has completed and no new command was issued.

Bit(s)	Field Name	Description	Type	Reset
31:0	RESPONSE	<u>Bits 31:0 of the card s response</u>	RW	0x0

## RESP1 Register

**Synopsis** In case of commands CMD2 and CMD10 this register contains CID[63:32] and in case of command CMD9 it contains CSD[63:32].  
 Note: this register is only valid once the last command has completed and no new command was issued.



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Bit(s)	Field Name	Description	Type	Reset
31:0	RESPONSE	<u>Bits 63:32 of the card s response</u>	RW	0x0

## RESP2 Register

**Synopsis** In case of commands CMD2 and CMD10 this register contains CID[95:64] and in case of command CMD9 it contains CSD[95:64].  
Note: this register is only valid once the last command has completed and no new command was issued.

Bit(s)	Field Name	Description	Type	Reset
31:0	RESPONSE	<u>Bits 95:64 of the card s response</u>	RW	0x0

## RESP3 Register

**Synopsis** In case of commands CMD2 and CMD10 this register contains CID[127:96] and in case of command CMD9 it contains CSD[127:96].  
Note: this register is only valid once the last command has completed and no new command was issued.

Bit(s)	Field Name	Description	Type	Reset
31:0	RESPONSE	<u>Bits 127:96 of the card s response</u>	RW	0x0

## DATA Register

**Synopsis** This register is used to transfer data to/from the card.  
Bit 1 of the INTERRUPT register can be used to check if data is available. For paced DMA transfers the high active signal dma\_req can be used.

Bit(s)	Field Name	Description	Type	Reset
31:0	DATA	<u>Data to/from the card</u>	RW	0x0

## STATUS Register

**Synopsis** This register contains information intended for debugging. Its values change automatically according to the hardware. As it involves resynchronisation between different clock domains it changes only after some latency and it is easy sample the values too early. Therefore it is not recommended to use this register for polling. Instead use the INTERRUPT register which implements a handshake mechanism which makes it impossible to miss a change when polling.

Bit(s)	Field Name	Description	Type	Reset
31:29		<i>Reserved - Write as 0, read as don't care</i>		
28:25	DAT_LEVEL1	<u>Value of data lines DAT7 to DAT4</u>	RW	0xf
24	CMD_LEVEL	<u>Value of command line CMD</u>	RW	0x1
23:20	DAT_LEVEL0	<u>Value of data lines DAT3 to DAT0</u>	RW	0xf
19:10		<i>Reserved - Write as 0, read as don't care</i>		
9	READ_TRANSFER	<u>New data can be read from EMMC:</u> 0 = no 1 = yes	RW	0x0
8	WRITE_TRANSFER	<u>New data can be written to EMMC:</u> 0 = no 1 = yes	RW	0x0
7:3		<i>Reserved - Write as 0, read as don't care</i>		
2	DAT_ACTIVE	<u>At least one data line is active:</u> 0 = no 1 = yes	RW	0x0
1	DAT_INHIBIT	<u>Data lines still used by previous data transfer:</u> 0 = no 1 = yes	RW	0x0
0	CMD_INHIBIT	<u>Command line still used by previous command:</u> 0 = no 1 = yes	RW	0x0





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## CONTROL0 Register

**Synopsis** This register is used to configure the EMMC module.  
 For the exact details please refer to the Arasan documentation SD3.0\_Host\_AHB\_eMMC4.4\_Usersguide\_ver5.9\_jan11\_10.pdf. Bits marked as reserved in this document but not by the Arasan documentation refer to functionality which has been disabled due to the changes listed in the previous chapter.

Bit(s)	Field Name	Description	Type	Reset
31:23		<b>Reserved</b> - Write as 0, read as don't care		
22	ALT_BOOT_EN	<u>Enable alternate boot mode access:</u> 0 = disabled 1 = enabled	RW	0x0
21	BOOT_EN	<u>Boot mode access:</u> 0 = stop boot mode access 1 = start boot mode access	RW	0x0
20	SPI_MODE	<u>SPI mode enable:</u> 0 = normal mode 1 = SPI mode	RW	0x0
19	GAP_IEN	<u>Enable SDIO interrupt at block gap (only valid if the HCTL_DWIDTH bit is set):</u> 0 = disabled 1 = enabled	RW	0x0
18	READWAIT_EN	<u>Use DAT2 read-wait protocol for SDIO cards supporting this:</u> 0 = disabled 1 = enabled	RW	0x0
17	GAP_RESTART	<u>Restart a transaction which was stopped using the GAP_STOP bit:</u> 0 = ignore 1 = restart	RW	0x0
16	GAP_STOP	<u>Stop the current transaction at the next block gap:</u> 0 = ignore 1 = stop	RW	0x0
15:6		<b>Reserved</b> - Write as 0, read as don't care		
5	HCTL_8BIT	<u>Use 8 data lines:</u> 0 = disabled 1 = enabled	RW	0x0



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4:3		<b>Reserved</b> - Write as 0, read as don't care		
2	HCTL_HS_EN	Select high speed mode (i.e. DAT and CMD lines change on the rising CLK edge): 0 = disabled 1 = enabled	RW	0x0
1	HCTL_DWIDTH	Use 4 data lines: 0 = disabled 1 = enabled	RW	0x0
0		<b>Reserved</b> - Write as 0, read as don't care		

## CONTROL1 Register

**Synopsis** This register is used to configure the EMMC module.  
 For the exact details please refer to the Arasan documentation SD3.0\_Host\_AHB\_eMMC4.4\_Usersguide\_ver5.9\_jan11\_10.pdf. Bits marked as reserved in this document but not by the Arasan documentation refer to functionality which has been disabled due to the changes listed in the previous chapter.  
 CLK\_STABLE seems contrary to its name only to indicate that there was a rising edge on the clk\_emmc input but not that the frequency of this clock is actually stable.

Bit(s)	Field Name	Description	Type	Reset
31:27		<b>Reserved</b> - Write as 0, read as don't care		
26	SRST_DATA	Reset the data handling circuit: 0 = disabled 1 = enabled	RW	0x0
25	SRST_CMD	Reset the command handling circuit: 0 = disabled 1 = enabled	RW	0x0
24	SRST_HC	Reset the complete host circuit: 0 = disabled 1 = enabled	RW	0x0
23:20		<b>Reserved</b> - Write as 0, read as don't care		
19:16	DATA_TOUNIT	Data timeout unit exponent: 1111 = disabled $x = TMCLK * 2^{(x+13)}$	RW	0x0
15:8	CLK_FREQ8	SD clock base divider LSBs	RW	0x0



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7:6	CLK_FREQ_MS2	<u>SD clock base divider MSBs</u>	RW	0x0
5	CLK_GENSEL	<u>Mode of clock generation:</u> 0 = divided 1 = programmable	RW	0x0
4:3		<b>Reserved</b> - Write as 0, read as don't care		
2	CLK_EN	<u>SD clock enable:</u> 0 = disabled 1 = enabled	RW	0x0
1	CLK_STABLE	<u>SD clock stable:</u> 0 = no 1 = yes	RO	0x0
0	CLK_INTLEN	<u>Clock enable for internal EMMC clocks for power saving:</u> 0 = disabled 1 = enabled	RW	0x0

## INTERRUPT Register

**Synopsis** This register holds the interrupt flags. Each flag can be disabled using the according bit in the IRPT\_MASK register.  
 For the exact details please refer to the Arasan documentation SD3.0\_Host\_AHB\_eMMC4.4\_Usersguide\_ver5.9\_jan11\_10.pdf. Bits marked as reserved in this document but not by the Arasan documentation refer to functionality which has been disabled due to the changes listed in the previous chapter.  
 ERR is a generic flag and is set if any of the enabled error flags is set.

Bit(s)	Field Name	Description	Type	Reset
31:25		<b>Reserved</b> - Write as 0, read as don't care		
24	ACMD_ERR	<u>Auto command error:</u> 0 = no error 1 = error	RW	0x0
23		<b>Reserved</b> - Write as 0, read as don't care		
22	DEND_ERR	<u>End bit on data line not 1:</u> 0 = no error 1 = error	RW	0x0



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21	DCRC_ERR	<u>Data CRC error:</u> 0 = no error 1 = error	RW	0x0
20	DTO_ERR	<u>Timeout on data line:</u> 0 = no error 1 = error	RW	0x0
19	CBAD_ERR	<u>Incorrect command index in response:</u> 0 = no error 1 = error	RW	0x0
18	CEND_ERR	<u>End bit on command line not 1:</u> 0 = no error 1 = error	RW	0x0
17	CCRC_ERR	<u>Command CRC error:</u> 0 = no error 1 = error	RW	0x0
16	CTO_ERR	<u>Timeout on command line:</u> 0 = no error 1 = error	RW	0x0
15	ERR	<u>An error has occurred:</u> 0 = no error 1 = error	RO	0x0
14	ENDBOOT	<u>Boot operation has terminated:</u> 0 = no 1 = yes	RW	0x0
13	BOOTACK	<u>Boot acknowledge has been received:</u> 0 = no 1 = yes	RW	0x0
12	RETUNE	<u>Clock retune request was made:</u> 0 = no 1 = yes	RO	0x0
11:9		<b>Reserved</b> - Write as 0, read as don't care		
8	CARD	<u>Card made interrupt request:</u> 0 = no 1 = yes	RO	0x0
7:6		<b>Reserved</b> - Write as 0, read as don't care		



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5	READ_RDY	<u>DATA register contains data to be read:</u> 0 = no 1 = yes	RW	0x0
4	WRITE_RDY	<u>Data can be written to DATA register:</u> 0 = no 1 = yes	RW	0x0
3		<b>Reserved</b> - Write as 0, read as don't care		
2	BLOCK_GAP	<u>Data transfer has stopped at block gap:</u> 0 = no 1 = yes	RW	0x0
1	DATA_DONE	<u>Data transfer has finished:</u> 0 = no 1 = yes	RW	0x0
0	CMD_DONE	<u>Command has finished:</u> 0 = no 1 = yes	RW	0x0

## IRPT\_MASK Register

**Synopsis** This register is used to mask the interrupt flags in the INTERRUPT register. For the exact details please refer to the Arasan documentation SD3.0\_Host\_AHB\_eMMC4.4\_Usersguide\_ver5.9\_jan11\_10.pdf. Bits marked as reserved in this document but not by the Arasan documentation refer to functionality which has been disabled due to the changes listed in the previous chapter.

Bit(s)	Field Name	Description	Type	Reset
31:25		<b>Reserved</b> - Write as 0, read as don't care		
24	ACMD_ERR	<u>Set flag if auto command error:</u> 0 = no 1 = yes	RW	0x0
23		<b>Reserved</b> - Write as 0, read as don't care		
22	DEND_ERR	<u>Set flag if end bit on data line not 1:</u> 0 = no 1 = yes	RW	0x0



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21	DCRC_ERR	<u>Set flag if data CRC error:</u> 0 = no 1 = yes	RW	0x0
20	DTO_ERR	<u>Set flag if timeout on data line:</u> 0 = no 1 = yes	RW	0x0
19	CBAD_ERR	<u>Set flag if incorrect command index in response:</u> 0 = no 1 = yes	RW	0x0
18	CEND_ERR	<u>Set flag if end bit on command line not 1:</u> 0 = no 1 = yes	RW	0x0
17	CCRC_ERR	<u>Set flag if command CRC error:</u> 0 = no 1 = yes	RW	0x0
16	CTO_ERR	<u>Set flag if timeout on command line:</u> 0 = no 1 = yes	RW	0x0
15		<b>Reserved</b> - Write as 0, read as don't care		
14	ENDBOOT	<u>Set flag if boot operation has terminated:</u> 0 = no 1 = yes	RW	0x0
13	BOOTACK	<u>Set flag if boot acknowledge has been received:</u> 0 = no 1 = yes	RW	0x0
12	RETUNE	<u>Set flag if clock retune request was made:</u> 0 = no 1 = yes	RW	0x0
11:9		<b>Reserved</b> - Write as 0, read as don't care		
8	CARD	<u>Set flag if card made interrupt request:</u> 0 = no 1 = yes	RW	0x0
7:6		<b>Reserved</b> - Write as 0, read as don't care		
5	READ_RDY	<u>Set flag if DATA register contains data to be read:</u> 0 = no 1 = yes	RW	0x0



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4	WRITE_RDY	<u>Set flag if data can be written to DATA register:</u> 0 = no 1 = yes	RW	0x0
3		<b>Reserved</b> - Write as 0, read as don't care		
2	BLOCK_GAP	<u>Set flag if data transfer has stopped at block gap:</u> 0 = no 1 = yes	RW	0x0
1	DATA_DONE	<u>Set flag if data transfer has finished:</u> 0 = no 1 = yes	RW	0x0
0	CMD_DONE	<u>Set flag if command has finished:</u> 0 = no 1 = yes	RW	0x0

## IRPT\_EN Register

**Synopsis** This register is used to enable the different interrupts in the INTERRUPT register to generate an interrupt on the int\_to\_arm output. For the exact details please refer to the Arasan documentation SD3.0\_Host\_AHB\_eMMC4.4\_Usersguide\_ver5.9\_jan11\_10.pdf. Bits marked as reserved in this document but not by the Arasan documentation refer to functionality which has been disabled due to the changes listed in the previous chapter.

Bit(s)	Field Name	Description	Type	Reset
31:25		<b>Reserved</b> - Write as 0, read as don't care		
24	ACMD_ERR	<u>Create interrupt if auto command error:</u> 0 = no 1 = yes	RW	0x0
23		<b>Reserved</b> - Write as 0, read as don't care		
22	DEND_ERR	<u>Create interrupt if end bit on data line not 1:</u> 0 = no 1 = yes	RW	0x0
21	DCRC_ERR	<u>Create interrupt if data CRC error:</u> 0 = no 1 = yes	RW	0x0



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20	DTO_ERR	<u>Create interrupt if timeout on data line:</u> 0 = no 1 = yes	RW	0x0
19	CBAD_ERR	<u>Create interrupt if incorrect command index in response:</u> 0 = no 1 = yes	RW	0x0
18	CEND_ERR	<u>Create interrupt if end bit on command line not 1:</u> 0 = no 1 = yes	RW	0x0
17	CCRC_ERR	<u>Create interrupt if command CRC error:</u> 0 = no 1 = yes	RW	0x0
16	CTO_ERR	<u>Create interrupt if timeout on command line:</u> 0 = no 1 = yes	RW	0x0
15		<b>Reserved</b> - Write as 0, read as don't care		
14	ENDBOOT	<u>Create interrupt if boot operation has terminated:</u> 0 = no 1 = yes	RW	0x0
13	BOOTACK	<u>Create interrupt if boot acknowledge has been received:</u> 0 = no 1 = yes	RW	0x0
12	RETUNE	<u>Create interrupt if clock retune request was made:</u> 0 = no 1 = yes	RW	0x0
11:9		<b>Reserved</b> - Write as 0, read as don't care		
8	CARD	<u>Create interrupt if card made interrupt request:</u> 0 = no 1 = yes	RW	0x0
7:6		<b>Reserved</b> - Write as 0, read as don't care		
5	READ_RDY	<u>Create interrupt if DATA register contains data to be read:</u> 0 = no 1 = yes	RW	0x0





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4	WRITE_RDY	Create interrupt if data can be written to DATA register: 0 = no 1 = yes	RW	0x0
3		<b>Reserved</b> - Write as 0, read as don't care		
2	BLOCK_GAP	Create interrupt if data transfer has stopped at block gap: 0 = no 1 = yes	RW	0x0
1	DATA_DONE	Create interrupt if data transfer has finished: 0 = no 1 = yes	RW	0x0
0	CMD_DONE	Create interrupt if command has finished: 0 = no 1 = yes	RW	0x0

## CONTROL2 Register

**Synopsis** This register is used to enable the different interrupts in the INTERRUPT register to generate an interrupt on the int\_to\_arm output. For the exact details please refer to the Arasan documentation SD3.0\_Host\_AHB\_eMMC4.4\_Usersguide\_ver5.9\_jan11\_10.pdf. Bits marked as reserved in this document but not by the Arasan documentation refer to functionality which has been disabled due to the changes listed in the previous chapter.

Bit(s)	Field Name	Description	Type	Reset
31:24		<b>Reserved</b> - Write as 0, read as don't care		
23	TUNED	Tuned clock is used for sampling data: 0 = no 1 = yes	RW	0x0
22	TUNEON	Start tuning the SD clock: 0 = not tuned or tuning complete 1 = tuning	RW	0x0
21:19		<b>Reserved</b> - Write as 0, read as don't care		



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18:16	UHSMODE	Select the speed mode of the SD card: 000 = SDR12 001 = SDR25 010 = SDR50 011 = SDR104 100 = DDR50 other = reserved	RW	0x0
15:8		<b>Reserved</b> - Write as 0, read as don't care		
7	NOTC12_ERR	<u>Error occurred during auto command CMD12 execution:</u> 0 = no error 1 = error	RO	0x0
6:5		<b>Reserved</b> - Write as 0, read as don't care		
4	ACBAD_ERR	<u>Command index error occurred during auto command execution:</u> 0 = no error 1 = error	RO	0x0
3	ACEND_ERR	<u>End bit is not 1 during auto command execution:</u> 0 = no error 1 = error	RO	0x0
2	ACCRC_ERR	<u>Command CRC error occurred during auto command execution:</u> 0 = no error 1 = error	RO	0x0
1	ACTO_ERR	<u>Timeout occurred during auto command execution:</u> 0 = no error 1 = error	RO	0x0
0	ACNOX_ERR	<u>Auto command not executed due to an error:</u> 0 = no 1 = yes	RO	0x0

## FORCE\_IRPT Register

**Synopsis** This register is used to fake the different interrupt events for debugging. For the exact details please refer to the Arasan documentation SD3.0\_Host\_AHB\_eMMC4.4\_Usersguide\_ver5.9\_jan11\_10.pdf. Bits marked as reserved in this document but not by the Arasan documentation refer to functionality which has been disabled due to the changes listed in the previous chapter.



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Bit(s)	Field Name	Description	Type	Reset
31:25		<b>Reserved</b> - Write as 0, read as don't care		
24	ACMD_ERR	<u>Create auto command error:</u> 0 = no 1 = yes	RW	0x0
23		<b>Reserved</b> - Write as 0, read as don't care		
22	DEND_ERR	<u>Create end bit on data line not 1:</u> 0 = no 1 = yes	RW	0x0
21	DCRC_ERR	<u>Create data CRC error:</u> 0 = no 1 = yes	RW	0x0
20	DTO_ERR	<u>Create timeout on data line:</u> 0 = no 1 = yes	RW	0x0
19	CBAD_ERR	<u>Create incorrect command index in response:</u> 0 = no 1 = yes	RW	0x0
18	CEND_ERR	<u>Create end bit on command line not 1:</u> 0 = no 1 = yes	RW	0x0
17	CCRC_ERR	<u>Create command CRC error:</u> 0 = no 1 = yes	RW	0x0
16	CTO_ERR	<u>Create timeout on command line:</u> 0 = no 1 = yes	RW	0x0
15		<b>Reserved</b> - Write as 0, read as don't care		
14	ENDBOOT	<u>Create boot operation has terminated:</u> 0 = no 1 = yes	RW	0x0
13	BOOTACK	<u>Create boot acknowledge has been received:</u> 0 = no 1 = yes	RW	0x0



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12	RETUNE	<u>Create clock retune request was made:</u> 0 = no 1 = yes	RW	0x0
11:9		<b>Reserved</b> - Write as 0, read as don't care		
8	CARD	<u>Create card made interrupt request:</u> 0 = no 1 = yes	RW	0x0
7:6		<b>Reserved</b> - Write as 0, read as don't care		
5	READ_RDY	<u>Create DATA register contains data to be read:</u> 0 = no 1 = yes	RW	0x0
4	WRITE_RDY	<u>Create data can be written to DATA register:</u> 0 = no 1 = yes	RW	0x0
3		<b>Reserved</b> - Write as 0, read as don't care		
2	BLOCK_GAP	<u>Create interrupt if data transfer has stopped at block gap:</u> 0 = no 1 = yes	RW	0x0
1	DATA_DONE	<u>Create data transfer has finished:</u> 0 = no 1 = yes	RW	0x0
0	CMD_DONE	<u>Create command has finished:</u> 0 = no 1 = yes	RW	0x0

## BOOT\_TIMEOUT Register

**Synopsis** This register configures after how many card clock cycles a timeout for e.MMC cards in boot mode is flagged

Bit(s)	Field Name	Description	Type	Reset
31:0	TIMEOUT	<u>Number of card clock cycles after which a timeout during boot mode is flagged</u>	RW	0x0



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## DBG\_SEL Register

**Synopsis** This register selects which submodules are accessed by the debug bus. For the exact details please refer to the Arasan documentation SD3.0\_Host\_AHB\_eMMC4.4\_Usersguide\_ver5.9\_jan11\_10.pdf. Bits marked as reserved in this document but not by the Arasan documentation refer to functionality which has been disabled due to the changes listed in the previous chapter.

Bit(s)	Field Name	Description	Type	Reset
31:1		<i>Reserved - Write as 0, read as don't care</i>		
0	SELECT	Submodules accessed by debug bus: 0 = receiver and fifo_ctrl 1 = others	RW	0x0

## EXRDFIFO\_CFG Register

**Synopsis** This register allows fine tuning the dma\_req generation for paced DMA transfers when reading from the card. If the extension data FIFO contains less than RD\_THRSH 32 bits words dma\_req becomes inactive until the card has filled the extension data FIFO above threshold. This compensates the DMA latency. When writing data to the card the extension data FIFO feeds into the EMMC module s FIFO and no fine tuning is required Therefore the RD\_THRSH value is in this case ignored.

Bit(s)	Field Name	Description	Type	Reset
31:3		<i>Reserved - Write as 0, read as don't care</i>		
2:0	RD_THRSH	<u>Read threshold in 32 bits words</u>	RW	0x0

## EXRDFIFO\_EN Register

**Synopsis** This register enables the extension data register. It should be enabled for paced DMA transfers and be bypassed for burst DMA transfers.

Bit(s)	Field Name	Description	Type	Reset
31:1		<i>Reserved - Write as 0, read as don't care</i>		



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0	ENABLE	Enable the extension FIFO: 0 = bypass 1 = enabled	RW	0x0
---	--------	---	----	-----

## TUNE\_STEP Register

**Synopsis** This register is used to delay the card clock when sampling the returning data and command response from the card.  
DELAY determines by how much the sampling clock is delayed per step.

Bit(s)	Field Name	Description	Type	Reset
31:3		<i>Reserved - Write as 0, read as don't care</i>		
2:0	DELAY	Sampling clock delay per step: 000 = 200ps typically 001 = 400ps typically 010 = 400ps typically 011 = 600ps typically 100 = 700ps typically 101 = 900ps typically 110 = 900ps typically 111 = 1100ps typically	RW	0x0

## TUNE\_STEPS\_STD Register

**Synopsis** This register is used to delay the card clock when sampling the returning data and command response from the card. It determines by how many steps the sampling clock is delayed in SDR mode.

Bit(s)	Field Name	Description	Type	Reset
31:6		<i>Reserved - Write as 0, read as don't care</i>		
5:0	STEPS	Number of steps (0 to 40)	RW	0x0

## TUNE\_STEPS\_DDR Register



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**Synopsis** This register is used to delay the card clock when sampling the returning data and command response from the card. It determines by how many steps the sampling clock is delayed in DDR mode.

Bit(s)	Field Name	Description	Type	Reset
31:6		<i>Reserved - Write as 0, read as don't care</i>		
5:0	STEPS	<u>Number of steps (0 to 40)</u>	RW	0x0

## SPI\_INT\_SPT Register

**Synopsis** This register controls whether assertion of interrupts in SPI mode is possible independent of the card select line.  
 For the exact details please refer to the Arasan documentation SD3.0\_Host\_AHB\_eMMC4.4\_Usersguide\_ver5.9\_jan11\_10.pdf. Bit marked as reserved in this document but not by the Arasan documentation refer to functionality which has been disabled due to the changes listed in the previous chapter.

Bit(s)	Field Name	Description	Type	Reset
31:8		<i>Reserved - Write as 0, read as don't care</i>		
7:0	SELECT	<u>Interrupt independent of card select line:</u> 0 = no 1 = yes	RW	0x0

## SLOTISR\_VER Register

**Synopsis** This register contains the version information and slot interrupt status.  
 For the exact details please refer to the Arasan documentation SD3.0\_Host\_AHB\_eMMC4.4\_Usersguide\_ver5.9\_jan11\_10.pdf. Bit marked as reserved in this document but not by the Arasan documentation refer to functionality which has been disabled due to the changes listed in the previous chapter.

Bit(s)	Field Name	Description	Type	Reset
31:24	VENDOR	<u>Vendor Version Number</u>	RW	0x0
23:16	SDVERSION	<u>Host Controller specification version</u>	RW	0x0



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15:8		<i>Reserved - Write as 0, read as don't care</i>		
7:0	SLOT_STATUS	<u>Logical OR of interrupt and wakeup signal for each slot</u>	RW	0x0



## 6 General Purpose I/O (GPIO)

There are 54 general-purpose I/O (GPIO) lines split into two banks. All GPIO pins have at least two alternative functions within BCM. The alternate functions are usually peripheral IO and a single peripheral may appear in each bank to allow flexibility on the choice of IO voltage. Details of alternative functions are given in section 6.2. Alternative Function Assignments.

The block diagram for an individual GPIO pin is given below :

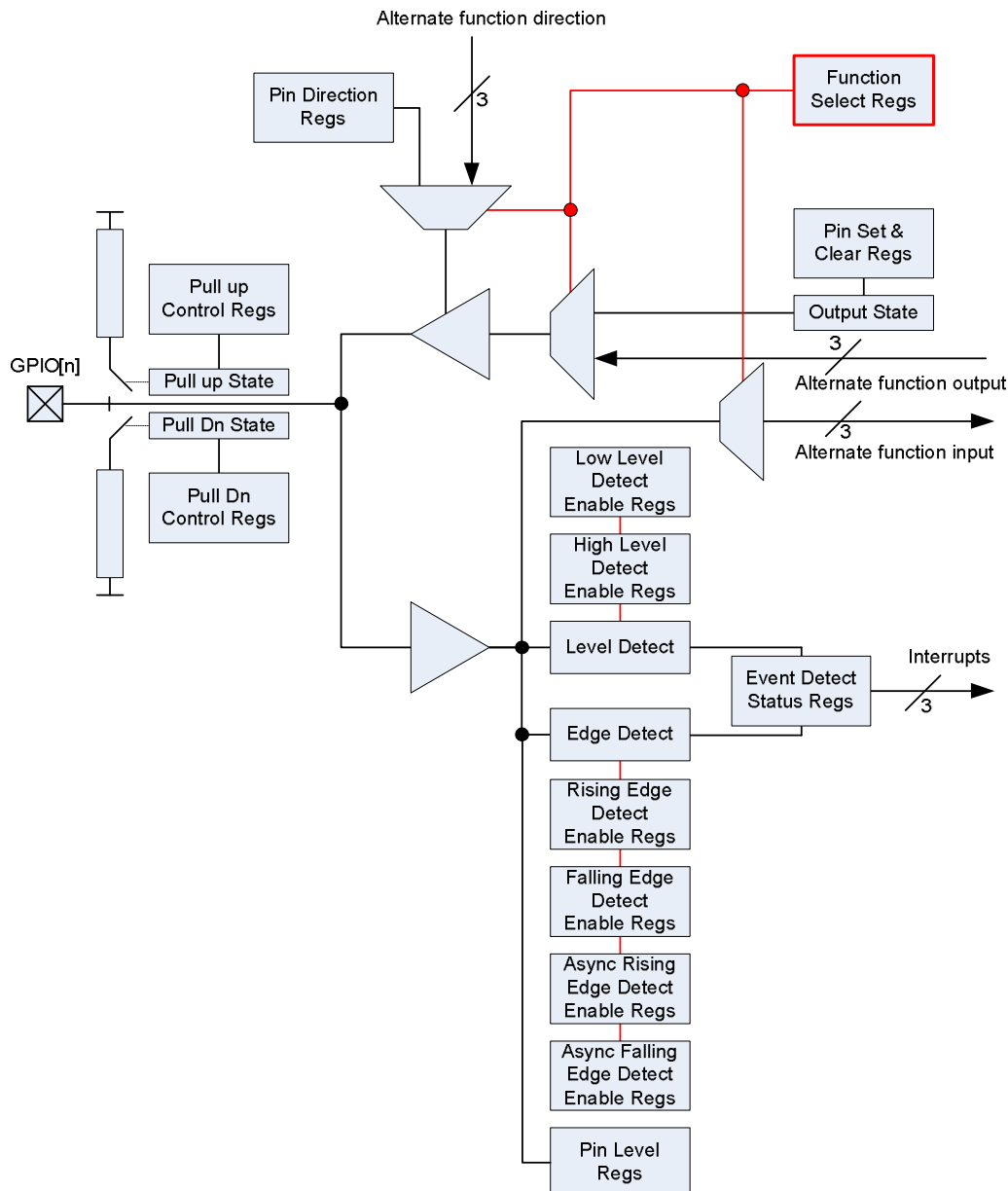


Figure 6-1 GPIO Block Diagram



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The GPIO peripheral has three dedicated interrupt lines. These lines are triggered by the setting of bits in the event detect status register. Each bank has its' own interrupt line with the third line shared between all bits.

The Alternate function table also has the pull state (pull-up/pull-down) which is applied after a power down.

## 6.1 Register View

The GPIO has 41 registers. All accesses are assumed to be 32-bit.

Address	Field Name	Description	Size	Read/Write
0x 7E20 0000	GPFSEL0	GPIO Function Select 0	32	R/W
0x 7E20 0000	GPFSEL0	GPIO Function Select 0	32	R/W
0x 7E20 0004	GPFSEL1	GPIO Function Select 1	32	R/W
0x 7E20 0008	GPFSEL2	GPIO Function Select 2	32	R/W
0x 7E20 000C	GPFSEL3	GPIO Function Select 3	32	R/W
0x 7E20 0010	GPFSEL4	GPIO Function Select 4	32	R/W
0x 7E20 0014	GPFSEL5	GPIO Function Select 5	32	R/W
0x 7E20 0018	-	Reserved	-	-
0x 7E20 001C	GPSET0	GPIO Pin Output Set 0	32	W
0x 7E20 0020	GPSET1	GPIO Pin Output Set 1	32	W
0x 7E20 0024	-	Reserved	-	-
0x 7E20 0028	GPCLR0	GPIO Pin Output Clear 0	32	W
0x 7E20 002C	GPCLR1	GPIO Pin Output Clear 1	32	W
0x 7E20 0030	-	Reserved	-	-
0x 7E20 0034	GPLEV0	GPIO Pin Level 0	32	R
0x 7E20 0038	GPLEV1	GPIO Pin Level 1	32	R
0x 7E20 003C	-	Reserved	-	-
0x 7E20 0040	GPEDS0	GPIO Pin Event Detect Status 0	32	R/W
0x 7E20 0044	GPEDS1	GPIO Pin Event Detect Status 1	32	R/W
0x 7E20 0048	-	Reserved	-	-
0x 7E20 004C	GPREN0	GPIO Pin Rising Edge Detect Enable 0	32	R/W
0x 7E20 0050	GPREN1	GPIO Pin Rising Edge Detect Enable 1	32	R/W
0x 7E20 0054	-	Reserved	-	-
0x 7E20 0058	GPFEN0	GPIO Pin Falling Edge Detect Enable 0	32	R/W
0x 7E20 005C	GPFEN1	GPIO Pin Falling Edge Detect Enable 1	32	R/W



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Address	Field Name	Description	Size	Read/Write
0x 7E20 0060	-	Reserved	-	-
0x 7E20 0064	GPHEN0	GPIO Pin High Detect Enable 0	32	R/W
0x 7E20 0068	GPHEN1	GPIO Pin High Detect Enable 1	32	R/W
0x 7E20 006C	-	Reserved	-	-
0x 7E20 0070	GPLEN0	GPIO Pin Low Detect Enable 0	32	R/W
0x 7E20 0074	GPLEN1	GPIO Pin Low Detect Enable 1	32	R/W
0x 7E20 0078	-	Reserved	-	-
0x 7E20 007C	GPAREN0	GPIO Pin Async. Rising Edge Detect 0	32	R/W
0x 7E20 0080	GPAREN1	GPIO Pin Async. Rising Edge Detect 1	32	R/W
0x 7E20 0084	-	Reserved	-	-
0x 7E20 0088	GPAFEN0	GPIO Pin Async. Falling Edge Detect 0	32	R/W
0x 7E20 008C	GPAFEN1	GPIO Pin Async. Falling Edge Detect 1	32	R/W
0x 7E20 0090	-	Reserved	-	-
0x 7E20 0094	GPPUD	GPIO Pin Pull-up/down Enable	32	R/W
0x 7E20 0098	GPPUDCLK0	GPIO Pin Pull-up/down Enable Clock 0	32	R/W
0x 7E20 009C	GPPUDCLK1	GPIO Pin Pull-up/down Enable Clock 1	32	R/W
0x 7E20 00A0	-	Reserved	-	-
0x 7E20 00B0	-	Test	4	R/W

**Table 6-1 GPIO Register Assignment**

## GPIO Function Select Registers (GPFSELn)

**SYNOPSIS** The function select registers are used to define the operation of the general-purpose I/O pins. Each of the 54 GPIO pins has at least two alternative functions as defined in section 16.2. The FSEL{n} field determines the functionality of the nth GPIO pin. All unused alternative function lines are tied to ground and will output a "0" if selected. All pins reset to normal GPIO input operation.

Bit(s)	Field Name	Description	Type	Reset
31-30	---	Reserved	R	0



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29-27	FSEL9	FSEL9 - Function Select 9 000 = GPIO Pin 9 is an input 001 = GPIO Pin 9 is an output 100 = GPIO Pin 9 takes alternate function 0 101 = GPIO Pin 9 takes alternate function 1 110 = GPIO Pin 9 takes alternate function 2 111 = GPIO Pin 9 takes alternate function 3 011 = GPIO Pin 9 takes alternate function 4 010 = GPIO Pin 9 takes alternate function 5	R/W	0
26-24	FSEL8	FSEL8 - Function Select 8	R/W	0
23-21	FSEL7	FSEL7 - Function Select 7	R/W	0
20-18	FSEL6	FSEL6 - Function Select 6	R/W	0
17-15	FSEL5	FSEL5 - Function Select 5	R/W	0
14-12	FSEL4	FSEL4 - Function Select 4	R/W	0
11-9	FSEL3	FSEL3 - Function Select 3	R/W	0
8-6	FSEL2	FSEL2 - Function Select 2	R/W	0
5-3	FSEL1	FSEL1 - Function Select 1	R/W	0
2-0	FSEL0	FSEL0 - Function Select 0	R/W	0

**Table 6-2 – GPIO Alternate function select register 0**

Bit(s)	Field Name	Description	Type	Reset
31-30	---	Reserved	R	0
29-27	FSEL19	FSEL19 - Function Select 19 000 = GPIO Pin 19 is an input 001 = GPIO Pin 19 is an output 100 = GPIO Pin 19 takes alternate function 0 101 = GPIO Pin 19 takes alternate function 1 110 = GPIO Pin 19 takes alternate function 2 111 = GPIO Pin 19 takes alternate function 3 011 = GPIO Pin 19 takes alternate function 4 010 = GPIO Pin 19 takes alternate function 5	R/W	0
26-24	FSEL18	FSEL18 - Function Select 18	R/W	0
23-21	FSEL17	FSEL17 - Function Select 17	R/W	0
20-18	FSEL16	FSEL16 - Function Select 16	R/W	0
17-15	FSEL15	FSEL15 - Function Select 15	R/W	0
14-12	FSEL14	FSEL14 - Function Select 14	R/W	0
11-9	FSEL13	FSEL13 - Function Select 13	R/W	0
8-6	FSEL12	FSEL12 - Function Select 12	R/W	0
5-3	FSEL11	FSEL11 - Function Select 11	R/W	0
2-0	FSEL10	FSEL10 - Function Select 10	R/W	0

**Table 6-3 – GPIO Alternate function select register 1**



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Bit(s)	Field Name	Description	Type	Reset
31-30	---	Reserved	R	0
29-27	FSEL29	<u>FSEL29 - Function Select 29</u> 000 = GPIO Pin 29 is an input 001 = GPIO Pin 29 is an output 100 = GPIO Pin 29 takes alternate function 0 101 = GPIO Pin 29 takes alternate function 1 110 = GPIO Pin 29 takes alternate function 2 111 = GPIO Pin 29 takes alternate function 3 011 = GPIO Pin 29 takes alternate function 4 010 = GPIO Pin 29 takes alternate function 5	R/W	0
26-24	FSEL28	FSEL28 - Function Select 28	R/W	0
23-21	FSEL27	FSEL27 - Function Select 27	R/W	0
20-18	FSEL26	FSEL26 - Function Select 26	R/W	0
17-15	FSEL25	FSEL25 - Function Select 25	R/W	0
14-12	FSEL24	FSEL24 - Function Select 24	R/W	0
11-9	FSEL23	FSEL23 - Function Select 23	R/W	0
8-6	FSEL22	FSEL22 - Function Select 22	R/W	0
5-3	FSEL21	FSEL21 - Function Select 21	R/W	0
2-0	FSEL20	FSEL20 - Function Select 20	R/W	0

**Table 6-4 – GPIO Alternate function select register 2**

Bit(s)	Field Name	Description	Type	Reset
31-30	---	Reserved	R	0
29-27	FSEL39	<u>FSEL39 - Function Select 39</u> 000 = GPIO Pin 39 is an input 001 = GPIO Pin 39 is an output 100 = GPIO Pin 39 takes alternate function 0 101 = GPIO Pin 39 takes alternate function 1 110 = GPIO Pin 39 takes alternate function 2 111 = GPIO Pin 39 takes alternate function 3 011 = GPIO Pin 39 takes alternate function 4 010 = GPIO Pin 39 takes alternate function 5	R/W	0
26-24	FSEL38	FSEL38 - Function Select 38	R/W	0
23-21	FSEL37	FSEL37 - Function Select 37	R/W	0
20-18	FSEL36	FSEL36 - Function Select 36	R/W	0
17-15	FSEL35	FSEL35 - Function Select 35	R/W	0
14-12	FSEL34	FSEL34 - Function Select 34	R/W	0
11-9	FSEL33	FSEL33 - Function Select 33	R/W	0
8-6	FSEL32	FSEL32 - Function Select 32	R/W	0



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5-3	FSEL31	FSEL31 - Function Select 31	R/W	0
2-0	FSEL30	FSEL30 - Function Select 30	R/W	0

**Table 6-5 – GPIO Alternate function select register 3**

Bit(s)	Field Name	Description	Type	Reset
31-30	---	Reserved	R	0
29-27	FSEL49	<u>FSEL49 - Function Select 49</u> 000 = GPIO Pin 49 is an input 001 = GPIO Pin 49 is an output 100 = GPIO Pin 49 takes alternate function 0 101 = GPIO Pin 49 takes alternate function 1 110 = GPIO Pin 49 takes alternate function 2 111 = GPIO Pin 49 takes alternate function 3 011 = GPIO Pin 49 takes alternate function 4 010 = GPIO Pin 49 takes alternate function 5	R/W	0
26-24	FSEL48	FSEL48 - Function Select 48	R/W	0
23-21	FSEL47	FSEL47 - Function Select 47	R/W	0
20-18	FSEL46	FSEL46 - Function Select 46	R/W	0
17-15	FSEL45	FSEL45 - Function Select 45	R/W	0
14-12	FSEL44	FSEL44 - Function Select 44	R/W	0
11-9	FSEL43	FSEL43 - Function Select 43	R/W	0
8-6	FSEL42	FSEL42 - Function Select 42	R/W	0
5-3	FSEL41	FSEL41 - Function Select 41	R/W	0
2-0	FSEL40	FSEL40 - Function Select 40	R/W	0

**Table 6-6 – GPIO Alternate function select register 4**

Bit(s)	Field Name	Description	Type	Reset
31-12	---	Reserved	R	0
11-9	FSEL53	<u>FSEL53 - Function Select 53</u> 000 = GPIO Pin 53 is an input 001 = GPIO Pin 53 is an output 100 = GPIO Pin 53 takes alternate function 0 101 = GPIO Pin 53 takes alternate function 1 110 = GPIO Pin 53 takes alternate function 2 111 = GPIO Pin 53 takes alternate function 3 011 = GPIO Pin 53 takes alternate function 4 010 = GPIO Pin 53 takes alternate function 5	R/W	0
8-6	FSEL52	FSEL52 - Function Select 52	R/W	0
5-3	FSEL51	FSEL51 - Function Select 51	R/W	0
2-0	FSEL50	FSEL50 - Function Select 50	R/W	0



Table 6-7 – GPIO Alternate function select register 5

## GPIO Pin Output Set Registers (GPSETn)

**SYNOPSIS** The output set registers are used to set a GPIO pin. The SET{n} field defines the respective GPIO pin to set, writing a “0” to the field has no effect. If the GPIO pin is being used as in input (by default) then the value in the SET{n} field is ignored. However, if the pin is subsequently defined as an output then the bit will be set according to the last set/clear operation. Separating the set and clear functions removes the need for read-modify-write operations

Bit(s)	Field Name	Description	Type	Reset
31-0	SETn (n=0..31)	0 = No effect 1 = Set GPIO pin <i>n</i>	R/W	0

Table 6-8 – GPIO Output Set Register 0

Bit(s)	Field Name	Description	Type	Reset
31-22	-	Reserved	R	0
21-0	SETn (n=32..53)	0 = No effect 1 = Set GPIO pin <i>n</i> .	R/W	0

Table 6-9 – GPIO Output Set Register 1

## GPIO Pin Output Clear Registers (GPCLRn)

**SYNOPSIS** The output clear registers) are used to clear a GPIO pin. The CLR{n} field defines the respective GPIO pin to clear, writing a “0” to the field has no effect. If the GPIO pin is being used as in input (by default) then the value in the CLR{n} field is ignored. However, if the pin is subsequently defined as an output then the bit will be set according to the last set/clear operation. Separating the set and clear functions removes the need for read-modify-write operations.

Bit(s)	Field Name	Description	Type	Reset
31-0	CLRn (n=0..31)	0 = No effect 1 = Clear GPIO pin <i>n</i>	R/W	0

Table 6-10 – GPIO Output Clear Register 0

Bit(s)	Field Name	Description	Type	Reset
31-22	-	Reserved	R	0



21-0	CLR <sub>n</sub> (n=32..53)	0 = No effect 1 = Set GPIO pin <i>n</i>	R/W	0
------	--------------------------------	--	-----	---

**Table 6-11 – GPIO Output Clear Register 1**

## GPIO Pin Level Registers (GPLEV<sub>n</sub>)

**SYNOPSIS** The pin level registers return the actual value of the pin. The LEV{*n*} field gives the value of the respective GPIO pin.

Bit(s)	Field Name	Description	Type	Reset
31-0	LEV <sub>n</sub> (n=0..31)	0 = GPIO pin <i>n</i> is low 1 = GPIO pin <i>n</i> is high	R/W	0

**Table 6-12 – GPIO Level Register 0**

Bit(s)	Field Name	Description	Type	Reset
31-22	-	Reserved	R	0
21-0	LEV <sub>n</sub> (n=32..53)	0 = GPIO pin <i>n</i> is low 1 = GPIO pin <i>n</i> is high	R/W	0

**Table 6-13 – GPIO Level Register 1**

## GPIO Event Detect Status Registers (GPEDS<sub>n</sub>)

**SYNOPSIS** The event detect status registers are used to record level and edge events on the GPIO pins. The relevant bit in the event detect status registers is set whenever: 1) an edge is detected that matches the type of edge programmed in the rising/falling edge detect enable registers, or 2) a level is detected that matches the type of level programmed in the high/low level detect enable registers. The bit is cleared by writing a “1” to the relevant bit.

The interrupt controller can be programmed to interrupt the processor when any of the status bits are set. The GPIO peripheral has three dedicated interrupt lines. Each GPIO bank can generate an independent interrupt. The third line generates a single interrupt whenever any bit is set.

Bit(s)	Field Name	Description	Type	Reset
31-0	EDS <sub>n</sub> (n=0..31)	0 = Event not detected on GPIO pin <i>n</i> 1 = Event detected on GPIO pin <i>n</i>	R/W	0

**Table 6-14 – GPIO Event Detect Status Register 0**





Bit(s)	Field Name	Description	Type	Reset
31-22	-	Reserved	R	0
21-0	EDSn (n=32..53)	0 = Event not detected on GPIO pin <i>n</i> 1 = Event detected on GPIO pin <i>n</i>	R/W	0

**Table 6-15 – GPIO Event Detect Status Register 1**

## GPIO Rising Edge Detect Enable Registers (GPRENn)

**SYNOPSIS** The rising edge detect enable registers define the pins for which a rising edge transition sets a bit in the event detect status registers (GPEDSn). When the relevant bits are set in both the GPRENn and GPFENn registers, any transition (1 to 0 and 0 to 1) will set a bit in the GPEDSn registers. The GPRENn registers use synchronous edge detection. This means the input signal is sampled using the system clock and then it is looking for a “011” pattern on the sampled signal. This has the effect of suppressing glitches.

Bit(s)	Field Name	Description	Type	Reset
31-0	RENn (n=0..31)	0 = Rising edge detect disabled on GPIO pin <i>n</i> . 1 = Rising edge on GPIO pin <i>n</i> sets corresponding bit in EDSn.	R/W	0

**Table 6-16 – GPIO Rising Edge Detect Status Register 0**

Bit(s)	Field Name	Description	Type	Reset
31-22	-	Reserved	R	0
21-0	RENn (n=32..53)	0 = Rising edge detect disabled on GPIO pin <i>n</i> . 1 = Rising edge on GPIO pin <i>n</i> sets corresponding bit in EDSn.	R/W	0

**Table 6-17 – GPIO Rising Edge Detect Status Register 1**

## GPIO Falling Edge Detect Enable Registers (GPRENn)

**SYNOPSIS** The falling edge detect enable registers define the pins for which a falling edge transition sets a bit in the event detect status registers (GPEDSn). When the relevant bits are set in both the GPRENn and GPFENn registers, any transition (1 to 0 and 0 to 1) will set a bit in the GPEDSn registers. The GPFENn registers use synchronous edge detection. This means the input signal is sampled using the system clock and then it is looking for a “100” pattern on the sampled signal. This has the effect of suppressing glitches.

Bit(s)	Field Name	Description	Type	Reset
31-0	FENn (n=0..31)	0 = Falling edge detect disabled on GPIO pin <i>n</i> . 1 = Falling edge on GPIO pin <i>n</i> sets corresponding bit in EDSn.	R/W	0

**Table 6-18 – GPIO Falling Edge Detect Status Register 0**

Bit(s)	Field Name	Description	Type	Reset
31-22	-	Reserved	R	0
21-0	FENn (n=32..53)	0 = Falling edge detect disabled on GPIO pin <i>n</i> . 1 = Falling edge on GPIO pin <i>n</i> sets corresponding bit in EDSn.	R/W	0

**Table 6-19 – GPIO Falling Edge Detect Status Register 1**

## GPIO High Detect Enable Registers (GPHENn)

**SYNOPSIS** The high level detect enable registers define the pins for which a high level sets a bit in the event detect status register (GPEDSn). If the pin is still high when an attempt is made to clear the status bit in GPEDSn then the status bit will remain set.

Bit(s)	Field Name	Description	Type	Reset
31-0	HENn (n=0..31)	0 = High detect disabled on GPIO pin <i>n</i> 1 = High on GPIO pin <i>n</i> sets corresponding bit in GPEDS	R/W	0

**Table 6-20 – GPIO High Detect Status Register 0**

Bit(s)	Field Name	Description	Type	Reset
31-22	-	Reserved	R	0
21-0	HENn (n=32..53)	0 = High detect disabled on GPIO pin <i>n</i> 1 = High on GPIO pin <i>n</i> sets corresponding bit in GPEDS	R/W	0

**Table 6-21 – GPIO High Detect Status Register 1**



## GPIO Low Detect Enable Registers (GPLENn)

**SYNOPSIS** The low level detect enable registers define the pins for which a low level sets a bit in the event detect status register (GPEDSn). If the pin is still low when an attempt is made to clear the status bit in GPEDSn then the status bit will remain set.

Bit(s)	Field Name	Description	Type	Reset
31-0	LENn (n=0..31)	0 = Low detect disabled on GPIO pin <i>n</i> 1 = Low on GPIO pin <i>n</i> sets corresponding bit in GPEDS	R/W	0

**Table 6-22 – GPIO Low Detect Status Register 0**

Bit(s)	Field Name	Description	Type	Reset
31-22	-	Reserved	R	0
21-0	LENn (n=32..53)	0 = Low detect disabled on GPIO pin <i>n</i> 1 = Low on GPIO pin <i>n</i> sets corresponding bit in GPEDS	R/W	0

**Table 6-23 – GPIO Low Detect Status Register 1**

## GPIO Asynchronous rising Edge Detect Enable Registers (GPARENn)

**SYNOPSIS** The asynchronous rising edge detect enable registers define the pins for which a asynchronous rising edge transition sets a bit in the event detect status registers (GPEDSn).

Asynchronous means the incoming signal is not sampled by the system clock. As such rising edges of very short duration can be detected.

Bit(s)	Field Name	Description	Type	Reset
31-0	ARENn (n=0..31)	0 = Asynchronous rising edge detect disabled on GPIO pin <i>n</i> . 1 = Asynchronous rising edge on GPIO pin <i>n</i> sets corresponding bit in EDSn.	R/W	0

**Table 6-24 – GPIO Asynchronous rising Edge Detect Status Register 0**

Bit(s)	Field Name	Description	Type	Reset
31-22	-	Reserved	R	0
21-0	ARENn (n=32..53)	0 = Asynchronous rising edge detect disabled on GPIO pin <i>n</i> . 1 = Asynchronous rising edge on GPIO pin <i>n</i> sets corresponding bit in EDSn.	R/W	0



Table 6-25 – GPIO Asynchronous rising Edge Detect Status Register 1

## GPIO Asynchronous Falling Edge Detect Enable Registers (GPAFENn)

**SYNOPSIS** The asynchronous falling edge detect enable registers define the pins for which a asynchronous falling edge transition sets a bit in the event detect status registers (GPEDSn). Asynchronous means the incoming signal is not sampled by the system clock. As such falling edges of very short duration can be detected.

Bit(s)	Field Name	Description	Type	Reset
31-0	AFENn (n=0..31)	0 = Asynchronous falling edge detect disabled on GPIO pin <i>n</i> . 1 = Asynchronous falling edge on GPIO pin <i>n</i> sets corresponding bit in EDSn.	R/W	0

Table 6-26 – GPIO Asynchronous Falling Edge Detect Status Register 0

Bit(s)	Field Name	Description	Type	Reset
31-22	-	Reserved	R	0
21-0	AFENn (n=32..53)	0 = Asynchronous falling edge detect disabled on GPIO pin <i>n</i> . 1 = Asynchronous falling edge on GPIO pin <i>n</i> sets corresponding bit in EDSn.	R/W	0

Table 6-27 – GPIO Asynchronous Falling Edge Detect Status Register 1

## GPIO Pull-up/down Register (GPPUD)

**SYNOPSIS** The GPIO Pull-up/down Register controls the actuation of the internal pull-up/down control line to ALL the GPIO pins. This register must be used in conjunction with the 2 GPPUDCLKn registers.

Note that it is not possible to read back the current Pull-up/down settings and so it is the users' responsibility to 'remember' which pull-up/downs are active. The reason for this is that GPIO pull-ups are maintained even in power-down mode when the core is off, when all register contents is lost.

The Alternate function table also has the pull state which is applied after a power down.

Bit(s)	Field Name	Description	Type	Reset
--------	------------	-------------	------	-------



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31-2	---	Unused	R	0
1-0	PUD	<u>PUD - GPIO Pin Pull-up/down</u> 00 = Off – disable pull-up/down 01 = Enable Pull Down control 10 = Enable Pull Up control 11 = Reserved *Use in conjunction with GPPUDCLK0/1/2	R/W	0

**Table 6-28 – GPIO Pull-up/down Register (GPPUD)**

## GPIO Pull-up/down Clock Registers (GPPUDCLKn)

**SYNOPSIS**

The GPIO Pull-up/down Clock Registers control the actuation of internal pull-downs on the respective GPIO pins. These registers must be used in conjunction with the GPPUD register to effect GPIO Pull-up/down changes. The following sequence of events is required:

1. Write to GPPUD to set the required control signal (i.e. Pull-up or Pull-Down or neither to remove the current Pull-up/down)
2. Wait 150 cycles – this provides the required set-up time for the control signal
3. Write to GPPUDCLK0/1 to clock the control signal into the GPIO pads you wish to modify – NOTE only the pads which receive a clock will be modified, all others will retain their previous state.
4. Wait 150 cycles – this provides the required hold time for the control signal
5. Write to GPPUD to remove the control signal
6. Write to GPPUDCLK0/1 to remove the clock

Bit(s)	Field Name	Description	Type	Reset
(31-0)	PUDCLKn (n=0..31)	0 = No Effect 1 = Assert Clock on line ( <i>n</i> ) *Must be used in conjunction with GPPUD	R/W	0

**Table 6-29 – GPIO Pull-up/down Clock Register 0**

Bit(s)	Field Name	Description	Type	Reset
31-22	-	Reserved	R	0
21-0	PUDCLKn (n=32..53)	0 = No Effect 1 = Assert Clock on line ( <i>n</i> ) *Must be used in conjunction with GPPUD	R/W	0

**Table 6-30 – GPIO Pull-up/down Clock Register 1**



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## 6.2 Alternative Function Assignments

Every GPIO pin can carry an alternate function. Up to 6 alternate function are available but not every pin has that many alternate functions. The table below gives a quick over view.

	Pull	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5
GPIO0	High	SDA0	SA5	<reserved>			
GPIO1	High	SCL0	SA4	<reserved>			
GPIO2	High	SDA1	SA3	<reserved>			
GPIO3	High	SCL1	SA2	<reserved>			
GPIO4	High	GPCLK0	SA1	<reserved>			ARM_TDI
GPIO5	High	GPCLK1	SA0	<reserved>			ARM_TDO
GPIO6	High	GPCLK2	SOE_N / SE	<reserved>			ARM_RTCK
GPIO7	High	SPI0_CE1_N	SWE_N / SBW_N	<reserved>			
GPIO8	High	SPI0_CE0_N	SD0	<reserved>			
GPIO9	Low	SPI0_MISO	SD1	<reserved>			
GPIO10	Low	SPI0_MOSI	SD2	<reserved>			
GPIO11	Low	SPI0_SCLK	SD3	<reserved>			
GPIO12	Low	PWM0	SD4	<reserved>			ARM_TMS
GPIO13	Low	PWM1	SD5	<reserved>			ARM_TCK
GPIO14	Low	TXD0	SD6	<reserved>			TXD1
GPIO15	Low	RXD0	SD7	<reserved>			RXD1
GPIO16	Low	<reserved>	SD8	<reserved>	CTS0	SPI1_CE2_N	CTS1
GPIO17	Low	<reserved>	SD9	<reserved>	RTS0	SPI1_CE1_N	RTS1
GPIO18	Low	PCM_CLK	SD10	<reserved>	BSCSL SDA / MOSI	SPI1_CE0_N	PWM0
GPIO19	Low	PCM_FS	SD11	<reserved>	BSCSL SCL / SCLK	SPI1_MISO	PWM1
GPIO20	Low	PCM_DIN	SD12	<reserved>	BSCSL / MISO	SPI1_MOSI	GPCLK0
GPIO21	Low	PCM_DOUT	SD13	<reserved>	BSCSL / CE_N	SPI1_SCLK	GPCLK1
GPIO22	Low	<reserved>	SD14	<reserved>	SD1_CLK	ARM_TRST	
GPIO23	Low	<reserved>	SD15	<reserved>	SD1_CMD	ARM_RTCK	
GPIO24	Low	<reserved>	SD16	<reserved>	SD1_DAT0	ARM_TDO	
GPIO25	Low	<reserved>	SD17	<reserved>	SD1_DAT1	ARM_TCK	
GPIO26	Low	<reserved>	<reserved>	<reserved>	SD1_DAT2	ARM_TDI	
GPIO27	Low	<reserved>	<reserved>	<reserved>	SD1_DAT3	ARM_TMS	
GPIO28	-	SDA0	SA5	PCM_CLK	<reserved>		
GPIO29	-	SCL0	SA4	PCM_FS	<reserved>		
GPIO30	Low	<reserved>	SA3	PCM_DIN	CTS0		CTS1
GPIO31	Low	<reserved>	SA2	PCM_DOUT	RTS0		RTS1
GPIO32	Low	GPCLK0	SA1	<reserved>	TXD0		TXD1
GPIO33	Low	<reserved>	SA0	<reserved>	RXD0		RXD1
GPIO34	High	GPCLK0	SOE_N / SE	<reserved>	<reserved>		
GPIO35	High	SPI0_CE1_N	SWE_N / SBW_N		<reserved>		
GPIO36	High	SPI0_CE0_N	SD0	TXD0	<reserved>		
GPIO37	Low	SPI0_MISO	SD1	RXD0	<reserved>		
GPIO38	Low	SPI0_MOSI	SD2	RTS0	<reserved>		
GPIO39	Low	SPI0_SCLK	SD3	CTS0	<reserved>		
GPIO40	Low	PWM0	SD4		<reserved>	SPI2_MISO	TXD1
	Pull	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5



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GPIO41	Low	PWM1	SD5	<reserved>	<reserved>	SPI2_MOSI	RXD1
GPIO42	Low	GPCLK1	SD6	<reserved>	<reserved>	SPI2_SCLK	RTS1
GPIO43	Low	GPCLK2	SD7	<reserved>	<reserved>	SPI2_CE0_N	CTS1
GPIO44	-	GPCLK1	SDA0	SDA1	<reserved>	SPI2_CE1_N	
GPIO45	-	PWM1	SCL0	SCL1	<reserved>	SPI2_CE2_N	
GPIO46	High	<Internal>					
GPIO47	High	<Internal>					
GPIO48	High	<Internal>					
GPIO49	High	<Internal>					
GPIO50	High	<Internal>					
GPIO51	High	<Internal>					
GPIO52	High	<Internal>					
GPIO53	High	<Internal>					

**Table 6-31 GPIO Pins Alternative Function Assignment**

Entries which are white should **not** be used. These may have unexpected results as some of these have special functions used in test mode. e.g. they may drive the output with high frequency signals.

Special function legend:

Name	Function	See section
SDA0	BSC <sup>6</sup> master 0 data line	BSC
SCL0	BSC master 0 clock line	BSC
SDA1	BSC master 1 data line	BSC
SCL1	BSC master 1 clock line	BSC
GPCLK0	General purpose Clock 0	<TBD>
GPCLK1	General purpose Clock 1	<TBD>
GPCLK2	General purpose Clock 2	<TBD>
SPI0_CE1_N	SPI0 Chip select 1	SPI
SPI0_CE0_N	SPI0 Chip select 0	SPI
SPI0_MISO	SPI0 MISO	SPI
SPI0_MOSI	SPI0 MOSI	SPI
SPI0_SCLK	SPI0 Serial clock	SPI
PWMx	Pulse Width Modulator 0..1	Pulse Width Modulator
TXD0	UART 0 Transmit Data	UART
RXD0	UART 0 Receive Data	UART
CTS0	UART 0 Clear To Send	UART
RTS0	UART 0 Request To Send	UART
PCM_CLK	PCM clock	PCM Audio
PCM_FS	PCM Frame Sync	PCM Audio
PCM_DIN	PCM Data in	PCM Audio
PCM_DOUT	PCM data out	PCM Audio
SAx	Secondary mem Address bus	Secondary Memory Interface
SOE_N / SE	Secondary mem. Controls	Secondary Memory Interface
SWE_N / SRW_N	Secondary mem. Controls	Secondary Memory Interface
SDx	Secondary mem. data bus	Secondary Memory Interface
BSCSL SDA / MOSI	BSC slave Data, SPI slave MOSI	BSC ISP slave
BSCSL SCL / SCLK	BSC slave Clock, SPI slave clock	BSC ISP slave
BSCSL - / MISO	BSC <not used>, SPI MISO	BSC ISP slave
BSCSL - / CE_N	BSC <not used>, SPI CSn	BSC ISP slave

<sup>6</sup> The Broadcom Serial Control bus is a proprietary bus compliant with the Philips<sup>®</sup> I2C bus/interface



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Name	Function	See section
SPI1_CEx_N	SPI1 Chip select 0-2	Auxiliary I/O
SPI1_MISO	SPI1 MISO	Auxiliary I/O
SPI1_MOSI	SPI1 MOSI	Auxiliary I/O
SPI1_SCLK	SPI1 Serial clock	Auxiliary I/O
TXD0	UART 1 Transmit Data	Auxiliary I/O
RXD0	UART 1 Receive Data	Auxiliary I/O
CTS0	UART 1 Clear To Send	Auxiliary I/O
RTS0	UART 1 Request To Send	Auxiliary I/O
SPI2_CEx_N	SPI2 Chip select 0-2	Auxiliary I/O
SPI2_MISO	SPI2 MISO	Auxiliary I/O
SPI2_MOSI	SPI2 MOSI	Auxiliary I/O
SPI2_SCLK	SPI2 Serial clock	Auxiliary I/O
ARM_TRST	ARM JTAG reset	<TBD>
ARM_RTCK	ARM JTAG return clock	<TBD>
ARM_TDO	ARM JTAG Data out	<TBD>
ARM_TCK	ARM JTAG Clock	<TBD>
ARM_TDI	ARM JTAG Data in	<TBD>
ARM_TMS	ARM JTAG Mode select	<TBD>



## 6.3 General Purpose GPIO Clocks

The General Purpose clocks can be output to GPIO pins. They run from the peripherals clock sources and use clock generators with noise-shaping MASH dividers. These allow the GPIO clocks to be used to drive audio devices.

The fractional divider operates by periodically dropping source clock pulses, therefore the output frequency will periodically switch between:

$$\frac{\text{source\_frequency}}{\text{DIVI}} \quad \& \quad \frac{\text{source\_frequency}}{\text{DIVI} + 1}$$

Jitter is therefore reduced by increasing the source clock frequency. In applications where jitter is a concern, the fastest available clock source should be used.

The General Purpose clocks have MASH noise-shaping dividers which push this fractional divider jitter out of the audio band.

MASH noise-shaping is incorporated to push the fractional divider jitter out of the audio band if required. The MASH can be programmed for 1, 2 or 3-stage filtering. MASH filter, the frequency is spread around the requested frequency and the user must ensure that the module is not exposed to frequencies higher than 25MHz. Also, the MASH filter imposes a low limit on the range of DIVI.

MASH	min DIVI	min output freq	average output freq	max output freq
0 (int divide)	1	source / ( DIVI )	source / ( DIVI )	source / ( DIVI )
1	2	source / ( DIVI )	source / ( DIVI + DIVF / 1024 )	source / ( DIVI + 1 )
2	3	source / ( DIVI - 1 )	source / ( DIVI + DIVF / 1024 )	source / ( DIVI + 2 )
3	5	source / ( DIVI - 3 )	source / ( DIVI + DIVF / 1024 )	source / ( DIVI + 4 )

**Table 6-32 Effect of MASH Filter on Frequency**

The following example illustrates the spreading of output clock frequency resulting from the use of the MASH filter. Note that the spread is greater for lower divisors.

PLL freq (MHz)	target freq (MHz)	MASH	divisor	DIVI	DIVF	min freq (MHz)	ave freq (MHz)	max freq (MHz)	error
650	18.32	0	35.480	35	492	18.57	18.57	18.57	ok
650	18.32	1	35.480	35	492	18.06	18.32	18.57	ok
650	18.32	2	35.480	35	492	17.57	18.32	19.12	ok
650	18.32	3	35.480	35	492	16.67	18.32	20.31	ok
400	18.32	0	21.834	21	854	19.05	19.05	19.05	ok
400	18.32	1	21.834	21	854	18.18	18.32	19.05	ok
400	18.32	2	21.834	21	854	17.39	18.32	20.00	ok
400	18.32	3	21.834	21	854	16.00	18.32	22.22	ok
200	18.32	0	10.917	10	939	20.00	20.00	20.00	ok
200	18.32	1	10.917	10	939	18.18	18.32	20.00	ok
200	18.32	2	10.917	10	939	16.67	18.32	22.22	ok
200	18.32	3	10.917	10	939	14.29	18.32	28.57	error

**Table 6-33 Example of Frequency Spread when using MASH Filtering**

It is beyond the scope of this specification to describe the operation of a MASH filter or to determine under what conditions the available levels of filtering are beneficial.



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### Operating Frequency

The maximum operating frequency of the General Purpose clocks is ~125MHz at 1.2V but this will be reduced if the GPIO pins are heavily loaded or have a capacitive load.



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## Register Definitions

### Clock Manager General Purpose Clocks Control (CM\_GP0CTL, GP1CTL & GP2CTL)

Address 0x 7e10 1070 CM\_GP0CTL  
 0x 7e10 1078 CM\_GP1CTL  
 0x 7e10 1080 CM\_GP2CTL

Bit Number	Field Name	Description	Read/Write	Reset
31-24	PASSWD	Clock Manager password "5a"	W	0
23-11	-	Unused	R	0
10-9	MASH	<u>MASH control</u> 0 = integer division 1 = 1-stage MASH (equivalent to non-MASH dividers) 2 = 2-stage MASH 3 = 3-stage MASH To avoid lock-ups and glitches do not change this control while BUSY=1 and do not change this control at the same time as asserting ENAB.	R/W	0
8	FLIP	<u>Invert the clock generator output</u> This is intended for use in test/debug only. Switching this control will generate an edge on the clock generator output. To avoid output glitches do not switch this control while BUSY=1.	R/W	0
7	BUSY	<u>Clock generator is running</u> Indicates the clock generator is running. To avoid glitches and lock-ups, clock sources and setups must not be changed while this flag is set.	R	0
6	-	Unused	R	0
5	KILL	<u>Kill the clock generator</u> 0 = no action 1 = stop and reset the clock generator This is intended for test/debug only. Using this control may cause a glitch on the clock generator output.	R/W	0
4	ENAB	<u>Enable the clock generator</u> This requests the clock to start or stop without glitches. The output clock will not stop immediately because the cycle must be allowed to complete to avoid glitches. The BUSY flag will go low when the final cycle is completed.	R/W	0
3-0	SRC	<u>Clock source</u> 0 = GND 1 = oscillator 2 = testdebug0 3 = testdebug1 4 = PLLA per 5 = PLLC per 6 = PLLD per 7 = HDMI auxiliary 8-15 = GND To avoid lock-ups and glitches do not change this control while BUSY=1 and do not change this control at the same time as asserting ENAB.	R/W	0



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Table 6-34 General Purpose Clocks Control

## Clock Manager General Purpose Clock Divisors (CM\_GP0DIV, CM\_GP1DIV & CM\_GP2DIV)

**Address**      0x 7e10 1074 CM\_GP0DIV  
                  0x 7e10 107c CM\_GP1DIV  
                  0x 7e10 1084 CM\_GP2DIV

Bit Number	Field Name	Description	Read/Write	Reset
31-24	PASSWD	Clock Manager password "5a"	W	0
23-12	DIVI	<u>Integer part of divisor</u> This value has a minimum limit determined by the MASH setting. See text for details. To avoid lock-ups and glitches do not change this control while BUSY=1.	R/W	0
11-0	DIVF	<u>Fractional part of divisor</u> To avoid lock-ups and glitches do not change this control while BUSY=1.	R/W	0

Table 6-35 General Purpose Clock Divisors



## 7 Interrupts

### 7.1 Introduction

The ARM has two types of interrupt sources:

1. Interrupts coming from the GPU peripherals.
2. Interrupts coming from local ARM control peripherals.

The ARM processor gets three types of interrupts:

1. Interrupts from ARM specific peripherals.
2. Interrupts from GPU peripherals.
3. Special events interrupts.

The ARM specific interrupts are:

- One timer.
- One Mailbox.
- Two Doorbells.
- Two GPU halted interrupts.
- Two Address/access error interrupt

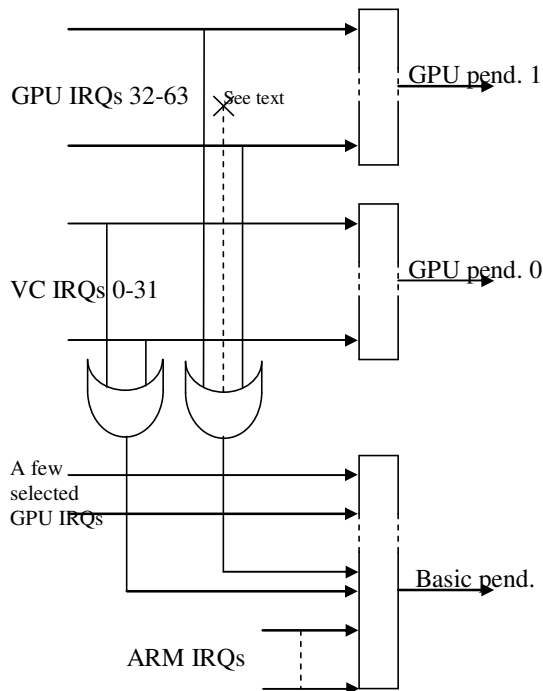
The Mailbox and Doorbell registers are not for general usage.

For each interrupt source (ARM or GPU) there is an interrupt enable bit (read/write) and an interrupt pending bit (Read Only). All interrupts generated by the arm control block are level sensitive interrupts. Thus all interrupts remain asserted until disabled or the interrupt source is cleared.

Default the interrupts from doorbell 0,1 and mailbox 0 go to the ARM this means that these resources should be written by the GPU and read by the ARM. The opposite holds for doorbells 2, 3 and mailbox 1.

## 7.2 Interrupt pending.

An interrupt vector module has NOT been implemented. To still have adequate interrupt processing the interrupt pending bits are organized as follows:



There are three interrupt pending registers.

One basic pending register and two GPU pending registers.

### Basic pending register.

The basic pending register has interrupt pending bits for the ARM specific interrupts .

To speed up the interrupt processing it also has a number of selected GPU interrupts which are deemed most likely to be required in ARM drivers.

Further there are two special GPU pending bits which tell if any of the two other pending registers has bits set, one bit if a GPU interrupt 0-31 is pending, a second bit if a GPU interrupt 32-63 is pending. The 'selected GPU interrupts' on the basic pending registers are NOT taken into account for these two status bits. So the two pending 0,1 status bits tell you that 'there are more interrupt which you have not seen yet'.

### GPU pending registers.

There are two GPU pending registers with one bit per GPU interrupt source.

## 7.3 Fast Interrupt (FIQ).

The ARM also supports a Fast Interrupt (FIQ). One interrupt sources can be selected to be connected to the ARM FIQ input. There is also one FIQ enable. An interrupt which is selected as FIQ should have its normal interrupt enable bit cleared. Otherwise an normal and a FIQ interrupt will be fired at the same time. Not a good idea!

## 7.4 Interrupt priority.

There is no priority for any interrupt. If one interrupt is much more important then all others it can be routed to the FIQ. Any remaining interrupts have to be processed by polling the pending



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registers. It is up to the ARM software to devise a strategy. e.g. First start looking for specific pending bits or process them all shifting one bit at a time.

As interrupt may arrive whilst this process is ongoing the usual care for any 'race-condition critical' code must be taken. The following ARM assembly code has been proven to work:

```
.macro get_irqnr_preamble, base, tmp
ldr \base, =IO_ADDRESS(ARMCTRL_IC_BASE)
.endm

.macro get_irqnr_and_base, irqnr, irqstat, base, tmp
ldr \irqstat, [\base, #(ARM_IRQ_PEND0 - ARMCTRL_IC_BASE)] @ get masked status
mov \irqnr, #(ARM_IRQ0_BASE + 31)
and \tmp, \irqstat, #0x300 @ save bits 8 and 9
bics \irqstat, \irqstat, #0x300 @ clear bits 8 and 9, and test
bne 1010f

tst \tmp, #0x100
ldrne \irqstat, [\base, #(ARM_IRQ_PEND1 - ARMCTRL_IC_BASE)]
movne \irqnr, #(ARM_IRQ1_BASE + 31)
@ Mask out the interrupts also present in PEND0 - see SW-5809
bicne \irqstat, #((1<<7) | (1<<9) | (1<<10))
bicne \irqstat, #((1<<18) | (1<<19))
bne 1010f

tst \tmp, #0x200
ldrne \irqstat, [\base, #(ARM_IRQ_PEND2 - ARMCTRL_IC_BASE)]
movne \irqnr, #(ARM_IRQ2_BASE + 31)
@ Mask out the interrupts also present in PEND0 - see SW-5809
bicne \irqstat, #((1<<21) | (1<<22) | (1<<23) | (1<<24) | (1<<25))
bicne \irqstat, #((1<<30))
beq 1020f

1010:
@ For non-zero x, LSB(x) = 31 - CLZ(x^(x-1))
@ N.B. CLZ is an ARM5 instruction.
sub \tmp, \irqstat, #1
eor \irqstat, \irqstat, \tmp
clz \tmp, \irqstat
sub \irqnr, \tmp

1020: @ EQ will be set if no irqs pending
```

## 7.5 Registers

The base address for the ARM interrupt register is 0x7E00B000.

Registers overview:

Address offset <sup>7</sup>	Name	Notes
0x200	IRQ basic pending	
0x204	IRQ pending 1	
0x208	IRQ pending 2	
0x20C	FIQ control	
0x210	Enable IRQs 1	
0x214	Enable IRQs 2	
0x218	Enable Basic IRQs	
0x21C	Disable IRQs 1	
0x220	Disable IRQs 2	
0x224	Disable Basic IRQs	

The following is a table which lists all interrupts which can come from the peripherals which can be handled by the ARM.

<sup>7</sup> This is the offset which needs to be added to the base address to get the full hardware address.





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ARM peripherals interrupts table.

#	IRQ 0-15	#	IRQ 16-31	#	IRQ 32-47	#	IRQ 48-63
0		16		32		48	smi
1		17		33		49	gpio_int[0]
2		18		34		50	gpio_int[1]
3		19		35		51	gpio_int[2]
4		20		36		52	gpio_int[3]
5		21		37		53	i2c_int
6		22		38		54	spi_int
7		23		39		55	pcm_int
8		24		40		56	
9		25		41		57	uart_int
10		26		42		58	
11		27		43	i2c_spi_slv_int	59	
12		28		44		60	
13		29	Aux int	45	pwa0	61	
14		30		46	pwa1	62	
15		31		47		63	

The table above has many empty entries. These should not be enabled as they will interfere with the GPU operation.

ARM peripherals interrupts table.

0	ARM Timer
1	ARM Mailbox
2	ARM Doorbell 0
3	ARM Doorbell 1
4	GPU0 halted (Or GPU1 halted if bit 10 of control register 1 is set)
5	GPU1 halted
6	Illegal access type 1
7	Illegal access type 0

### Basic pending register.

The basic pending register shows which interrupt are pending. To speed up interrupts processing, a number of 'normal' interrupt status bits have been added to this register. This makes the 'IRQ pending base' register different from the other 'base' interrupt registers

Name: IRQ pend base		Address: 0x200	Reset: 0x000
Bit(s)	R/W	Function	
31:21	-	<unused>	
20	R	GPU IRQ 62	



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Name: IRQ pend base		Address: 0x200	Reset: 0x000
19	R	GPU IRQ 57	
18	R	GPU IRQ 56	
17	R	GPU IRQ 55	
16	R	GPU IRQ 54	
15	R	GPU IRQ 53	
14	R	GPU IRQ 19	
13	R	GPU IRQ 18	
12	R	GPU IRQ 10	
11	R	GPU IRQ 9	
10	R	GPU IRQ 7	
9	R	One or more bits set in pending register 2	
8	R	One or more bits set in pending register 1	
7	R	Illegal access type 0 IRQ pending	
6	R	Illegal access type 1 IRQ pending	
5	R	GPU1 halted IRQ pending	
4	R	GPU0 halted IRQ pending (Or GPU1 halted if bit 10 of control register 1 is set)	
3	R	ARM Doorbell 1 IRQ pending	
2	R	ARM Doorbell 0 IRQ pending	
1	R	ARM Mailbox IRQ pending	
0	R	ARM Timer IRQ pending	

### GPU IRQ x (10,11..20)

These bits are direct interrupts from the GPU. They have been selected as interrupts which are most likely to be useful to the ARM. The GPU interrupt selected are 7, 9, 10, 18, 19, 53,54,55,56,57,62. For details see the *GPU interrupts table*.

### Bits set in pending registers (8,9)

These bits indicates if there are bits set in the pending 1/2 registers. The pending 1/2 registers hold ALL interrupts 0..63 from the GPU side. Some of these 64 interrupts are also connected to the basic pending register. Any bit set in pending register 1/2 which is NOT connected to the basic pending register causes bit 8 or 9 to set. Status bits 8 and 9 should be seen as "There are some interrupts pending which you don't know about. They are in pending register 1 /2."

### Illegal access type-0 IRQ (7)

This bit indicate that the address/access error line from the ARM processor has generated an interrupt. That signal is asserted when either an address bit 31 or 30 was high or when an access was



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seen on the ARM Peripheral bus. The status of that signal can be read from Error/HALT status register bit 2.

## Illegal access type-1 IRQ (6)

This bit indicates that an address/access error is seen in the ARM control has generated an interrupt. That can either be an address bit 29..26 was high or when a burst access was seen on the GPU Peripheral bus. The status of that signal can be read from Error/HALT status register bits 0 and 1.

## GPU-1 halted IRQ (5)

This bit indicate that the GPU-1 halted status bit has generated an interrupt. The status of that signal can be read from Error/HALT status register bits 4.

## GPU-0 (or any GPU) halted IRQ (4)

This bit indicate that the GPU-0 halted status bit has generated an interrupt. The status of that signal can be read from Error/HALT status register bits 3.

In order to allow a fast interrupt (FIQ) routine to cope with GPU 0 OR GPU-1 there is a bit in control register 1 which, if set will also route a GPU-1 halted status on this bit.

## Standard peripheral IRQs (0,1,2,3)

These bits indicate if an interrupt is pending for one of the ARM control peripherals.

## GPU pending 1 register.

Name: IRQ pend base		Address: 0x204	Reset: 0x000
Bit(s)	R/W	Function	
31:0	R	IRQ pending source 31:0 (See IRQ table above)	

This register holds ALL interrupts 0..31 from the GPU side. Some of these interrupts are also connected to the basic pending register. Any interrupt status bit in here which is NOT connected to the basic pending will also cause bit 8 of the basic pending register to be set. That is all bits except 7, 9, 10, 18, 19.

## GPU pending 2 register.

Name: IRQ pend base		Address: 0x208	Reset: 0x000
Bit(s)	R/W	Function	
31:0	R	IRQ pending source 63:32 (See IRQ table above)	

This register holds ALL interrupts 32..63 from the GPU side. Some of these interrupts are also connected to the basic pending register. Any interrupt status bit in here which is NOT connected to the basic pending will also cause bit 9 of the basic pending register to be set. That is all bits except . register bits 21..25, 30 (Interrupts 53..57,62).

## FIQ register.

The FIQ register control which interrupt source can generate a FIQ to the ARM. Only a single interrupt can be selected.



## BCM2835 ARM Peripherals

Name: FIQ		Address: 0x20C	Reset: 0x000
Bit(s)	R/W	Function	
31:8	R	<unused>	
7	R	FIQ enable. Set this bit to 1 to enable FIQ generation. If set to 0 bits 6:0 are don't care.	
6:0	R/W	Select FIQ Source	

### FIQ Source.

The FIQ source values 0-63 correspond to the GPU interrupt table. (See above)

The following values can be used to route ARM specific interrupts to the FIQ vector/routine:

FIQ index	Source
0-63	GPU Interrupts (See GPU IRQ table)
64	ARM Timer interrupt
65	ARM Mailbox interrupt
66	ARM Doorbell 0 interrupt
67	ARM Doorbell 1 interrupt
68	GPU0 Halted interrupt (Or GPU1)
69	GPU1 Halted interrupt
70	Illegal access type-1 interrupt
71	Illegal access type-0 interrupt
72-127	Do Not Use

### Interrupt enable register 1.

Name: IRQ enable 1		Address: 0x210	Reset: 0x000
Bit(s)	R/W	Function	
31:0	R/Wbs	Set to enable IRQ source 31:0 (See IRQ table above)	

Writing a 1 to a bit will set the corresponding IRQ enable bit. All other IRQ enable bits are unaffected. Only bits which are enabled can be seen in the interrupt pending registers. There is no provision here to see if there are interrupts which are pending but not enabled.



## Interrupt enable register 2.

Name: IRQ enable 2		Address: 0x214	Reset: 0x000
Bit(s)	R/W	Function	
31:0	R/Wbs	Set to enable IRQ source 63:32 (See IRQ table above)	

Writing a 1 to a bit will set the corresponding IRQ enable bit. All other IRQ enable bits are unaffected. Only bits which are enabled can be seen in the interrupt pending registers. There is no provision here to see if there are interrupts which are pending but not enabled.

## Base Interrupt enable register.

Name: IRQ enable 3		Address: 0x218	Reset: 0x000
Bit(s)	R/W	Function	
31:8	R/Wbs	<Unused>	
7	R/Wbs	Set to enable Access error type -0 IRQ	
6	R/Wbs	Set to enable Access error type -1 IRQ	
5	R/Wbs	Set to enable GPU 1 Halted IRQ	
4	R/Wbs	Set to enable GPU 0 Halted IRQ	
3	R/Wbs	Set to enable ARM Doorbell 1 IRQ	
2	R/Wbs	Set to enable ARM Doorbell 0 IRQ	
1	R/Wbs	Set to enable ARM Mailbox IRQ	
0	R/Wbs	Set to enable ARM Timer IRQ	

Writing a 1 to a bit will set the corresponding IRQ enable bit. All other IRQ enable bits are unaffected. Again only bits which are enabled can be seen in the basic pending register. There is no provision here to see if there are interrupts which are pending but not enabled.

## Interrupt disable register 1.

Name: IRQ disable 1		Address: 0x21C	Reset: 0x000
Bit(s)	R/W	Function	
31:0	R/Wbc	Set to disable IRQ source 31:0 (See IRQ table above)	

Writing a 1 to a bit will clear the corresponding IRQ enable bit. All other IRQ enable bits are unaffected.



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## Interrupt disable register 2.

Name: IRQ disable 2		Address: 0x220	Reset: 0x000
Bit(s)	R/W	Function	
31:0	R/Wbc	Set to disable IRQ source 63:32 (See IRQ table above)	

Writing a 1 to a bit will clear the corresponding IRQ enable bit. All other IRQ enable bits are unaffected.

## Base disable register.

Name: IRQ disable 3		Address: 0x224	Reset: 0x000
Bit(s)	R/W	Function	
31:8	-	<Unused>	
7	R/Wbc	Set to disable Access error type -0 IRQ	
6	R/Wbc	Set to disable Access error type -1 IRQ	
5	R/Wbc	Set to disable GPU 1 Halted IRQ	
4	R/Wbc	Set to disable GPU 0 Halted IRQ	
3	R/Wbc	Set to disable ARM Doorbell 1 IRQ	
2	R/Wbc	Set to disable ARM Doorbell 0 IRQ	
1	R/Wbc	Set to disable ARM Mailbox IRQ	
0	R/Wbc	Set to disable ARM Timer IRQ	

Writing a 1 to a bit will clear the corresponding IRQ enable bit. All other IRQ enable bits are unaffected.

## 8 PCM / I2S Audio

The PCM audio interface is an APB peripheral providing input and output of telephony or high quality serial audio streams. It supports many classic PCM formats including I2S.

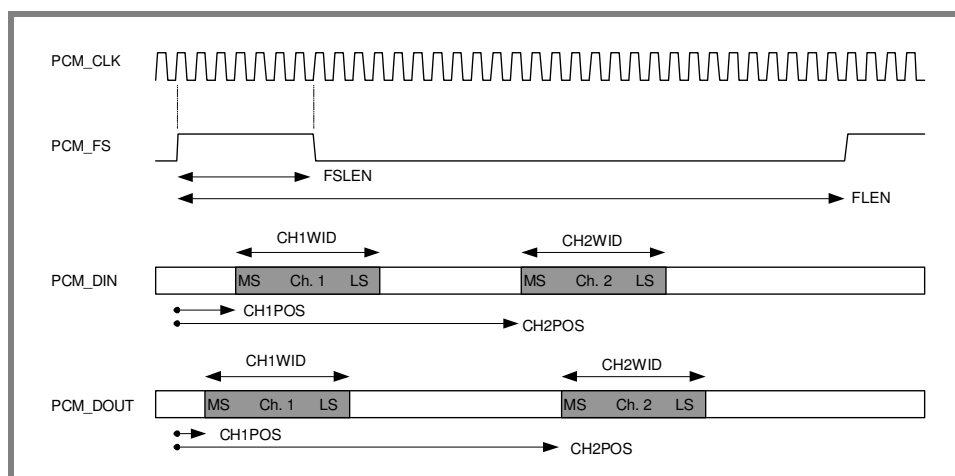
The PCM audio interface has 4 interface signals;

- PCM\_CLK - bit clock.
- PCM\_FS - frame sync signal.
- PCM\_DIN - serial data input.
- PCM\_DOUT - serial data output.

PCM is a serial format with a single bit data\_in and single bit data\_out. Data is always serialised MS-bit first.

The frame sync signal (PCM\_FS) is used to delimit the serial data into individual frames. The length of the frame and the size and position of the frame sync are fully programmable.

Frames can contain 1 or 2 audio/data channels in each direction. Each channel can be between 8 and 32 bits wide and can be positioned anywhere within the frame as long as the two channels don't overlap. The channel format is separately programmable for transmit and receive directions.



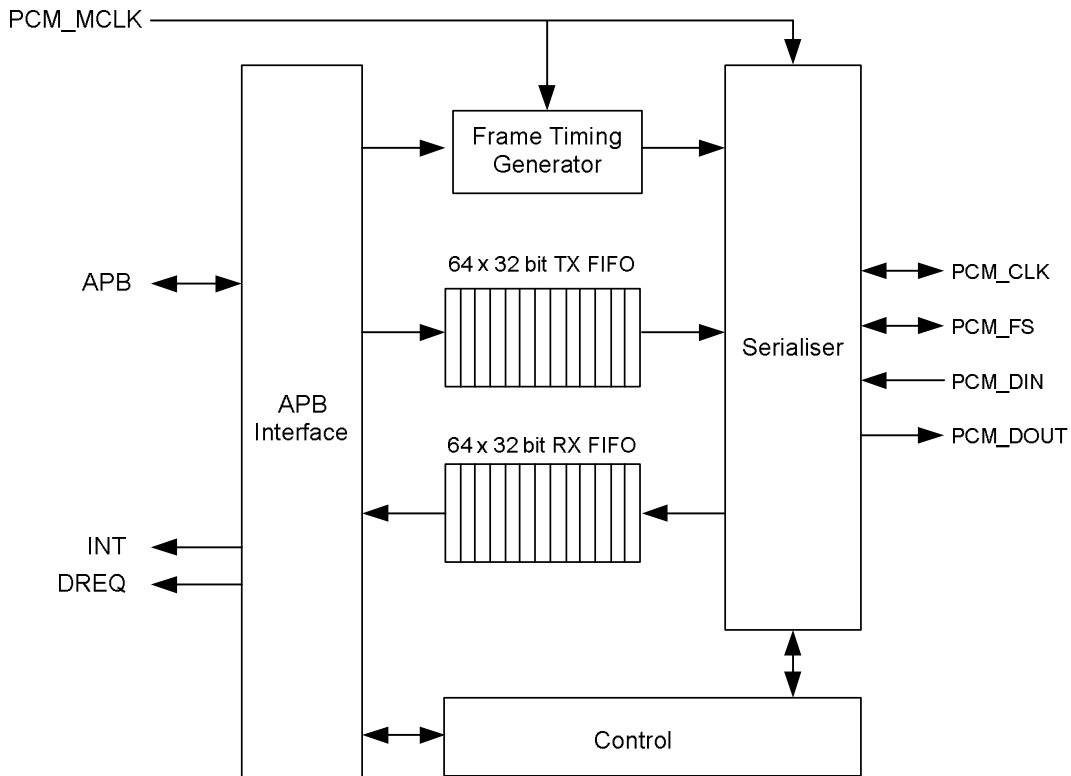
**Figure 8-1 PCM Audio Interface Typical Timing**

The PCM\_CLK can be asynchronous to the bus APB clock and can be logically inverted if required.

The direction of the PCM\_CLK and PCM\_FS signals can be individually selected, allowing the interface to act as a master or slave device.

The input interface is also capable of supporting up to 2 PDM microphones, as an alternative to the classic PCM input format, in conjunction with a PCM output.

## 8.1 Block Diagram



**Figure 8-2 PCM Audio Interface Block Diagram**

The PCM audio interface contains separate transmit and receive FIFOs. Note that if the frame contains two data channels, they must share the same FIFO and so the channel data will be interleaved. The block can be driven using simple polling, an interrupt based method or direct DMA control.

## 8.2 Typical Timing

Figure 8-1 shows typical interface timing and indicates the flexibility that the peripheral offers.

Normally PCM output signals change on the rising edge of PCM\_CLK and input signals are sampled on its falling edge. The frame sync is considered as a data signal and sampled in the same way.

The front end of the PCM audio interface is run off the PCM\_CLK and the PCM signals are timed against this clock. However, the polarity of the PCM\_CLK can be physically inverted, in which case the edges are reversed.

In clock master mode (CLKM=0), the PCM\_CLK is an output and is driven from the PCM\_MCLK clock input.

In clock slave mode (CLKM=1), the PCM\_CLK is an input, supplied by some external clock source.





In frame sync master mode (FSM=0), the PCM\_FS is internally generated and is treated as a data output that changes on the positive edge of the clock. The length and polarity of the frame sync is fully programmable and it can be used as a standard frame sync signal, or as an L-R signal for I2S.

In frame sync slave mode (FSM=1), the PCM\_FS is treated as a data input and is sampled on the negative edge of PCM\_CLK. The first clock of a frame is taken as the first clock period where PCM\_FS is sampled as a 1 following a period or periods where it was previously a 0. The PCM audio interface locks onto the incoming frame sync and uses this to indicate where the data channels are positioned. The precise timing at the start of frame is shown in Figure 8-3.

Note that in frame sync slave mode there are two synchronising methods. The legacy method is used when the frame length = 0. In this case the internal frame logic has to detect the incoming PCM\_FS signal and reset the internal frame counter at the start of every frame. The logic relies on the PCM\_FS to indicate the length of the frame and so can cope with adjacent frames of different lengths. However, this creates a short timing path that will corrupt the PCM\_DOUT for one specific frame/channel setting.

The preferred method is to set the frame length to the expected length. Here the incoming PCM\_FS is used to resynchronise the internal frame counter and this eliminates the short timing path.

## 8.3 Operation

The PCM interface runs asynchronously at the PCM\_CLK rate and automatically transfers transmit and receive data across to the internal APB clock domain. The control registers are NOT synchronised and should be programmed before the device is enabled and should NOT be changed whilst the interface is running.

Only the EN, RXON and TXON bits of the PCMCS register are synchronised across the PCM - APB clock domain and are allowed to be changed whilst the interface is running.

The EN bit is a global power-saving enable. The TXON and RXON bits enable transmit and receive, and the interface is running whenever either TXON or RXON is enabled.

In operation, the PCM format is programmed by setting the appropriate frame length, frame sync, channel position values, and signal polarity controls. The transmit FIFO should be preloaded with data and the interface can then be enabled and started, and will run continuously until stopped. If the transmit FIFO becomes empty or the receive FIFO becomes full, the RXERR or TXERR error flags will be set, but the interface will just continue. If the RX FIFO overflows, new samples are discarded and if the TX FIFO underflows, zeros are transmitted.

Normally channel data is read or written into the appropriate FIFO as a single word. If the channel is less than 32 bits, the data is right justified and should be padded with zeros. If the RXSEX bit is set then the received data is sign extended up to the full 32 bits. When a frame is programmed to have two data channels, then each channel is written/read as a separate word in the FIFO, producing an interleaved data stream. When initialising the interface, the first word read out of the TX FIFO will be used for the first channel, and the data from the first channel on the first frame to be received will be the first word written into the RX FIFO.

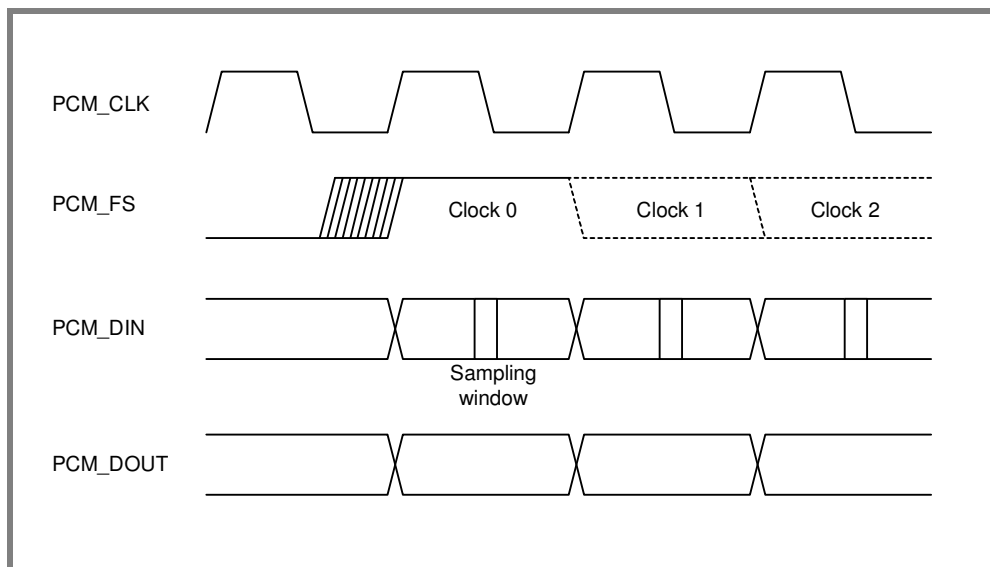
If a FIFO error occurs in a two channel frame, then channel synchronisation may be lost which may result in a left right audio channel swap. RXSYNC and TXSYNC status bits are

provided to help determine if channel slip has occurred. They indicate if the number of words in the FIFO is a multiple of a full frame (taking into account where we are in the current frame being transferred). This assumes that an integer number of frames data has been sent/read from the FIFOs.

If a frame is programmed to have two data channels and the packed mode bits are set (FRXP FTXP) then the FIFOs are configured so that each word contains the data for both channels (2x 16 bit samples). In this mode each word written to the TX FIFO contains 2 16 bit samples, and the Least Significant sample is transmitted first. Each word read from the RX FIFO will contain the data received from 2 channels, the first channel received will be in the Least Significant half of the word. If the channels size is less than 16 bits, the TX data will be truncated and RX data will be padded to 16 bits with zeros.

Note that data is always serialised MS-bit first. This is well-established behaviour in both PCM and I2S.

If the PDM input mode is enabled then channel 1 is sampled on the negative edge of PCM\_CLK whilst channel 2 is sampled on the positive edge of PCM\_CLK.



**Figure 8-3 Timing at Start of Frame**

Note that the precise timing of FS (when it is an input) is not clearly defined and it may change state before or after the positive edge of the clock. Here the first clock of the frame is defined as the clock period where the PCM\_FS is sampled (negative edge) as a 1 where it was previously sampled as a 0.

## 8.4 Software Operation

### 8.4.1 Operating in Polled mode

Set the EN bit to enable the PCM block. Set all operational values to define the frame and channel settings. Assert RXCLR and/or TXCLR wait for 2 PCM clocks to ensure the FIFOs are reset. The SYNC bit can be used to determine when 2 clocks have passed. Set RXTHR/TXTHR to determine the FIFO thresholds.



If transmitting, ensure that sufficient sample words have been written to PCMFIFO before transmission is started. Set TXON and/or RXON to begin operation. Poll TXW writing sample words to PCMFIFO and RXR reading sample words from PCMFIFO until all data is transferred.

## 8.4.2 Operating in Interrupt mode

- a) Set the EN bit to enable the PCM block. Set all operational values to define the frame and channel settings. Assert RXCLR and/or TXCLR wait for 2 PCM clocks to ensure the FIFOs are reset. The SYNC bit can be used to determine when 2 clocks have passed. Set RXTHR/TXTHR to determine the FIFO thresholds.
- b) Set INTR and/or INTT to enable interrupts.
- c) If transmitting, ensure that sufficient sample words have been written to PCMFIFO before transmission is started. Set TXON and/or RXON to begin operation.
- d) When an interrupt occurs, check RXR. If this is set then one or more sample words are available in PCMFIFO. If TXW is set then one or more sample words can be sent to PCMFIFO.

## 8.4.3 DMA

- a) Set the EN bit to enable the PCM block. Set all operational values to define the frame and channel settings. Assert RXCLR and/or TXCLR wait for 2 PCM clocks to ensure the FIFOs are reset. The SYNC bit can be used to determine when 2 clocks have passed.
- b) Set DMAEN to enable DMA DREQ generation and set RXREQ/TXREQ to determine the FIFO thresholds for the DREQs. If required, set TXPANIC and RXPANIC to determine the level at which the DMA should increase its AXI priority,
- c) In the DMA controllers set the correct DREQ channels, one for RX and one for TX. Start the DMA which should fill the TX FIFO.
- d) Set TXON and/or RXON to begin operation.

## 8.5 Error Handling.

In all software operational modes, the possibility of FIFO over or under run exists. Should this happen when using 2 channels per frame, there is a risk of losing sync with the channel data stored in the FIFO. If this happens and is not detected and corrected, then the data channels may become swapped.

The FIFO's will automatically detect an error condition caused by a FIFO over or under-run and this will set the appropriate latching error bit in the control/status register. Writing a '1' back to this error bit will clear the latched flag.

In a system using a polled operation, the error bits can be checked manually. For an interrupt or DMA based system, setting the INTE bit will cause the PCM interface to generate an interrupt when an error is detected.

If a FIFO error occurs during operation in which 2 data channels are being used then the synchronisation of the data may be lost. This can be recovered by either of these two methods:

- a) Disable transmit and receive (TXON and RXON =0). Clear the FIFO's (RXCLR and TXCLR =1). Note that it may take up to 2 PCM clocks for the FIFOs to be physically cleared after initiating a clear. Then preload the transmit FIFO and restart transmission. This of course loses the data in the FIFO and further interrupts the data flow to the external device.
- b) Examine the TXSYNC and RXSYNC flags. These flags indicate if the amount of data in the FIFO is a whole number of frames, automatically taking into account where we are in the current frame being transmitted or received. Thus, providing an even number of samples was read or written to the FIFOs, then if the flags are set then this indicates that a single word needs to be written or read to adjust the data. Normal exchange of data can then proceed (where the first word in a data pair is for channel 1). This method should cause less disruption to the data stream.

## 8.6 PDM Input Mode Operation

The PDM input mode is capable of interfacing with two digital half-cycle PDM microphones and implements a 4<sup>th</sup> order CIC decimation filter with a selectable decimation factor. The clock input of the microphones is shared with the PCM output codec and it should be configured to provide the correct clock rate for the microphones. As a result it may be necessary to add a number of padding bits into the PCM output and configure the output codec to allow for this.

When using the PDM input mode the bit width and the rate of the data received will depend on the decimation factor used. Once the data has been read from the peripheral a further decimation and filtering stage will be required and can be implemented in software. The software filter should also correct the droop introduced by the CIC filter stage. Similarly a DC correction stage should also be employed.

PDMN	PCM_CLK (MHz)	Peripheral Output Format	OSR	Fs
0 (N=16)	3.072	16 bits unsigned	4	48kHz
1 (N=32)	3.072	20 bits unsigned	2	48kHz

**Table 8-1 PDM Input Mode Configuration**

## 8.7 GRAY Code Input Mode Operation

GRAY mode is used for an incoming data stream only. GRAY mode is selected by setting the enable bit (EN) in the PCM\_GRAY register.

In this mode data is received on the PCM\_DIN (data) and the PCM\_FS (strobe) pins. The data is expected to be in data/strobe format. In this mode data is detected when either the data or the strobe change state. As each bit is received it is written into the RX buffer and when 32 bits are received they are written out to the RXFIFO as a 32 bit word. In order for this mode to work the user must program a PCM clock rate which is 4 times faster than the gray data rate. Also the gray coded data input signals should be clean.



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The normal RXREQ and RXTHR FIFO levels will apply as for normal PCM received data.

If a message is received that is not a multiple of 32 bits, any data in the RX Buffer can be flushed out by setting the flush bit (FLUSH). Once set, this bit will read back as zero until the flush operation has completed. This may take several cycles as the APB clock may be many times faster than the PCM clock. Once the flush has occurred, the bits are packed up to 32 bits with zeros and written out to the RXFIFO. The flushed field (FLUSHED) will indicate how many of bits of this word are valid.

Note that to get an accurate indication of the number of bits currently in the rx shift register (RXLEVEL) the APB clock must be at least 2x the PCM\_CLK.

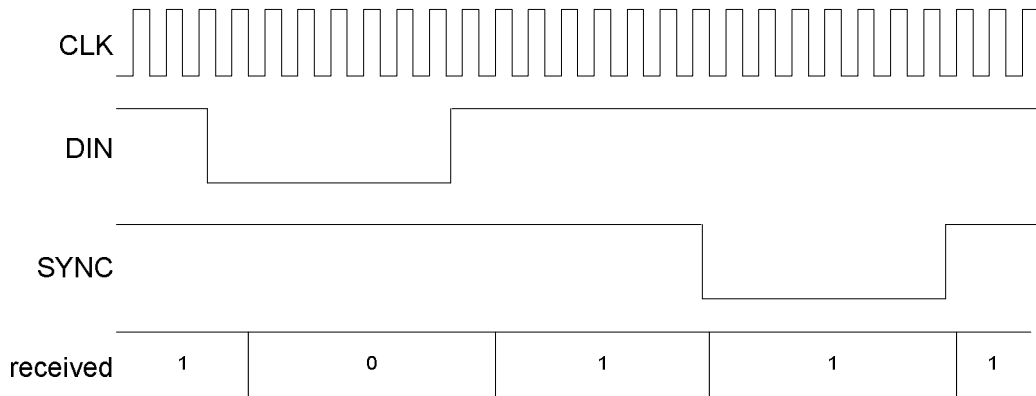


Figure 8-4 Gray mode input format

## 8.8 PCM Register Map

There is only PCM module in the BCM2835. The PCM base address for the registers is 0x7E203000.

PCM Address Map			
Address Offset	Register Name	Description	Size
0x0	<a href="#">CS_A</a>	PCM Control and Status	32
0x4	<a href="#">FIFO_A</a>	PCM FIFO Data	32
0x8	<a href="#">MODE_A</a>	PCM Mode	32
0xc	<a href="#">RXC_A</a>	PCM Receive Configuration	32
0x10	<a href="#">TXC_A</a>	PCM Transmit Configuration	32
0x14	<a href="#">DREQ_A</a>	PCM DMA Request Level	32



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0x18	<a href="#">INTEN_A</a>	PCM Interrupt Enables	32
0x1c	<a href="#">INTSTC_A</a>	PCM Interrupt Status & Clear	32
0x20	<a href="#">GRAY</a>	PCM Gray Mode Control	32

## CS\_A Register

**Synopsis** This register contains the main control and status bits for the PCM. The bottom 3 bits of this register can be written to whilst the PCM is running. The remaining bits cannot.

Bit(s)	Field Name	Description	Type	Reset
31:26		<b>Reserved</b> - Write as 0, read as don't care		
25	STBY	<u>RAM Standby</u> This bit is used to control the PCM Rams standby mode. By default this bit is 0 causing RAMs to start initially in standby mode. Rams should be released from standby prior to any transmit/receive operation. Allow for at least 4 PCM clock cycles to take effect. This may or may not be implemented, depending upon the RAM libraries being used.	RW	0x0
24	SYNC	<u>PCM Clock sync helper.</u> This bit provides a software synchronisation mechanism to allow the software to detect when 2 PCM clocks have occurred. It takes 2 PCM clocks before the value written to this bit will be echoed back in the read value.	RW	0x0
23	RXSEX	<u>RX Sign Extend</u> 0 = No sign extension. 1 = Sign extend the RX data. When set, the MSB of the received data channel (as set by the CHxWID parameter) is repeated in all the higher data bits up to the full 32 bit data width.	RW	0x0
22	RXF	<u>RX FIFO is Full</u> 0 = RX FIFO can accept more data. 1 = RX FIFO is full and will overflow if more data is received.	RO	0x0



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21	TXE	<u>TX FIFO is Empty</u> 0 = TX FIFO is not empty. 1 = TX FIFO is empty and underflow will take place if no more data is written.	RO	0x1
20	RXD	<u>Indicates that the RX FIFO contains data</u> 0 = RX FIFO is empty. 1 = RX FIFO contains at least 1 sample.	RO	0x0
19	TXD	<u>Indicates that the TX FIFO can accept data</u> 0 = TX FIFO is full and so cannot accept more data. 1 = TX FIFO has space for at least 1 sample.	RO	0x1
18	RXR	<u>Indicates that the RX FIFO needs reading</u> 0 = RX FIFO is less than RXTHR full. 1 = RX FIFO is RXTHR or more full. This is cleared by reading sufficient data from the RX FIFO.	RO	0x0
17	TXW	<u>Indicates that the TX FIFO needs Writing</u> 0 = TX FIFO is at least TXTHR full. 1 = TX FIFO is less than TXTHR full. This is cleared by writing sufficient data to the TX FIFO.	RO	0x1
16	RXERR	<u>RX FIFO Error</u> 0 = FIFO has had no errors. 1 = FIFO has had an under or overflow error. This flag is cleared by writing a 1.	RW	0x0
15	TXERR	<u>TX FIFO Error</u> 0 = FIFO has had no errors. 1 = FIFO has had an under or overflow error. This flag is cleared by writing a 1.	RW	0x0
14	RXSYNC	<u>RX FIFO Sync</u> 0 = FIFO is out of sync. The amount of data left in the FIFO is not a multiple of that required for a frame. This takes into account if we are halfway through the frame. 1 = FIFO is in sync.	RO	0x0
13	TXSYNC	<u>TX FIFO Sync</u> 0 = FIFO is out of sync. The amount of data left in the FIFO is not a multiple of that required for a frame. This takes into account if we are halfway through the frame. 1 = FIFO is in sync.	RO	0x0
12:10		<b>Reserved</b> - Write as 0, read as don't care		



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9	DMAEN	<p><u>DMA DREQ Enable</u>            0 = Don't generate DMA DREQ requests.            1 = Generates a TX DMA DREQ requests whenever the TX FIFO level is lower than TXREQ or generates a RX DMA DREQ when the RX FIFO level is higher than RXREQ.</p>	RW	0x0
8:7	RXTHR	<p><u>Sets the RX FIFO threshold at which point the RXR flag is set</u>            00 = set when we have a single sample in the RX FIFO            01 = set when the RX FIFO is at least full            10 = set when the RX FIFO is at least            11 = set when the RX FIFO is full</p>	RW	0x0
6:5	TXTHR	<p><u>Sets the TX FIFO threshold at which point the TXW flag is set</u>            00 = set when the TX FIFO is empty            01 = set when the TX FIFO is less than full            10 = set when the TX FIFO is less than full            11 = set when the TX FIFO is full but for one sample</p>	RW	0x0
4	RXCLR	<p><u>Clear the RX FIFO.</u>            Assert to clear RX FIFO. This bit is self clearing and is always read as clear            Note that it will take 2 PCM clocks for the FIFO to be physically cleared.</p>	WO	0x0
3	TXCLR	<p><u>Clear the TX FIFO</u>            Assert to clear TX FIFO. This bit is self clearing and is always read as clear.            Note that it will take 2 PCM clocks for the FIFO to be physically cleared.</p>	WO	0x0
2	TXON	<p><u>Enable transmission</u>            0 = Stop transmission. This will stop immediately if possible or else at the end of the next frame. The TX FIFO can still be written to to preload data.            1 = Start transmission. This will start transmitting at the start of the next frame. Once enabled, the first data read from the TX FIFO will be placed in the first channel of the frame, thus ensuring proper channel synchronisation.            The frame counter will be started whenever TXON or RXON are set.            This bit can be written whilst the interface is running.</p>	RW	0x0





# BCM2835 ARM Peripherals

1	RXON	<p><u>Enable reception.</u>            0 = Disable reception. This will stop on the next available frame end. RX FIFO data can still be read.            1 = Enable reception. This will be start receiving at the start of the next frame. The first channel to be received will be the first word written to the RX FIFO.            This bit can be written whilst the interface is running.</p>	RW	0x0
0	EN	<p><u>Enable the PCM Audio Interface</u>            0 = The PCM interface is disabled and most logic is gated off to save power.            1 = The PCM Interface is enabled.            This bit can be written whilst the interface is running.</p>	RW	0x0

## FIFO\_A Register

**Synopsis** This is the FIFO port of the PCM. Data written here is transmitted, and received data is read from here.

Bit(s)	Field Name	Description	Type	Reset
31:0		<i>Reserved - Write as 0, read as don't care</i>		

## MODE\_A Register

**Synopsis** This register defines the basic PCM Operating Mode. It is used to configure the frame size and format and whether the PCM is in master or slave modes for its frame sync or clock. This register cannot be changed whilst the PCM is running.

Bit(s)	Field Name	Description	Type	Reset
31:29		<i>Reserved - Write as 0, read as don't care</i>		



## BCM2835 ARM Peripherals

28	CLK_DIS	<u>PCM Clock Disable</u> 1 = Disable the PCM Clock. This cleanly disables the PCM clock. This enables glitch free clock switching between an internal and an uncontrollable external clock. The PCM clock can be disabled, and then the clock source switched, and then the clock re-enabled. 0 = Enable the PCM clock.	RW	0x0
27	PDMN	<u>PDM Decimation Factor (N)</u> 0 = Decimation factor 16. 1 = Decimation factor 32. Sets the decimation factor of the CIC decimation filter.	RW	0x0
26	PDME	<u>PDM Input Mode Enable</u> 0 = Disable PDM (classic PCM input). 1 = Enable PDM input filter. Enable CIC filter on input pin for PDM inputs. In order to receive data RXON must also be set.	RW	0x0
25	FRXP	<u>Receive Frame Packed Mode</u> 0 = The data from each channel is written into the RX FIFO. 1 = The data from both RX channels is merged (1st channel is in the LS half) and then written to the RX FIFO as a single 2x16 bit packed mode word. First received channel in the frame goes into the LS half word. If the received data is larger than 16 bits, the upper bits are truncated. The maximum channel size is 16 bits.	RW	0x0
24	FTXP	<u>Transmit Frame Packed Mode</u> 0 = Each TX FIFO word is written into a single channel. 1 = Each TX FIFO word is split into 2 16 bit words and used to fill both data channels in the same frame. The maximum channel size is 16 bits. The LS half of the word is used in the first channel of the frame.	RW	0x0
23	CLKM	<u>PCM Clock Mode</u> 0 = Master mode. The PCM CLK is an output and drives at the MCLK rate. 1 = Slave mode. The PCM CLK is an input.	RW	0x0



# BCM2835 ARM Peripherals

22	CLKI	<p><u>Clock Invert</u> this logically inverts the PCM_CLK signal.</p> <p>0 = Outputs change on rising edge of clock, inputs are sampled on falling edge.</p> <p>1 = Outputs change on falling edge of clock, inputs are sampled on rising edge.</p>	RW	0x0
21	FSM	<p><u>Frame Sync Mode</u></p> <p>0 = Master mode. The PCM_FS is an output and we generate the frame sync.</p> <p>1 = Slave mode. The PCM_FS is an input and we lock onto the incoming frame sync signal.</p>	RW	0x0
20	FSI	<p><u>Frame Sync Invert</u> This logically inverts the frame sync signal.</p> <p>0 = In master mode, FS is normally low and goes high to indicate frame sync. In slave mode, the frame starts with the clock where FS is a 1 after being a 0.</p> <p>1 = In master mode, FS is normally high and goes low to indicate frame sync. In slave mode, the frame starts with the clock where FS is a 0 after being a 1.</p>	RW	0x0
19:10	FLEN	<p><u>Frame Length</u></p> <p>Sets the frame length to (FLEN+1) clocks. Used only when FSM == 0.</p> <p>1 = frame length of 2 clocks.</p> <p>2 = frame length of 3 clocks. etc</p>	RW	0x0
9:0	FSLEN	<p><u>Frame Sync Length</u></p> <p>Sets the frame sync length to (FSLEN) clocks. This is only used when FSM == 0. PCM_FS will remain permanently active if FSLEN &gt;= FLEN.</p> <p>0 = frame sync pulse is off.</p> <p>1 = frame sync pulse is 1 clock wide. etc</p>	RW	0x0

## RXC\_A Register

**Synopsis** Sets the Channel configurations for Receiving. This sets the position and width of the 2 receive channels within the frame. The two channels cannot overlap, however they channel 1 can come after channel zero, although the first data will always be from the first channel in the frame. Channels can also straddle the frame begin end boundary as that is set by the frame sync position. This register cannot be changed whilst the PCM is running.

Bit(s)	Field Name	Description	Type	Reset
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## BCM2835 ARM Peripherals

31	CH1WEX	<u>Channel 1 Width Extension Bit</u> This is the MSB of the channel 1 width (CH1WID). It allows widths greater than 24 bits to be programmed and is added here to keep backwards compatibility with older versions of the PCM	RW	0x0
30	CH1EN	<u>Channel 1 Enable</u> 0 = Channel 1 disabled and no data is received from channel 1 and written to the RX FIFO. 1 = Channel 1 enabled.	RW	0x0
29:20	CH1POS	<u>Channel 1 Position</u> This sets the bit clock at which the first bit (MS bit) of channel 1 data occurs in the frame. 0 indicates the first clock of frame.	RW	0x0
19:16	CH1WID	<u>Channel 1 Width</u> This sets the width of channel 1 in bit clocks. This field has been extended with the CH1WEX bit giving a total width of $(CH1WEX * 16) + CH1WID + 8$ . The Maximum supported width is 32 bits. 0 = 8 bits wide 1 = 9 bits wide	RW	0x0
15	CH2WEX	<u>Channel 2 Width Extension Bit</u> This is the MSB of the channel 2 width (CH2WID). It allows widths greater than 24 bits to be programmed and is added here to keep backwards compatibility with older versions of the PCM	RW	0x0
14	CH2EN	<u>Channel 2 Enable</u> 0 = Channel 2 disabled and no data is received from channel 2 and written to the RX FIFO. 1 = Channel 2 enabled.	RW	0x0
13:4	CH2POS	<u>Channel 2 Position</u> This sets the bit clock at which the first bit (MS bit) of channel 2 data occurs in the frame. 0 indicates the first clock of frame.	RW	0x0
3:0	CH2WID	<u>Channel 2 Width</u> This sets the width of channel 2 in bit clocks. This field has been extended with the CH2WEX bit giving a total width of $(CH2WEX * 16) + CH2WID + 8$ . The Maximum supported width is 32 bits. 0 = 8 bits wide 1 = 9 bits wide	RW	0x0



# BCM2835 ARM Peripherals

## TXC\_A Register

**Synopsis** Sets the Channel configurations for Transmitting. This sets the position and width of the 2 transmit channels within the frame. The two channels cannot overlap, however they channel 1 can come after channel zero, although the first data will always be used in the first channel in the frame. Channels can also straddle the frame begin end boundary as that is set by the frame sync position. This register cannot be changed whilst the PCM is running.

Bit(s)	Field Name	Description	Type	Reset
31	CH1WEX	<u>Channel 1 Width Extension Bit</u> This is the MSB of the channel 1 width (CH1WID). It allows widths greater than 24 bits to be programmed and is added here to keep backwards compatibility with older versions of the PCM	RW	0x0
30	CH1EN	<u>Channel 1 Enable</u> 0 = Channel 1 disabled and no data is taken from the TX FIFO and transmitted on channel 1. 1 = Channel 1 enabled.	RW	0x0
29:20	CH1POS	<u>Channel 1 Position</u> This sets the bit clock at which the first bit (MS bit) of channel 1 data occurs in the frame. 0 indicates the first clock of frame.	RW	0x0
19:16	CH1WID	<u>Channel 1 Width</u> This sets the width of channel 1 in bit clocks. This field has been extended with the CH1WEX bit giving a total width of (CH1WEX* 16) + CH1WID + 8. The Maximum supported width is 32 bits. 0 = 8 bits wide 1 = 9 bits wide	RW	0x0
15	CH2WEX	<u>Channel 2 Width Extension Bit</u> This is the MSB of the channel 2 width (CH2WID). It allows widths greater than 24 bits to be programmed and is added here to keep backwards compatibility with older versions of the PCM	RW	0x0
14	CH2EN	<u>Channel 2 Enable</u> 0 = Channel 2 disabled and no data is taken from the TX FIFO and transmitted on channel 2. 1 = Channel 2 enabled.	RW	0x0



# BCM2835 ARM Peripherals

13:4	CH2POS	<u>Channel 2 Position</u> This sets the bit clock at which the first bit (MS bit) of channel 2 data occurs in the frame. 0 indicates the first clock of frame.	RW	0x0
3:0	CH2WID	<u>Channel 2 Width</u> This sets the width of channel 2 in bit clocks. This field has been extended with the CH2WEX bit giving a total width of (CH2WEX* 16) + CH2WID + 8. The Maximum supported width is 32 bits. 0 = 8 bits wide 1 = 9 bits wide	RW	0x0

## DREQ\_A Register

**Synopsis** Set the DMA DREQ and Panic thresholds. The PCM drives 2 DMA controls back to the DMA, one for the TX channel and one for the RX channel. DMA DREQ is used to request the DMA to perform another transfer, and DMA Panic is used to tell the DMA to use its panic level of priority when requesting things on the AXI bus. This register cannot be changed whilst the PCM is running.

Bit(s)	Field Name	Description	Type	Reset
31		<b>Reserved</b> - Write as 0, read as don't care		
30:24	TX_PANIC	<u>TX Panic Level</u> This sets the TX FIFO Panic level. When the level is below this the PCM will assert its TX DMA Panic signal.	RW	0x10
23		<b>Reserved</b> - Write as 0, read as don't care		
22:16	RX_PANIC	<u>RX Panic Level</u> This sets the RX FIFO Panic level. When the level is above this the PCM will assert its RX DMA Panic signal.	RW	0x30
15		<b>Reserved</b> - Write as 0, read as don't care		
14:8	TX	<u>TX Request Level</u> This sets the TX FIFO DREQ level. When the level is below this the PCM will assert its DMA DREQ signal to request more data is written to the TX FIFO.	RW	0x30
7		<b>Reserved</b> - Write as 0, read as don't care		



# BCM2835 ARM Peripherals

6:0	RX	<u>RX Request Level</u> This sets the RX FIFO DREQ level. When the level is above this the PCM will assert its DMA DREQ signal to request that some more data is read out of the RX FIFO.	RW	0x20
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## INTEN\_A Register

**Synopsis** Set the reasons for generating an Interrupt. This register cannot be changed whilst the PCM is running.

Bit(s)	Field Name	Description	Type	Reset
31:4		<i>Reserved - Write as 0, read as don't care</i>		
3	RXERR	<u>RX Error Interrupt</u> Setting this bit enables interrupts from PCM block when RX FIFO error occurs.	RW	0x0
2	TXERR	<u>TX Error Interrupt</u> Setting this bit enables interrupts from PCM block when TX FIFO error occurs.	RW	0x0
1	RXR	<u>RX Read Interrupt Enable</u> Setting this bit enables interrupts from PCM block when RX FIFO level is greater than or equal to the specified RXTHR level.	RW	0x0
0	TXW	<u>TX Write Interrupt Enable</u> Setting this bit enables interrupts from PCM block when TX FIFO level is less than the specified TXTHR level.	RW	0x0

## INTSTC\_A Register

**Synopsis** This register is used to read and clear the PCM interrupt status. Writing a 1 to the asserted bit clears the bit. Writing a 0 has no effect.

Bit(s)	Field Name	Description	Type	Reset
31:4		<i>Reserved - Write as 0, read as don't care</i>		



# BCM2835 ARM Peripherals

3	RXERR	<u>RX Error Interrupt Status / Clear</u> This bit indicates an interrupt occurred on RX FIFO Error. Writing 1 to this bit clears it. Writing 0 has no effect.	RW	0x0
2	TXERR	<u>TX Error Interrupt Status / Clear</u> This bit indicates an interrupt occurred on TX FIFO Error. Writing 1 to this bit clears it. Writing 0 has no effect.	RW	0x0
1	RXR	<u>RX Read Interrupt Status / Clear</u> This bit indicates an interrupt occurred on RX Read. Writing 1 to this bit clears it. Writing 0 has no effect.	RW	0x0
0	TXW	<u>TX Write Interrupt Status / Clear</u> This bit indicates an interrupt occurred on TX Write. Writing 1 to this bit clears it. Writing 0 has no effect.	RW	0x0

## GRAY Register

**Synopsis** This register is used to control the gray mode generation. This is used to put the PCM into a special data/strobe mode. This mode is under 'best effort' contract.

Bit(s)	Field Name	Description	Type	Reset
31:22		<b>Reserved</b> - Write as 0, read as don't care		
21:16	RXFIFOLEVEL	<u>The Current level of the RXFIFO</u> This indicates how many words are currently in the RXFIFO.	RO	0x0
15:10	FLUSHED	<u>The Number of bits that were flushed into the RXFIFO</u> This indicates how many bits were valid when the flush operation was performed. The valid bits are from bit 0 upwards. Non-valid bits are set to zero.	RO	0x0
9:4	RXLEVEL	<u>The Current fill level of the RX Buffer</u> This indicates how many GRAY coded bits have been received. When 32 bits are received, they are written out into the RXFIFO.	RO	0x0





## BCM2835 ARM Peripherals

3		<i>Reserved - Write as 0, read as don't care</i>		
2	FLUSH	<u>Flush the RX Buffer into the RX FIFO</u> This forces the RX Buffer to do an early write. This is necessary if we have reached the end of the message and we have bits left in the RX Buffer. Flushing will write these bits as a single 32 bit word, starting at bit zero. Empty bits will be packed with zeros. The number of bits written will be recorded in the FLUSHED Field. This bit is written as a 1 to initiate a flush. It will read back as a zero until the flush operation has completed (as the PCM Clock may be very slow).	RW	0x0
1	CLR	<u>Clear the GRAY Mode Logic</u> This Bit will reset all the GRAY mode logic, and flush the RX buffer. It is not self clearing.	RW	0x0
0	EN	<u>Enable GRAY Mode</u> Setting this bit will put the PCM into GRAY mode. In gray mode the data is received on the data in and the frame sync pins. The data is expected to be in data/strobe format.	RW	0x0

## 9 Pulse Width Modulator

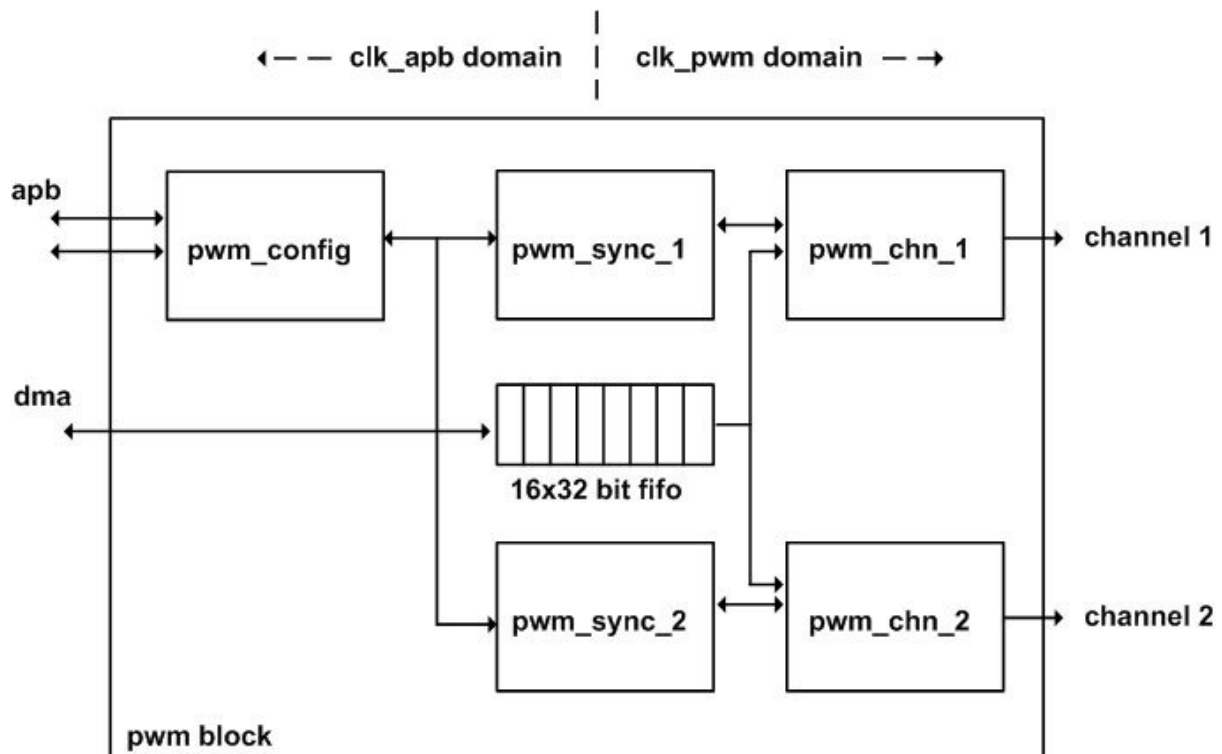
### 9.1 Overview

This section specifies in detail the functionality provided by the device Pulse Width Modulator (PWM) peripheral.

The PWM controller incorporates the following features:

- Two independent output bit-streams, clocked at a fixed frequency.
- Bit-streams configured individually to output either PWM or a serialised version of a 32-bit word.
- PWM outputs have variable input and output resolutions.
- Serialise mode configured to load data to and/or read data from a FIFO storage block, which can store up to eight 32-bit words.
- Both modes clocked by `clk_pwm` which is nominally 100MHz, but can be varied by the clock manager.

### 9.2 Block Diagram



## 9.3 PWM Implementation

A value represented as a ratio of N/M can be transmitted along a serial channel with pulse width modulation in which the value is represented by the duty cycle of the output signal. To send value N/M within a periodic sequence of M cycles, output should be 1 for N cycles and 0 for (M-N) cycles. The desired sequence should have 1's and 0's spread out as even as possible so that during any arbitrary period of time duty cycle achieves closest approximation of the value. This can be shown in the following table where 4/8 is modulated (N= 4, M= 8).

Bad	0	0	0	0	1	1	1	1	0	0	0	0
Fair	0	0	1	1	0	0	1	1	0	0	1	1
Good	0	1	0	1	0	1	0	1	0	1	0	1

Sequence which gives the 'good' approximation from the table above can be achieved by the following algorithm:

```

1. Set context = 0
2. context = context + N
3. if (context >= M)
    context = context - M
    send 1
else

```

where context is a register which stores the result of the addition/subtractions.

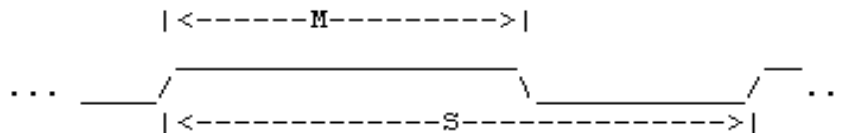
## 9.4 Modes of Operation

PWM controller consists of two independent channels (pwm\_chn in block diagram) which implement the pwm algorithm explained in section 1.3. Each channel can operate in either pwm mode or serialiser mode.

PWM mode: There are two sub-modes in PWM mode: MSEN=0 and MSEN=1.

When MSEN=0, which is the default mode, data to be sent is interpreted as the value N of the algorithm explained above. Number of clock cycles (range) used to send data is the value M of the algorithm. Pulses are sent within this range so that the resulting duty cycle is N/M. Channel sends its output continuously as long as data register is used, or buffer is used and it is not empty.

When MSEN=1, PWM block does not use the algorithm explained above, instead it sends serial data with the M/S ratio as in the picture below. M is the data to be sent, and S is the range. This mode may be preferred if high frequency modulation is not required or has negative effects. Channel sends its output continuously as long as data register is used, or buffer is used and it is not empty.



Serial bit transmission when M/S Mode enabled

Serialiser mode: Each channel is also capable of working as a serialiser. In this mode data written in buffer or the data register is sent serially.

## 9.5 Quick Reference

- PWM DMA is mapped to DMA channel 5.
- GPIOs are assigned to PWM channels as below. Please refer to GPIO section for further details:

	PWM0	PWM1
<b>GPIO 12</b>	Alt Fun 0	-
<b>GPIO 13</b>	-	Alt Fun 0
<b>GPIO 18</b>	Alt Fun 5	-
<b>GPIO 19</b>	-	Alt Fun 5
<b>GPIO 40</b>	Alt Fun 0	-
<b>GPIO 41</b>	-	Alt Fun 0
<b>GPIO 45</b>	-	Alt Fun 0
<b>GPIO 52</b>	Alt Fun 1	-
<b>GPIO 53</b>	-	Alt Fun 1



- PWM clock source and frequency is controlled in CPRMAN.

## 9.6 Control and Status Registers

PWM Address Map			
Address Offset	Register Name	Description	Size
0x0	<a href="#">CTL</a>	PWM Control	32
0x4	<a href="#">STA</a>	PWM Status	32
0x8	<a href="#">DMAC</a>	PWM DMA Configuration	32
0x10	<a href="#">RNG1</a>	PWM Channel 1 Range	32
0x14	<a href="#">DAT1</a>	PWM Channel 1 Data	32
0x18	<a href="#">FIF1</a>	PWM FIFO Input	32
0x20	<a href="#">RNG2</a>	PWM Channel 2 Range	32
0x24	<a href="#">DAT2</a>	PWM Channel 2 Data	32

CTL Register
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# BCM2835 ARM Peripherals

**Synopsis** PWENi is used to enable/disable the corresponding channel. Setting this bit to 1 enables the channel and transmitter state machine. All registers and FIFO is writable without setting this bit.

MODEi bit is used to determine mode of operation. Setting this bit to 0 enables PWM mode. In this mode data stored in either PWM\_DATi or FIFO is transmitted by pulse width modulation within the range defined by PWM\_RNGi. When this mode is used MSENi defines whether to use PWM algorithm. Setting MODEi to 1 enables serial mode, in which data stored in either PWM\_DATi or FIFO is transmitted serially within the range defined by PWM\_RNGi. Data is transmitted MSB first and truncated or zero-padded depending on PWM\_RNGi. Default mode is PWM.

RPTLi is used to enable/disable repeating of the last data available in the FIFO just before it empties. When this bit is 1 and FIFO is used, the last available data in the FIFO is repeatedly sent. This may be useful in PWM mode to avoid duty cycle gaps. If the FIFO is not used this bit does not have any effect. Default operation is do-not-repeat.

SBITi defines the state of the output when no transmission takes place. It also defines the zero polarity for the zero padding in serialiser mode. This bit is padded between two consecutive transfers as well as tail of the data when PWM\_RNGi is larger than bit depth of data being transferred. this bit is zero by default.

POLAi is used to configure the polarity of the output bit. When set to high the final output is inverted. Default operation is no inversion.

USEFi bit is used to enable/disable FIFO transfer. When this bit is high data stored in the FIFO is used for transmission. When it is low, data written to PWM\_DATi is transferred. This bit is 0 as default.

CLRF is used to clear the FIFO. Writing a 1 to this bit clears the FIFO. Writing 0 has no effect. This is a single shot operation and reading the bit always returns 0.

MSENi is used to determine whether to use PWM algorithm or simple M/S ratio transmission. When this bit is high M/S transmission is used. This bit is zero as default. When MODEi is 1, this configuration bit has no effect.

Bit(s)	Field Name	Description	Type	Reset
31:16		<b>Reserved</b> - Write as 0, read as don't care		
15	MSEN2	<u>Channel 2 M/S Enable</u> 0: PWM algorithm is used 1: M/S transmission is used.	RW	0x0
14		<b>Reserved</b> - Write as 0, read as don't care		
13	USEF2	<u>Channel 1 Use Fifo</u> 0: Data register is transmitted 1: Fifo is used for transmission	RW	0x0
12	POLA2	<u>Channel 1 Polarity</u> 0 : 0=low 1=high 1: 1=low 0=high	RW	0x0
11	SBIT2	<u>Channel 1 Silence Bit</u> Defines the state of the output when no transmission takes place	RW	0x0



## BCM2835 ARM Peripherals

10	RPTL2	<u>Channel 1 Repeat Last Data</u> 0: Transmission interrupts when FIFO is empty 1: Last data in FIFO is transmitted repeatedly until FIFO is not empty	RW	0x0
9	MODE2	<u>Channel 1 Mode</u> 0: PWM mode 1: Serialiser mode	RW	0x0
8	PWEN2	<u>Channel 1 Enable</u> 0: Channel is disabled 1: Channel is enabled	RW	0x0
7	MSEN1	<u>Channel 1 M/S Enable</u> 0: PWM algorithm is used 1: M/S transmission is used.	RW	0x0
6	CLRF1	<u>Clear Fifo</u> 1: Clears FIFO 0: Has no effect This is a single shot operation. This bit always reads 0	RO	0x0
5	USEF1	<u>Channel 1 Use Fifo</u> 0: Data register is transmitted 1: Fifo is used for transmission	RW	0x0
4	POLA1	<u>Channel 1 Polarity</u> 0 : 0=low 1=high 1: 1=low 0=high	RW	0x0
3	SBIT1	<u>Channel 1 Silence Bit</u> Defines the state of the output when no transmission takes place	RW	0x0
2	RPTL1	<u>Channel 1 Repeat Last Data</u> 0: Transmission interrupts when FIFO is empty 1: Last data in FIFO is transmitted repeatedly until FIFO is not empty	RW	0x0
1	MODE1	<u>Channel 1 Mode</u> 0: PWM mode 1: Serialiser mode	RW	0x0
0	PWEN1	<u>Channel 1 Enable</u> 0: Channel is disabled 1: Channel is enabled	RW	0x0



# BCM2835 ARM Peripherals

## STA Register

**Synopsis** FULL1 bit indicates the full status of the FIFO. If this bit is high FIFO is full.  
EMPT1 bit indicates the empty status of the FIFO. If this bit is high FIFO is empty.  
WERR1 bit sets to high when a write when full error occurs. Software must clear this bit by writing 1. Writing 0 to this bit has no effect.  
RERR1 bit sets to high when a read when empty error occurs. Software must clear this bit by writing 1. Writing 0 to this bit has no effect.  
GAPOi. bit indicates that there has been a gap between transmission of two consecutive data from FIFO. This may happen when FIFO gets empty after state machine has sent a word and waits for the next. If control bit RPTLi is set to high this event will not occur. Software must clear this bit by writing 1. Writing 0 to this bit has no effect.  
BERR sets to high when an error has occurred while writing to registers via APB. This may happen if the bus tries to write successively to same set of registers faster than the synchroniser block can cope with. Multiple switching may occur and contaminate the data during synchronisation. Software should clear this bit by writing 1. Writing 0 to this bit has no effect.  
STAi bit indicates the current state of the channel which is useful for debugging purposes. 0 means the channel is not currently transmitting. 1 means channel is transmitting data.

Bit(s)	Field Name	Description	Type	Reset
31:13		<i>Reserved - Write as 0, read as don't care</i>		
12	STA4	<u>Channel 4 State</u>	RW	0x0
11	STA3	<u>Channel 3 State</u>	RW	0x0
10	STA2	<u>Channel 2 State</u>	RW	0x0
9	STA1	<u>Channel 1 State</u>	RW	0x0
8	BERR	<u>Bus Error Flag</u>	RW	0x0
7	GAPO4	<u>Channel 4 Gap Occurred Flag</u>	RW	0x0
6	GAPO3	<u>Channel 3 Gap Occurred Flag</u>	RW	0x0
5	GAPO2	<u>Channel 2 Gap Occurred Flag</u>	RW	0x0
4	GAPO1	<u>Channel 1 Gap Occurred Flag</u>	RW	0x0
3	RERR1	<u>Fifo Read Error Flag</u>	RW	0x0
2	WERR1	<u>Fifo Write Error Flag</u>	RW	0x0





# BCM2835 ARM Peripherals

1	EMPT1	<u>Fifo Empty Flag</u>	RW	0x1
0	FULL1	<u>Fifo Full Flag</u>	RW	0x0

## DMAC Register

**Synopsis** ENAB bit is used to start DMA.  
 PANIC bits are used to determine the threshold level for PANIC signal going active.  
 Default value is 7.  
 DREQ bits are used to determine the threshold level for DREQ signal going active.  
 Default value is 7.

Bit(s)	Field Name	Description	Type	Reset
31	ENAB	<u>DMA Enable</u> 0: DMA disabled 1: DMA enabled	RW	0x0
30:16		<b>Reserved</b> - Write as 0, read as don't care		
15:8	PANIC	<u>DMA Threshold for PANIC signal</u>	RW	0x7
7:0	DREQ	<u>DMA Threshold for DREQ signal</u>	RW	0x7

## RNG1 Register

**Synopsis** This register is used to define the range for the corresponding channel. In PWM mode evenly distributed pulses are sent within a period of length defined by this register. In serial mode serialised data is transmitted within the same period. If the value in PWM\_RNGi is less than 32, only the first PWM\_RNGi bits are sent resulting in a truncation. If it is larger than 32 excess zero bits are padded at the end of data. Default value for this register is 32.  
 Note: Channels 3 and 4 are not available in B0 and corresponding Channel Range Registers are ignored.

Bit(s)	Field Name	Description	Type	Reset
31:0	PWM_RNGi	<u>Channel i Range</u>	RW	0x20



# BCM2835 ARM Peripherals

## DAT1 Register

**Synopsis** This register stores the 32 bit data to be sent by the PWM Controller when USEFi is 0. In PWM mode data is sent by pulse width modulation: the value of this register defines the number of pulses which is sent within the period defined by PWM\_RNGi. In serialiser mode data stored in this register is serialised and transmitted.  
Note: Channels 3 and 4 are not available in B0 and corresponding Channel Data Registers are ignored.

Bit(s)	Field Name	Description	Type	Reset
31:0	PWM_DATi	<u>Channel i Data</u>	RW	0x0

## FIF1 Register

**Synopsis** This register is the FIFO input for the all channels. Data written to this address is stored in channel FIFO and if USEFi is enabled for the channel i it is used as data to be sent. This register is write only, and reading this register will always return bus default return value, pwm0 .  
When more than one channel is enabled for FIFO usage, the data written into the FIFO is shared between these channels in turn. For example if the word series A B C D E F G H I .. is written to FIFO and two channels are active and configured to use FIFO then channel 1 will transmit words A C E G I .. and channel 2 will transmit words B D F H .. .  
Note that requesting data from the FIFO is in locked-step manner and therefore requires tight coupling of state machines of the channels. If any of the channel range (period) value is different than the others this will cause the channels with small range values to wait between words hence resulting in gaps between words. To avoid that, each channel sharing the FIFO should be configured to use the same range value. Also note that RPTLi are not meaningful when the FIFO is shared between channels as there is no defined channel to own the last data in the FIFO. Therefore sharing channels must have their RPTLi set to zero.  
If the set of channels to share the FIFO has been modified after a configuration change, FIFO should be cleared before writing new data.

Bit(s)	Field Name	Description	Type	Reset
31:0	PWM_FIFO	<u>Channel FIFO Input</u>	RW	0x0

## RNG2 Register



## BCM2835 ARM Peripherals

**Synopsis** This register is used to define the range for the corresponding channel. In PWM mode evenly distributed pulses are sent within a period of length defined by this register. In serial mode serialised data is transmitted within the same period. If the value in PWM\_RNGi is less than 32, only the first PWM\_RNGi bits are sent resulting in a truncation. If it is larger than 32 excess zero bits are padded at the end of data. Default value for this register is 32.

Note: Channels 3 and 4 are not available in B0 and corresponding Channel Range Registers are ignored.

Bit(s)	Field Name	Description	Type	Reset
31:0	PWM_RNGi	<u>Channel i Range</u>	RW	0x20

### DAT2 Register

**Synopsis** This register stores the 32 bit data to be sent by the PWM Controller when USEFi is 1. In PWM mode data is sent by pulse width modulation: the value of this register defines the number of pulses which is sent within the period defined by PWM\_RNGi. In serialiser mode data stored in this register is serialised and transmitted.

Note: Channels 3 and 4 are not available in B0 and corresponding Channel Data Registers are ignored.

Bit(s)	Field Name	Description	Type	Reset
31:0	PWM_DATi	<u>Channel i Data</u>	RW	0x0

## 10 SPI

### 10.1 Introduction

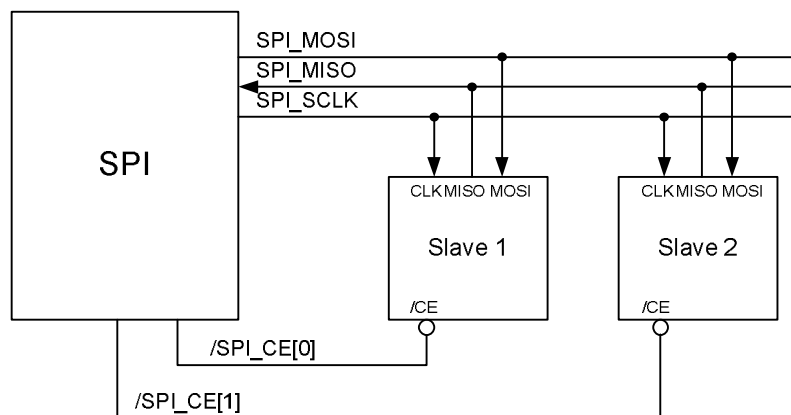
This Serial interface peripheral supports the following features:

- Implements a 3 wire serial protocol, variously called Serial Peripheral Interface (SPI) or Synchronous Serial Protocol (SSP).
- Implements a 2 wire version of SPI that uses a single wire as a bidirectional data wire instead of one for each direction as in standard SPI.
- Implements a LoSSI Master (Low Speed Serial Interface)
- Provides support for polled, interrupt or DMA operation.

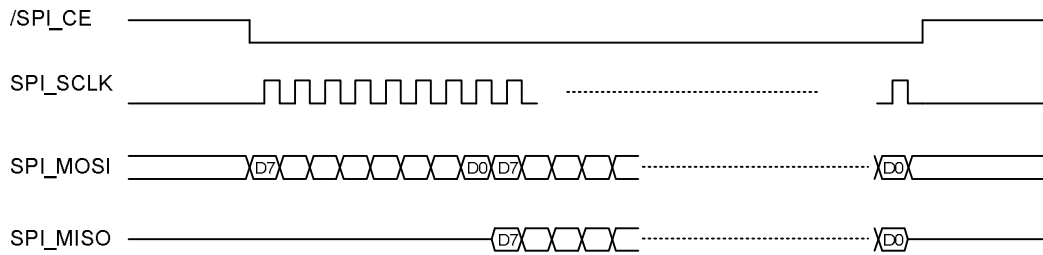
### 10.2 SPI Master Mode

#### 10.2.1 Standard mode

In Standard SPI master mode the peripheral implements the standard 3 wire serial protocol described below.



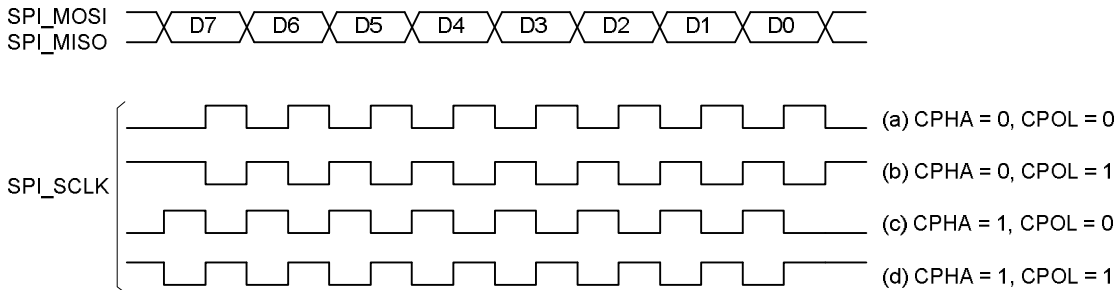
**Figure 10-1 SPI Master Typical Usage**



**Notes**

1. Slave enables itself onto SPI\_MISO only when it is outputting data. At other times, output is tristate.
2. Different SCLK polarity and phase values are possible. Case illustrated is CPOL = 0, CPHA = 0.
3. Data is transmitted MSB first.
4. Transactions can be from a single byte to hundreds of bytes.

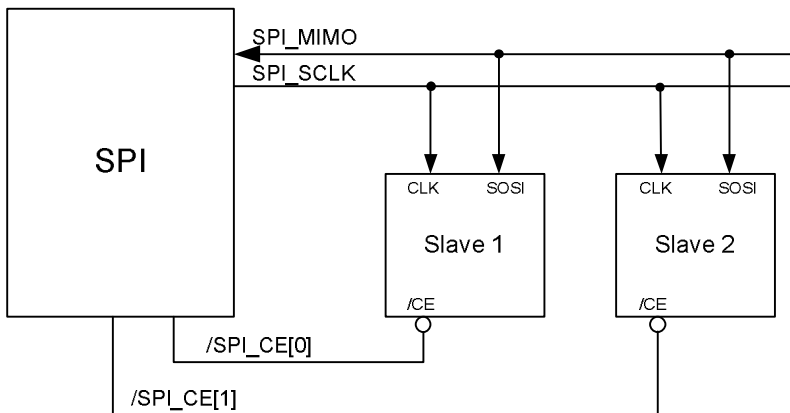
**Figure 10-2 SPI Cycle**



**Figure 10-3 Different Clock Polarity/Phase**

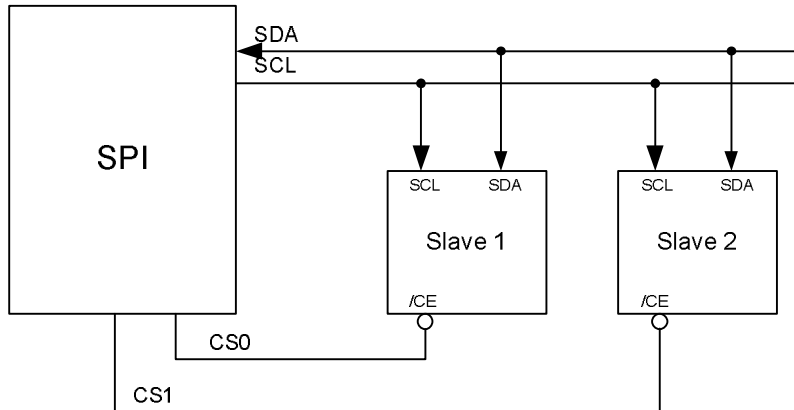
### 10.2.2 Bidirectional mode

In bidirectional SPI master mode the same SPI standard is implemented except that a single wire is used for the data (MIMO) instead of the two as in standard mode (MISO and MOSI). Bidirectional mode is used in a similar way to standard mode, the only difference is that before attempting to read data from the slave, you must set the read enable (SPI\_REN) bit in the SPI control and status register (SPI\_CS). This will turn the bus around, and when you write to the SPI\_FIFO register (with junk) a read transaction will take place on the bus, and the read data will appear in the FIFO.



**Figure 10-4 Bidirectional SPI Master Typical Usage**

## 10.3 LoSSI mode

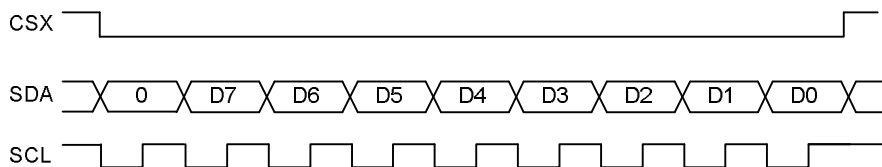


**Figure 10-5 LoSSI mode Typical usage**

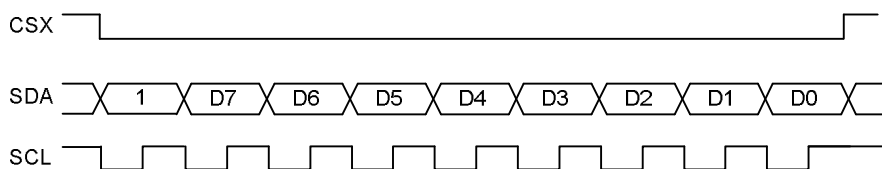
The LoSSI standard allows us to issue commands to peripherals and to transfer data to and from them. LoSSI commands and parameters are 8 bits long, but an extra bit is used to indicate whether the byte is a command or data. This extra bit is set high for a parameter and low for a command. The resulting 9-bit value is serialized to the output. When reading from a LoSSI peripheral the standard allows us to read bytes of data, as well as 24 and 32 bit words.

Commands and parameters are issued to a LoSSI peripheral by writing the 9-bit value of the command or data into the SPI\_FIFO register as you would for SPI mode. Reads are automated in that if the serial interface peripheral detects a read command being issued, it will issue the command and complete the read transaction, putting the received data into the FIFO.

### 10.3.1 Command write

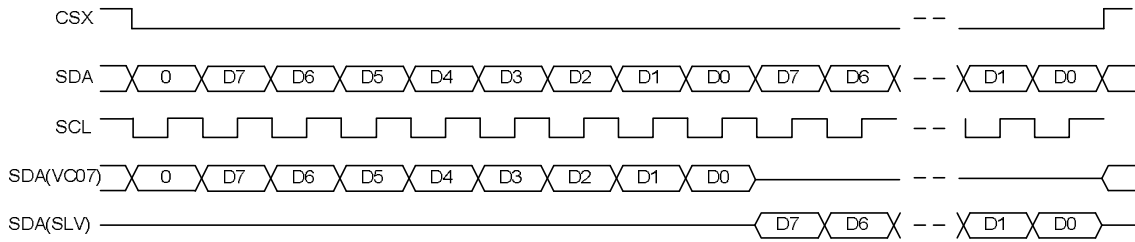


### 10.3.2 Parameter write



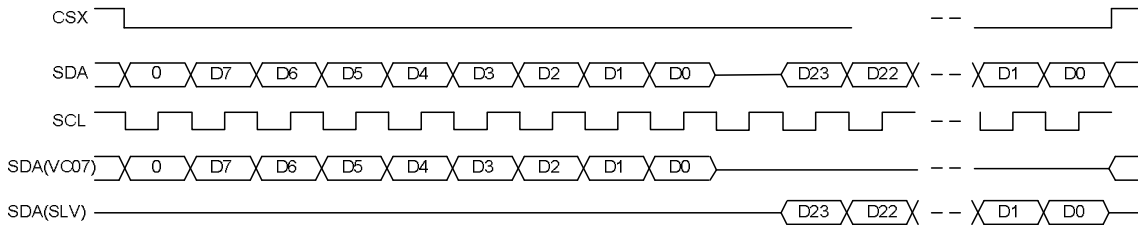
### 10.3.3 Byte read commands

Byte read commands are 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f, 0xda, 0xdb, 0xdc.



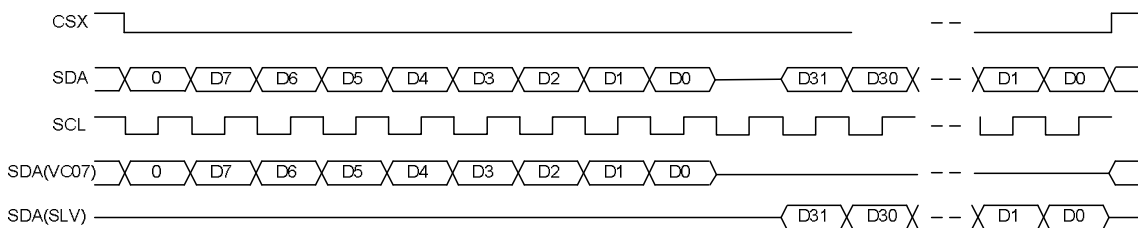
### 10.3.4 24bit read command

A 24 bit read can be achieved by using the command 0x04.



### 10.3.5 32bit read command

A 32bit read can be achieved by using the command 0x09.



## 10.4 Block Diagram

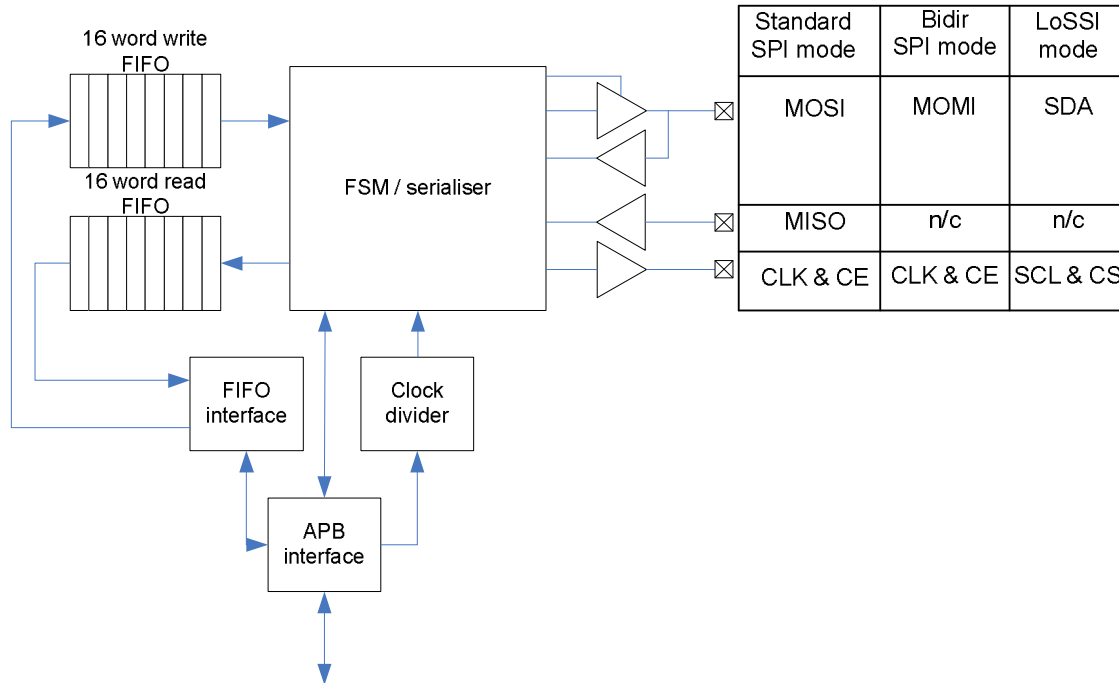


Figure 10-6 Serial interface Block Diagram

## 10.5 SPI Register Map

The BCM2835 devices has only one SPI interface of this type. It is referred to in all the documentation as SPI0. It has two additional mini SPI interfaces (SPI1 and SPI2). The specification of those can be found under 2.3 *Universal SPI Master (2x)*.

The base address of this SPI0 interface is 0x7E204000.

SPI Address Map			
Address Offset	Register Name	Description	Size
0x0	<a href="#">CS</a>	SPI Master Control and Status	32
0x4	<a href="#">FIFO</a>	SPI Master TX and RX FIFOs	32
0x8	<a href="#">CLK</a>	SPI Master Clock Divider	32





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0xc	<a href="#">DLEN</a>	SPI Master Data Length	32
0x10	<a href="#">LTOH</a>	SPI LOSSI mode TOH	32
0x14	<a href="#">DC</a>	SPI DMA DREQ Controls	32

## CS Register

**Synopsis** This register contains the main control and status bits for the SPI.

Bit(s)	Field Name	Description	Type	Reset
31:26		<b>Reserved</b> - Write as 0, read as don't care		
25	LEN_LONG	<u>Enable Long data word in Lossi mode if DMA_LEN is set</u> 0= writing to the FIFO will write a single byte 1= wrirng to the FIFO will write a 32 bit word	RW	0x0
24	DMA_LEN	<u>Enable DMA mode in Lossi mode</u>	RW	0x0
23	CSPOL2	<u>Chip Select 2 Polarity</u> 0= Chip select is active low. 1= Chip select is active high.	RW	0x0
22	CSPOL1	<u>Chip Select 1 Polarity</u> 0= Chip select is active low. 1= Chip select is active high.	RW	0x0
21	CSPOL0	<u>Chip Select 0 Polarity</u> 0= Chip select is active low. 1= Chip select is active high.	RW	0x0
20	RXF	<u>RXF - RX FIFO Full</u> 0 = RXFIFO is not full. 1 = RX FIFO is full. No further serial data will be sent/ received until data is read from FIFO.	RO	0x0
19	RXR	<u>RXR RX FIFO needs Reading ( full)</u> 0 = RX FIFO is less than full (or not active TA = 0). 1 = RX FIFO is or more full. Cleared by reading sufficient data from the RX FIFO or setting TA to 0.	RO	0x0



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18	TXD	<u>TXD TX FIFO can accept Data</u> 0 = TX FIFO is full and so cannot accept more data. 1 = TX FIFO has space for at least 1 byte.	RO	0x1
17	RXD	<u>RXD RX FIFO contains Data</u> 0 = RX FIFO is empty. 1 = RX FIFO contains at least 1 byte.	RO	0x0
16	DONE	<u>Done transfer Done</u> 0 = Transfer is in progress (or not active TA = 0). 1 = Transfer is complete. Cleared by writing more data to the TX FIFO or setting TA to 0.	RO	0x0
15	TE_EN	<u>Unused</u>	RW	0x0
14	LMONO	<u>Unused</u>	RW	0x0
13	LEN	<u>LEN LoSSI enable</u> The serial interface is configured as a LoSSI master. 0 = The serial interface will behave as an SPI master. 1 = The serial interface will behave as a LoSSI master.	RW	0x0
12	REN	<u>REN Read Enable</u> read enable if you are using bidirectional mode. If this bit is set, the SPI peripheral will be able to send data to this device. 0 = We intend to write to the SPI peripheral. 1 = We intend to read from the SPI peripheral.	RW	0x1
11	ADCS	<u>ADCS Automatically Deassert Chip Select</u> 0 = Don t automatically deassert chip select at the end of a DMA transfer chip select is manually controlled by software. 1 = Automatically deassert chip select at the end of a DMA transfer (as determined by SPIDLEN)	RW	0x0
10	INTR	<u>INTR Interrupt on RXR</u> 0 = Don t generate interrupts on RX FIFO condition. 1 = Generate interrupt while RXR = 1.	RW	0x0
9	INTD	<u>INTD Interrupt on Done</u> 0 = Don t generate interrupt on transfer complete. 1 = Generate interrupt when DONE = 1.	RW	0x0



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8	DMAEN	<u>DMAEN DMA Enable</u> 0 = No DMA requests will be issued. 1 = Enable DMA operation. Peripheral generates data requests. These will be taken in four-byte words until the SPIDLEN has been reached.	RW	0x0
7	TA	<u>Transfer Active</u> 0 = Transfer not active./CS lines are all high (assuming CSPOL = 0). RXR and DONE are 0. Writes to SPIFIFO write data into bits -0 of SPICS allowing DMA data blocks to set mode before sending data. 1 = Transfer active. /CS lines are set according to CS bits and CSPOL. Writes to SPIFIFO write data to TX FIFO.TA is cleared by a dma_frame_end pulse from the DMA controller.	RW	0x0
6	CSPOL	<u>Chip Select Polarity</u> 0 = Chip select lines are active low 1 = Chip select lines are active high	RW	0x0
5:4	CLEAR	<u>CLEAR FIFO Clear</u> 00 = No action. x1 = Clear TX FIFO. One shot operation. 1x = Clear RX FIFO. One shot operation. If CLEAR and TA are both set in the same operation, the FIFOs are cleared before the new frame is started. Read back as 0.	RW	0x0
3	CPOL	<u>Clock Polarity</u> 0 = Rest state of clock = low. 1 = Rest state of clock = high.	RW	0x0
2	CPHA	<u>Clock Phase</u> 0 = First SCLK transition at middle of data bit. 1 = First SCLK transition at beginning of data bit.	RW	0x0
1:0	CS	<u>Chip Select</u> 00 = Chip select 0 01 = Chip select 1 10 = Chip select 2 11 = Reserved	RW	0x0

## FIFO Register

**Synopsis** This register allows TX data to be written to the TX FIFO and RX data to be read from the RX FIFO.



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Bit(s)	Field Name	Description	Type	Reset
31:0	DATA	<u>DMA Mode (DMAEN set)</u> If TA is clear, the first 32-bit write to this register will control SPIDLEN and SPICS. Subsequent reads and writes will be taken as four-byte data words to be read/written to the FIFOs <u>Poll/Interrupt Mode (DMAEN clear, TA set)</u> Writes to the register write bytes to TX FIFO. Reads from register read bytes from the RX FIFO	RW	0x0

## CLK Register

**Synopsis** This register allows the SPI clock rate to be set.

Bit(s)	Field Name	Description	Type	Reset
31:16		<b>Reserved</b> - Write as 0, read as don't care		
15:0	CDIV	<u>Clock Divider</u> $SCLK = \text{Core Clock} / CDIV$ If CDIV is set to 0, the divisor is 65536. The divisor must be a power of 2. Odd numbers rounded down. The maximum SPI clock rate is of the APB clock.	RW	0x0

## DLEN Register

**Synopsis** This register allows the SPI data length rate to be set.

Bit(s)	Field Name	Description	Type	Reset
31:16		<b>Reserved</b> - Write as 0, read as don't care		
15:0	LEN	<u>Data Length</u> The number of bytes to transfer. This field is only valid for DMA mode (DMAEN set) and controls how many bytes to transmit (and therefore receive).	RW	0x0



## BCM2835 ARM Peripherals

### LTOH Register

**Synopsis** This register allows the LoSSI output hold delay to be set.

Bit(s)	Field Name	Description	Type	Reset
31:4		<i>Reserved - Write as 0, read as don't care</i>		
3:0	TOH	<u>This sets the Output Hold delay in APB clocks. A value of 0 causes a 1 clock delay.</u>	RW	0x1

### DC Register

**Synopsis** This register controls the generation of the DREQ and Panic signals to an external DMA engine. The DREQ signals are generated when the FIFOs reach their defined levels and need servicing. The Panic signals instruct the external DMA engine to raise the priority of its AXI requests.

Bit(s)	Field Name	Description	Type	Reset
31:24	RPANIC	<u>DMA Read Panic Threshold.</u> Generate the Panic signal to the RX DMA engine whenever the RX FIFO level is greater than this amount.	RW	0x30
23:16	RDREQ	<u>DMA Read Request Threshold.</u> Generate a DREQ to the RX DMA engine whenever the RX FIFO level is greater than this amount, (RX DREQ is also generated if the transfer has finished but the RXFIFO isn't empty).	RW	0x20
15:8	TPANIC	<u>DMA Write Panic Threshold.</u> Generate the Panic signal to the TX DMA engine whenever the TX FIFO level is less than or equal to this amount.	RW	0x10
7:0	TDREQ	<u>DMA Write Request Threshold.</u> Generate a DREQ signal to the TX DMA engine whenever the TX FIFO level is less than or equal to this amount.	RW	0x20

## 10.6 Software Operation

### 10.6.1 Polled

- a) Set CS, CPOL, CPHA as required and set TA = 1.
- b) Poll TXD writing bytes to SPI\_FIFO, RXD reading bytes from SPI\_FIFO until all data written.
- c) Poll DONE until it goes to 1.
- d) Set TA = 0.

### 10.6.2 Interrupt

- e) Set INTR and INTD. These can be left set over multiple operations.
- f) Set CS, CPOL, CPHA as required and set TA = 1. This will immediately trigger a first interrupt with DONE == 1.
- g) On interrupt:
- h) If DONE is set and data to write (this means it is the first interrupt), write up to 16 bytes to SPI\_FIFO. If DONE is set and no more data, set TA = 0. Read trailing data from SPI\_FIFO until RXD is 0.
- i) If RXR is set read 12 bytes data from SPI\_FIFO and if more data to write, write up to 12 bytes to SPI\_FIFO.

### 10.6.3 DMA

**Note:** In order to function correctly, each DMA channel must be set to perform 32-bit transfers when communicating with the SPI. Either the Source or the Destination Transfer Width field in the DMA TI register must be set to 0 (i.e. 32-bit words) depending upon whether the channel is reading or writing to the SPI.

Two DMA channels are required, one to read from and one to write to the SPI.

- j) Enable DMA DREQ's by setting the DMAEN bit and ADCS if required.
- k) Program two DMA control blocks, one for each DMA controller.
- l) DMA channel 1 control block should have its PER\_MAP set to x and should be set to write 'transfer length' + 1 words to SPI\_FIFO. The data should comprise:
  - i) A word with the transfer length in bytes in the top sixteen bits, and the control register settings [7:0] in the bottom eight bits (i.e. TA = 1, CS, CPOL, CPHA as required.)
  - ii) 'Transfer length' number in words of data to send.
- m) DMA channel 2 control block should have its PER\_MAP set to y and should be set to read 'transfer length' words from SPI\_FIFO.
- n) Point each DMA channel at its CB and set its ACTIVE bit to 1.
- o) On receipt of an interrupt from DMA channel 2, the transfer is complete.

## 10.6.4 Notes

1. The SPI Master knows nothing of the peripherals it is connected to. It always both sends and receives bytes for every byte of the transaction.
2. SCLK is only generated during byte serial transfer. It pauses in the rest state if the next byte to send is not ready or RXF is set.
3. Setup and Hold times related to the automatic assertion and de-assertion of the CS lines when operating in DMA mode (DMAEN and ADCS set) are as follows:

The CS line will be asserted at least 3 core clock cycles before the msb of the first byte of the transfer.

The CS line will be de-asserted no earlier than 1 core clock cycle after the trailing edge of the final clock pulse.

If these parameters are insufficient, software control should alleviate the problem. ADCS should be 0 allowing software to manually control the assertion and de-assertion of the CS lines.



## 11 SPI/BSC SLAVE

### 11.1 Introduction

The BSC interface can be used as either a Broadcom Serial Controller (BSC) or a Serial Peripheral Interface (SPI) controller. The BSC bus is a proprietary bus compliant with the Philips® I2C bus/interface version 2.1 January 2000. Both BSC and SPI controllers work in the slave mode. The BSC slave controller has specially built in the Host Control and Software Registers for a Chip booting. The BCS controller supports fast-mode (400Kb/s) and it is compliant to the I<sup>2</sup>C bus specification version 2.1 January 2000 with the restrictions:

- I<sup>2</sup>C slave only operation
- clock stretching is not supported
- 7-bit addressing only
- 

There is only one BSC/SPI slave. The registers base addresses is 0x7E21\_4000.

### 11.2 Registers

The SPI controller implements 3 wire serial protocol variously called Serial Peripheral Interface (SPI) or Synchronous Serial Protocol (SSP). BSC and SPI controllers do not have DMA connected, hence DMA is not supported.

I2C_SPI_SLV Address Map			
Address Offset	Register Name	Description	Size
0x0	<a href="#">DR</a>	Data Register	32
0x4	<a href="#">RSR</a>	The operation status register and error clear register	32
0x8	<a href="#">SLV</a>	The I2C SPI Address Register holds the I2C slave address value	32
0xc	<a href="#">CR</a>	The Control register is used to configure the I2C or SPI operation	32
0x10	<a href="#">FR</a>	Flag register	32
0x14	<a href="#">IFLS</a>	Interrupt fifo level select register	32
0x18	<a href="#">IMSC</a>	Interupt Mask Set Clear Register	32





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0x1c	<a href="#">RIS</a>	Raw Interupt Status Register	32
0x20	<a href="#">MIS</a>	Masked Interupt Status Register	32
0x24	<a href="#">ICR</a>	Interupt Clear Register	32
0x28	<a href="#">DMACR</a>	DMA Control Register	32
0x2c	<a href="#">TDR</a>	FIFO Test Data	32
0x30	<a href="#">GPUSTAT</a>	GPU Status Register	32
0x34	<a href="#">HCTRL</a>	Host Control Register	32
0x38	<a href="#">DEBUG1</a>	I2C Debug Register	32
0x3c	<a href="#">DEBUG2</a>	SPI Debug Register	32

## DR Register

**Synopsis** The I2C SPI Data Register is used to transfer/receive data characters and provide a Status and Flag information. Status and Flag information is also available via individual registers.

Bit(s)	Field Name	Description	Type	Reset
31:27	RXFLEVEL	<u>RXFLEVEL RX FIFO Level</u> Returns the current level of the RX FIFO use	RO	0x0
26:22	TXFLEVEL	<u>TXFLEVEL TX FIFO Level</u> Returns the current level of the TX FIFO use	RO	0x0
21	RXBUSY	<u>RXBUSY Receive Busy</u> 0 Receive operation inactive 1 Receive operation in operation	RO	0x0
20	TXFE	<u>TXFE TX FIFO Empty</u> 0 TX FIFO is not empty 1 When TX FIFO is empty	RO	0x1
19	RXFF	<u>RXFE RX FIFO Full</u> 0 FX FIFO is not full 1 When FX FIFO is full	RO	0x0



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18	TXFF	<u>TXFF TX FIFO Full</u> 0 TX FIFO is not full 1 When TX FIFO is full	RO	0x0
17	RXFE	<u>RXFE RX FIFO Empty</u> 0 FX FIFO is not empty 1 When FX FIFO is empty	RO	0x1
16	TXBUSY	<u>TXBUSY Transmit Busy</u> 0 Transmit operation inactive 1 Transmit operation in operation	RO	0x0
15:10		<b>Reserved</b> - Write as 0, read as don't care		
9	UE	<u>TXUE TX Underrun Error</u> 0 - No error case detected 1 Set when TX FIFO is empty and I2C master attempt to read a data character from I2C slave. Cleared by writing 0 to I2C SPI Status register .	RO	0x0
8	OE	<u>RXOE RX Overrun Error</u> 0 No error case detected 1 Set when RX FIFO is full and a new data character is received. Cleared by writing 0 to I2C SPI Status register .	RO	0x0
7:0	DATA	<u>DATA Received/Transferred data characters</u> Data written to this location is pushed into the TX FIFO. Data read from this location is fetched from the RX FIFO.	RW	0x0

## RSR Register

**Synopsis** The operation status register and error clear register.

Bit(s)	Field Name	Description	Type	Reset
31:6		<b>Reserved</b> - Write as 0, read as don't care		
5	RXDMABREQ	<u>Unsupported, write zero, read as don't care</u>	RO	0x0
4	RXDMAPREQ	<u>Unsupported, write zero, read as don't care</u>	RO	0x0
3	TXDMABREQ	<u>Unsupported, write zero, read as don't care</u>	RO	0x0



# BCM2835 ARM Peripherals

2	TXDMPREQ	<u>Unsupported, write zero, read as don't care</u>	RO	0x0
1	UE	<u>TXUE TX Underrun Error</u> 0 - No error case detected 1 Set when TX FIFO is empty and I2C master attempt to read a data character from I2C slave. Cleared by writing 0 to it.	RW	0x0
0	OE	<u>RXOE RX Overrun Error</u> 0 No error case detected 1 Set when RX FIFO is full and a new data character is received. Cleared by writing 0 to it.	RW	0x0

## SLV Register

**Synopsis** The I2C SPI Address Register holds the I2C slave address value. NOTE: It is of no use in SPI mode.

Bit(s)	Field Name	Description	Type	Reset
31:7		<b>Reserved</b> - Write as 0, read as don't care		
6:0	ADDR	<u>SLVADDR I2C Slave Address</u> Programmable I2C slave address Note: In case HOSTCTRLLEN bit is set from the I2C SPI Control Register bit SLVADDR[0] chooses the following: 0 - selects normal operation, i.e. accessing RX and TX FIFOs. 1 - selects access to I2C SPI SW Status Register or I2C SPI Host Control Register	RW	0x0

## CR Register

**Synopsis** The Control register is used to configure the I2C or SPI operation.

Bit(s)	Field Name	Description	Type	Reset
31:14		<b>Reserved</b> - Write as 0, read as don't care		



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13	INV_TXF	<p><u>INV-RX Inverse TX status flags</u>            0 = default status flags            When this bit is 0, bit 6 (TXFE - TX FIFO Empty) will reset to a 1            1 = inverted status flags            When this bit is set, bit 6 (TXFE - TX FIFO Full) will reset to a 0</p> <p>* Note: INV_TX bit changes the default values of 6 bit as it is specified for I2C SPI GPU Host Status Register .</p>	RW	0x0
12	HOSTCTRLLEN	<p><u>HOSTCTRLLEN Enable Control for Host</u>            0 = Host Control disabled            1 = Host Control enabled            Note: HOSTCTRLLEN allows Host to request GPUSTAT or HCTRL register. The same behaviour is achieved from the GPU side using ENSTAT and ENCTRL.</p>	RW	0x0
11	TESTFIFO	<p><u>TESTFIFO TEST FIFO</u>            0 = TESTT FIFO disabled            1 = TESTT FIFO enabled</p>	RW	0x0
10	INV_RXF	<p><u>INV-RX Inverse RX status flags</u>            0 = default status flags            When this bit is 0, bit 6 (RXFF - RX FIFO Full) will reset to a 0</p> <p>1 = inverted status flags            When this bit is 0, bit 6 (RXFF - RX FIFO Empty) will reset to a 1            * NOTE: INV_RX bit changes the default values of 7 bit as it is specified for I2C SPI GPU Host Status Register .</p>	RW	0x0
9	RXE	<p><u>RXE Receive Enable</u>            0 = Receive mode disabled            1 = Receive mode enabled</p>	RW	0x0
8	TXE	<p><u>TXE Transmit Enable</u>            0 = Transmit mode disabled            1 = Transmit mode enabled</p>	RW	0x0
7	BRK	<p><u>BRK Break current operation</u>            0 = No effect.            1 = Stop operation and clear the FIFOs.</p>	RW	0x0



# BCM2835 ARM Peripherals

6	ENCTRL	<u>ENCTRL ENABLE CONTROL 8bit register</u> 0 = Control register disabled. Implies ordinary I2C protocol. 1 = Control register enabled. When enabled the control register is received as a first data character on the I2C bus. NOTE: The same behaviour is achieved from the Host side by using bit SLVADDR[6] of the slave address.	RO	0x0
5	ENSTAT	<u>ENSTAT ENABLE STATUS 8bit register</u> 0 = Status register disabled. Implies ordinary I2C protocol. 1 = Status register enabled. When enabled the status register is transferred as a first data character on the I2C bus. Status register is transferred to the host. NOTE: The same behaviour is achieved from the Host side by using bit SLVADDR[6] of the slave address.	RW	0x0
4	CPOL	<u>CPOL Clock Polarity</u> 0 = 1 = SPI Related	RW	0x0
3	CPHA	<u>CPHA Clock Phase</u> 0 = 1 = SPI Related	RW	0x0
2	I2C	<u>SPI Mode</u> 0 = Disabled I2C mode 1 = Enabled I2C mode	RW	0x0
1	SPI	<u>SPI Mode</u> 0 = Disabled SPI mode 1 = Enabled SPI mode	RW	0x0
0	EN	<u>EN Enable Device</u> 1 = Enable I2C SPI Slave. 0 = Disable I2C SPI Slave.	RW	0x0

## FR Register

**Synopsis** The flag register indicates the current status of the operation.

Bit(s)	Field Name	Description	Type	Reset
31:16		<b>Reserved</b> - Write as 0, read as don't care		



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15:11	RXFLEVEL	<u>RXFLEVEL RX FIFO Level</u> Returns the current level of the RX FIFO use	RW	0x0
10:6	TXFLEVEL	<u>TXFLEVEL TX FIFO Level</u> Returns the current level of the TX FIFO use	RW	0x0
5	RXBUSY	<u>RXBUSY Receive Busy</u> 0 Receive operation inactive 1 Receive operation in operation	RW	0x0
4	TXFE	<u>TXFE TX FIFO Empty</u> 0 TX FIFO is not empty 1 When TX FIFO is empty	RW	0x1
3	RXFF	<u>RXFE RX FIFO Full</u> 0 FX FIFO is not full 1 When FX FIFO is full	RW	0x0
2	TXFF	<u>TXFF TX FIFO Full</u> 0 TX FIFO is not full 1 When TX FIFO is full	RW	0x0
1	RXFE	<u>RXFE RX FIFO Empty</u> 0 FX FIFO is not empty 1 When FX FIFO is empty	RW	0x1
0	TXBUSY	<u>TXBUSY Transmit Busy</u> 0 Transmit operation inactive 1 Transmit operation in operation	RW	0x0

## IFLS Register

**Synopsis** The flag register indicates the current status of the operation.

Bit(s)	Field Name	Description	Type	Reset
31:12		<b>Reserved</b> - Write as 0, read as don't care		
11:9	RXIFPSEL	<u>Unsupported, write zero, read as don't care</u>	RO	0x0
8:6	TXIFPSEL	<u>Unsupported, write zero, read as don't care</u>	RO	0x0



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5:3	RXIFLSEL	<u>RXIFLSEL RX Interrupt FIFO Level Select</u> Interrupt is triggered when : 000 RX FIFO gets 1/8 full 001 RX FIFO gets 1/4 full 010 RX FIFO gets 1/2 full 011 RX FIFO gets 3/4 full 100 RX FIFO gets 7/8 full 101 111 not used	RW	0x0
2:0	TXIFLSEL	<u>TXIFLSEL TX Interrupt FIFO Level Select</u> Interrupt is triggered when : 000 TX FIFO gets 1/8 full 001 TX FIFO gets 1/4 full 010 TX FIFO gets 1/2 full 011 TX FIFO gets 3/4 full 100 TX FIFO gets 7/8 full 101 111 not used	RW	0x0

## IMSC Register

**Synopsis** Interrupt Mask Set/Clear Register. On a read this register returns the current value of the mask on the relevant interrupt. On a write of 1 to the particular bit, it sets the corresponding mask of that interrupt. A write of 0 clears the corresponding mask.

Bit(s)	Field Name	Description	Type	Reset
31:4		<b>Reserved</b> - Write as 0, read as don't care		
3	OEIM	Overrun error interrupt mask. A read returns the current mask for the interrupt. On a write of 1, the mask of the OEINTR interrupt is set. A write of 0 clears the mask.	RW	0x0
2	BEIM	Break error interrupt mask. A read returns the current mask for the BEINTR interrupt. On a write of 1, the mask of the interrupt is set. A write of 0 clears the mask.	RW	0x0
1	TXIM	Transmit interrupt mask. A read returns the current mask for the TXINTR interrupt. On a write of 1, the mask of the interrupt is set. A write of 0 clears the mask.	RW	0x0
0	RXIM	Receive interrupt mask. A read returns the current mask for the RXINTR interrupt. On a write of 1, the mask of the interrupt is set. A write of 0 clears the mask.	RW	0x0



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### RIS Register

**Synopsis** The Raw Interrupt Status Register returns the current raw status value, prior to masking, of the corresponding interrupt.

Bit(s)	Field Name	Description	Type	Reset
31:4		<i>Reserved - Write as 0, read as don't care</i>		
3	OERIS	Overrun error interrupt status. Returns the raw interrupt state of the OEINTR interrupt.	RW	0x0
2	BERIS	Break error interrupt status. Returns the raw interrupt state of the BEINTR interrupt.	RW	0x0
1	TXRIS	Transmit interrupt status. Returns the raw interrupt state of the TXINTR interrupt.	RW	0x0
0	RXRIS	Receive interrupt status. Returns the raw interrupt state of the RXINTR interrupt.	RW	0x0

### MIS Register

**Synopsis** The Masked Interrupt Status Register returns the current masked status value of the corresponding interrupt.

Bit(s)	Field Name	Description	Type	Reset
31:4		<i>Reserved - Write as 0, read as don't care</i>		
3	OEMIS	Overrun error masked interrupt status. Returns the masked interrupt state of the OEINTR interrupt.	RW	0x0
2	BEMIS	Break error masked interrupt status. Returns the masked interrupt state of the BEINTR interrupt.	RW	0x0
1	TXMIS	Transmit masked interrupt status. Returns the masked interrupt state of the TXINTR interrupt.	RW	0x0
0	RXMIS	Receive masked interrupt status. Returns the masked interrupt state of the RXINTR interrupt.	RW	0x0





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## ICR Register

**Synopsis** The Interrupt Clear Register.

Bit(s)	Field Name	Description	Type	Reset
31:4		<i>Reserved - Write as 0, read as don't care</i>		
3	OEIC	Overrun error interrupt clear. Clears the OEINTR interrupt.	RW	0x0
2	BEIC	Break error interrupt clear. Clears the BEINTR interrupt.	RW	0x0
1	TXIC	Transmit interrupt clear. Clears the TXINTR interrupt.	RW	0x0
0	RXIC	Receive masked interrupt status. Returns the masked interrupt state of the RXINTR interrupt.	RW	0x0

## DMACR Register

**Synopsis** The DMA Control register is not supported in this version.

Bit(s)	Field Name	Description	Type	Reset
31:3		<i>Reserved - Write as 0, read as don't care</i>		
2	DMAONERR	Unsupported, write zero, read as don't care	RW	0x0
1	TXDMAE	Unsupported, write zero, read as don't care	RW	0x0
0	RXDMAE	Unsupported, write zero, read as don't care	RW	0x0

## TDR Register

**Synopsis** The Test Data Register enables data to be written into the receive FIFO and read out from the transmit FIFO for test purposes.



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Bit(s)	Field Name	Description	Type	Reset
31:8		<i>Reserved - Write as 0, read as don't care</i>		
7:0	DATA	Test data is written into the receive FIFO and read out of the transmit FIFO.	RW	0x0

## GPUSTAT Register

**Synopsis** The GPU SW Status Register to be passed via I2C bus to a Host.  
 NOTE: GPU SW Status Register is combined with the status bit coming from within I2C SPI Slave device. Hence, the I2C SPI GPU Host Status Register as it is seen by a Host is depicted on Table 1 14.

Bit(s)	Field Name	Description	Type	Reset
31:4		<i>Reserved - Write as 0, read as don't care</i>		
3:0	DATA	<u>GPUSTAT GPU to Host Status Register</u> SW controllable	RW	0x0

## HCTRL Register

**Synopsis** The Host Control register is received from the host side via I2C bus. When ENCTRL - enable control register bit is set, the host control register is received as the first data character after the I2C address.

Bit(s)	Field Name	Description	Type	Reset
31:8		<i>Reserved - Write as 0, read as don't care</i>		
7:0	DATA	<u>HCTRL Host Control Register</u> SW processing received via I2C bus	RW	0x0

## DEBUG1 Register

**Synopsis** I2C Debug Register



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Bit(s)	Field Name	Description	Type	Reset
31:26		<i>Reserved - Write as 0, read as don't care</i>		
25:0	DATA		RW	0xe

### DEBUG2 Register

**Synopsis** SPI Debug Register

Bit(s)	Field Name	Description	Type	Reset
31:24		<i>Reserved - Write as 0, read as don't care</i>		
23:0	DATA		RW	0x400000

## 12 System Timer

The System Timer peripheral provides four 32-bit timer channels and a single 64-bit free running counter. Each channel has an output compare register, which is compared against the 32 least significant bits of the free running counter values. When the two values match, the system timer peripheral generates a signal to indicate a match for the appropriate channel. The match signal is then fed into the interrupt controller. The interrupt service routine then reads the output compare register and adds the appropriate offset for the next timer tick. The free running counter is driven by the timer clock and stopped whenever the processor is stopped in debug mode.

The Physical (hardware) base address for the system timers is 0x7E003000.

### 12.1 System Timer Registers

ST Address Map			
Address Offset	Register Name	Description	Size
0x0	<a href="#">CS</a>	System Timer Control/Status	32
0x4	<a href="#">CLO</a>	System Timer Counter Lower 32 bits	32
0x8	<a href="#">CHI</a>	System Timer Counter Higher 32 bits	32
0xc	<a href="#">C0</a>	System Timer Compare 0	32
0x10	<a href="#">C1</a>	System Timer Compare 1	32
0x14	<a href="#">C2</a>	System Timer Compare 2	32
0x18	<a href="#">C3</a>	System Timer Compare 3	32

#### CS Register

**Synopsis** System Timer Control / Status.

This register is used to record and clear timer channel comparator matches. The system timer match bits are routed to the interrupt controller where they can generate an interrupt.

The M0-3 fields contain the free-running counter match status. Write a one to the relevant bit to clear the match detect status bit and the corresponding interrupt request line.

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Bit(s)	Field Name	Description	Type	Reset
31:4		<i>Reserved - Write as 0, read as don't care</i>		
3	M3	<u>System Timer Match 3</u> 0 = No Timer 3 match since last cleared. 1 = Timer 3 match detected.	RW	0x0
2	M2	<u>System Timer Match 2</u> 0 = No Timer 2 match since last cleared. 1 = Timer 2 match detected.	RW	0x0
1	M1	<u>System Timer Match 1</u> 0 = No Timer 1 match since last cleared. 1 = Timer 1 match detected.	RW	0x0
0	M0	<u>System Timer Match 0</u> 0 = No Timer 0 match since last cleared. 1 = Timer 0 match detected.	RW	0x0

## CLO Register

**Synopsis** System Timer Counter Lower bits.

The system timer free-running counter lower register is a read-only register that returns the current value of the lower 32-bits of the free running counter.

Bit(s)	Field Name	Description	Type	Reset
31:0	CNT	<u>Lower 32-bits of the free running counter value.</u>	RW	0x0

## CHI Register

**Synopsis** System Timer Counter Higher bits.

The system timer free-running counter higher register is a read-only register that returns the current value of the higher 32-bits of the free running counter.

Bit(s)	Field Name	Description	Type	Reset
31:0	CNT	<u>Higher 32-bits of the free running counter value.</u>	RW	0x0

## C0 C1 C2 C3 Register

**Synopsis** System Timer Compare.

The system timer compare registers hold the compare value for each of the four timer channels. Whenever the lower 32-bits of the free-running counter matches one of the compare values the corresponding bit in the system timer control/status register is set.

Each timer peripheral (minirun and run) has a set of four compare registers.

Bit(s)	Field Name	Description	Type	Reset
31:0	CMP	<u>Compare value for match channel n.</u>	RW	0x0

## 13 UART

The BCM2835 device has two UARTS. One mini UART and one PL011 UART. This section describes the PL011 UART. For details of the mini UART see 2.2 *Mini UART*.

The PL011 UART is a Universal Asynchronous Receiver/Transmitter. This is the ARM UART (PL011) implementation. The UART performs serial-to-parallel conversion on data characters received from an external peripheral device or modem, and parallel-to-serial conversion on data characters received from the Advanced Peripheral Bus (APB).

The ARM PL011 UART has some optional functionality which can be included or left out.

The following functionality is *not supported* :

- Infrared Data Association (IrDA)
- Serial InfraRed (SIR) protocol Encoder/Decoder (ENDEC)
- Direct Memory Access (DMA).

The UART provides:

- Separate 16x8 transmit and 16x12 receive FIFO memory.
- Programmable baud rate generator.
- Standard asynchronous communication bits (start, stop and parity). These are added prior to transmission and removed on reception.
- False start bit detection.
- Line break generation and detection.
- Support of the modem control functions CTS and RTS. However DCD, DSR, DTR, and RI are not supported.
- Programmable hardware flow control.
- Fully-programmable serial interface characteristics:
  - data can be 5, 6, 7, or 8 bits
  - even, odd, stick, or no-parity bit generation and detection
  - 1 or 2 stop bit generation
  - baud rate generation, dc up to  $UARTCLK/16$

The UART clock source and associated dividers are controlled by the Clock Manager.

For the in-depth UART overview, please, refer to the ARM PrimeCell UART (PL011) Revision: r1p5 Technical Reference Manual.

### 13.1 Variations from the 16C650 UART

The UART varies from the industry-standard 16C650 UART device as follows:

- Receive FIFO trigger levels are 1/8, 1/4, 1/2, 3/4, and 7/8
- Transmit FIFO trigger levels are 1/8, 1/4, 1/2, 3/4, and 7/8
- The internal register map address space, and the bit function of each register differ



- The deltas of the modem status signals are not available.

The following 16C650 UART features are not supported:

- 1.5 stop bits (1 or 2 stop bits only are supported)
- Independent receive clock.

## 13.2 Primary UART Inputs and Outputs

The UART has two primary inputs RXD, nCTS and two primary outputs TXD, nRTS. The remaining signals like SRIN, SROUT, OUT1, OUT2, DSR, DTR, and RI are not supported in this implementation. The following table shows the UART signals map on the General Purpose I/O (GPIO). For the insight on how to program alternate function refer to the GPIO paragraph.

	Pull	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5
GPIO14	Low	TXD0					
GPIO15	Low	RXD0					
GPIO16	Low				CTS0		
GPIO17	Low				RTS0		
GPIO30	Low				CTS0		
GPIO31	Low				RTS0		
GPIO32	Low				TXD0		
GPIO33	Low				RXD0		
GPIO36	High			TXD0			
GPIO37	Low			RXD0			
GPIO38	Low			RTS0			
GPIO39	Low			CTS0			

Table 13-1 UART Assignment on the GPIO Pin map

## 13.3 UART Interrupts

The UART has one intra-chip interrupt UARTINTR generated as the OR-ed function of the five individual interrupts.

- UARTINTR, this is an OR function of the five individual masked outputs:
  - UARTRXINTR
  - UARTRTXINTR
  - UARTRTINTR
  - UARTMSINTR, that can be caused by:
    - UARTCTSINTR, because of a change in the nUARTCTS modem status
    - UARTDSRINTR, because of a change in the nUARTDSR modem status.
  - UARTEINTR, that can be caused by an error in the reception:





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- UARTOEINTR, because of an overrun error
- UARTBEINTR, because of a break in the reception
- UARTPEINTR, because of a parity error in the received character
- UARTFEINTR, because of a framing error in the received character.

One can enable or disable the individual interrupts by changing the mask bits in the Interrupt Mask Set/Clear Register, UART\_IMSC. Setting the appropriate mask bit HIGH enables the interrupt.

## UARTRXINTR:

The transmit interrupt changes state when one of the following events occurs:

- If the FIFOs are enabled and the transmit FIFO is equal to or lower than the programmed trigger level then the transmit interrupt is asserted HIGH. The transmit interrupt is cleared by writing data to the transmit FIFO until it becomes greater than the trigger level, or by clearing the interrupt.
- If the FIFOs are disabled (have a depth of one location) and there is no data present in the transmitters single location, the transmit interrupt is asserted HIGH. It is cleared by performing a single write to the transmit FIFO, or by clearing the interrupt.

## UARTRTINTR:

The receive interrupt changes state when one of the following events occurs:

- If the FIFOs are enabled and the receive FIFO reaches the programmed trigger level. When this happens, the receive interrupt is asserted HIGH. The receive interrupt is cleared by reading data from the receive FIFO until it becomes less than the trigger level, or by clearing the interrupt.
- If the FIFOs are disabled (have a depth of one location) and data is received thereby filling the location, the receive interrupt is asserted HIGH. The receive interrupt is cleared by performing a single read of the receive FIFO, or by clearing the interrupt.

## 13.4 Register View

The PL011 USRT is mapped on base address 0x7E20100. It has the following memory-mapped registers.

UART Address Map			
Address Offset	Register Name	Description	Size
0x0	<a href="#">DR</a>	Data Register	32
0x4	<a href="#">RSRECR</a>		32
0x18	<a href="#">FR</a>	Flag register	32



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0x20	<a href="#">ILPR</a>	not in use	32
0x24	<a href="#">IBRD</a>	Integer Baud rate divisor	32
0x28	<a href="#">FBRD</a>	Fractional Baud rate divisor	32
0x2c	<a href="#">LCRH</a>	Line Control register	32
0x30	<a href="#">CR</a>	Control register	32
0x34	<a href="#">IFLS</a>	Interupt FIFO Level Select Register	32
0x38	<a href="#">IMSC</a>	Interupt Mask Set Clear Register	32
0x3c	<a href="#">RIS</a>	Raw Interupt Status Register	32
0x40	<a href="#">MIS</a>	Masked Interupt Status Register	32
0x44	<a href="#">ICR</a>	Interupt Clear Register	32
0x48	<a href="#">DMACR</a>	DMA Control Register	32
0x80	<a href="#">ITCR</a>	Test Control register	32
0x84	<a href="#">ITIP</a>	Integration test input reg	32
0x88	<a href="#">ITOP</a>	Integration test output reg	32
0x8c	<a href="#">TDR</a>	Test Data reg	32

**DR Register**



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**Synopsis** The UART\_DR Register is the data register. For words to be transmitted:  
if the FIFOs are enabled, data written to this location is pushed onto the transmit FIFO.  
if the FIFOs are not enabled, data is stored in the transmitter holding register (the bottom word of the transmit FIFO).  
The write operation initiates transmission from the UART. The data is prefixed with a start bit, appended with the appropriate parity bit (if parity is enabled), and a stop bit. The resultant word is then transmitted.  
For received words:  
if the FIFOs are enabled, the data byte and the 4-bit status (break, frame, parity, and overrun) is pushed onto the 12-bit wide receive FIFO  
if the FIFOs are not enabled, the data byte and status are stored in the receiving holding register (the bottom word of the receive FIFO).

Bit(s)	Field Name	Description	Type	Reset
31:12		<b>Reserved</b> - Write as 0, read as don't care		
11	OE	Overrun error. This bit is set to 1 if data is received and the receive FIFO is already full. This is cleared to 0 once there is an empty space in the FIFO and a new character can be written to it.	RW	0x0
10	BE	Break error. This bit is set to 1 if a break condition was detected, indicating that the received data input was held LOW for longer than a full-word transmission time (defined as start, data, parity and stop bits). In FIFO mode, this error is associated with the character at the top of the FIFO. When a break occurs, only one 0 character is loaded into the FIFO. The next character is only enabled after the receive data input goes to a 1 (marking state), and the next valid start bit is received.	RW	0x0
9	PE	Parity error. When set to 1, it indicates that the parity of the received data character does not match the parity that the EPS and SPS bits in the Line Control Register, UART_LCRH select. In FIFO mode, this error is associated with the character at the top of the FIFO.	RW	0x0



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8	FE	Framing error. When set to 1, it indicates that the received character did not have a valid stop bit (a valid stop bit is 1). In FIFO mode, this error is associated with the character at the top of the FIFO.	RW	0x0
7:0	DATA	Receive (read) data character. Transmit (write) data character.	RW	0x0

### RSRECR Register

**Synopsis** The UART\_RSRECR Register is the receive status register/error clear register. If the status is read from this register, then the status information for break, framing and parity corresponds to the data character read from the Data Register, UART\_DR. The status information for overrun is set immediately when an overrun condition occurs. NOTE: The received data character must be read first from the Data Register, UART\_DR on before reading the error status associated with that data character from this register.

Bit(s)	Field Name	Description	Type	Reset
31:4		<i>Reserved - Write as 0, read as don't care</i>		
3	OE	Overrun error. This bit is set to 1 if data is received and the receive FIFO is already full. This is cleared to 0 once there is an empty space in the FIFO and a new character can be written to it.	RW	0x0

2	BE	Break error. This bit is set to 1 if a break condition was detected, indicating that the received data input was held LOW for longer than a full-word transmission time (defined as start, data, parity and stop bits). In FIFO mode, this error is associated with the character at the top of the FIFO. When a break occurs, only one 0 character is loaded into the FIFO. The next character is only enabled after the receive data input goes to a 1 (marking state), and the next valid start bit is received.	RW	0x0
1	PE	Parity error. When set to 1, it indicates that the parity of the received data character does not match the parity that the EPS and SPS bits in the Line Control Register, UART_LCRH select. In FIFO mode, this error is associated with the character at the top of the FIFO.	RW	0x0
0	FE	Framing error. When set to 1, it indicates that the received character did not have a valid stop bit (a valid stop bit is 1). In FIFO mode, this error is associated with the character at the top of the FIFO.	RW	0x0

## FR Register

**Synopsis** The UART\_FR Register is the flag register.

Bit(s)	Field Name	Description	Type	Reset
31:9		<i>Reserved - Write as 0, read as don't care</i>		
8	RI	Unsupported, write zero, read as don't care	RW	0x0



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7	TXFE	<p>Transmit FIFO empty. The meaning of this bit depends on the state of the FEN bit in the Line Control Register, UARTLCR_LCRH.</p> <p>If the FIFO is disabled, this bit is set when the transmit holding register is empty.</p> <p>If the FIFO is enabled, the TXFE bit is set when the transmit FIFO is empty. This bit does not indicate if there is data in the transmit shift register.</p>	RW	0x1
6	RXFF	<p>Receive FIFO full. The meaning of this bit depends on the state of the FEN bit in the UARTLCR_LCRH Register.</p> <p>If the FIFO is disabled, this bit is set when the receive holding register is full.</p> <p>If the FIFO is enabled, the RXFF bit is set when the receive FIFO is full.</p>	RW	0x0
5	TXFF	<p>Transmit FIFO full. The meaning of this bit depends on the state of the FEN bit in the UARTLCR_LCRH Register.</p> <p>If the FIFO is disabled, this bit is set when the transmit holding register is full.</p> <p>If the FIFO is enabled, the TXFF bit is set when the transmit FIFO is full.</p>	RW	0x0
4	RXFE	<p>Receive FIFO empty. The meaning of this bit depends on the state of the FEN bit in the UARTLCR_H Register.</p> <p>If the FIFO is disabled, this bit is set when the receive holding register is empty.</p> <p>If the FIFO is enabled, the RXFE bit is set when the receive FIFO is empty.</p>	RW	0x0
3	BUSY	<p>UART busy. If this bit is set to 1, the UART is busy transmitting data. This bit remains set until the complete byte, including all the stop bits, has been sent from the shift register.</p> <p>This bit is set as soon as the transmit FIFO becomes non-empty, regardless of whether the UART is enabled or not.</p>	RW	0x0
2	DCD	Unsupported, write zero, read as don't care	RW	0x0
1	DSR	Unsupported, write zero, read as don't care	RW	0x0



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0	CTS	Clear to send. This bit is the complement of the UART clear to send, nUARTCTS, modem status input. That is, the bit is 1 when nUARTCTS is LOW.	RW	0x0
---	-----	--	----	-----

## ILPR Register

**Synopsis** This is the disabled IrDA register, writing to it has not effect and reading returns 0.

Bit(s)	Field Name	Description	Type	Reset
31:0	ILPR	Reserved - write zero, read as don't care.	RW	0x0

## IBRD Register

**Synopsis** The UART\_IBRD Register is the integer part of the baud rate divisor value.

Bit(s)	Field Name	Description	Type	Reset
31:16		<i>Reserved - Write as 0, read as don't care</i>		
15:0	IBRD	The integer baud rate divisor.	RW	0x0

## FBRD Register

**Synopsis** The UART\_FBRD Register is the fractional part of the baud rate divisor value. The baud rate divisor is calculated as follows:  
 Baud rate divisor BAUDDIV = (FUARTCLK/(16 Baud rate))  
 where FUARTCLK is the UART reference clock frequency. The BAUDDIV is comprised of the integer value IBRD and the fractional value FBRD. NOTE: The contents of the IBRD and FBRD registers are not updated until transmission or reception of the current character is complete.



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Bit(s)	Field Name	Description	Type	Reset
31:6		<i>Reserved - Write as 0, read as don't care</i>		
5:0	FBRD	The fractional baud rate divisor.	RW	0x0

## LCRH Register

**Synopsis** The UARTLCR\_LCRH Register is the line control register.  
 NOTE: The UART\_LCRH, UART\_IBRD, and UART\_FBRD registers must not be changed:  
 when the UART is enabled  
 when completing a transmission or a reception when it has been programmed to become disabled.

Bit(s)	Field Name	Description	Type	Reset
31:8		<i>Reserved - Write as 0, read as don't care</i>		
7	SPS	Stick parity select. 0 = stick parity is disabled 1 = either: if the EPS bit is 0 then the parity bit is transmitted and checked as a 1 if the EPS bit is 1 then the parity bit is transmitted and checked as a 0. See Table 25 9.	RO	0x0
6:5	WLEN	Word length. These bits indicate the number of data bits transmitted or received in a frame as follows: b11 = 8 bits b10 = 7 bits b01 = 6 bits b00 = 5 bits.	RW	0x0
4	FEN	Enable FIFOs: 0 = FIFOs are disabled (character mode) that is, the FIFOs become 1-byte-deep holding registers 1 = transmit and receive FIFO buffers are enabled (FIFO mode).	RW	0x0



3	STP2	Two stop bits select. If this bit is set to 1, two stop bits are transmitted at the end of the frame. The receive logic does not check for two stop bits being received.	RW	0x0
2	EPS	Even parity select. Controls the type of parity the UART uses during transmission and reception: 0 = odd parity. The UART generates or checks for an odd number of 1s in the data and parity bits. 1 = even parity. The UART generates or checks for an even number of 1s in the data and parity bits. This bit has no effect when the PEN bit disables parity checking and generation. See Table 25 9.	RW	0x0
1	PEN	Parity enable: 0 = parity is disabled and no parity bit added to the data frame 1 = parity checking and generation is enabled. See Table 25 9.	RW	0x0
0	BRK	Send break. If this bit is set to 1, a low-level is continually output on the TXD output, after completing transmission of the current character.	RW	0x0

## CR Register

**Synopsis** The UART\_CR Register is the control register.

NOTE:

To enable transmission, the TXE bit and UARTEN bit must be set to 1. Similarly, to enable reception, the RXE bit and UARTEN bit, must be set to 1.

NOTE:

Program the control registers as follows:

1. Disable the UART.
2. Wait for the end of transmission or reception of the current character.
3. Flush the transmit FIFO by setting the FEN bit to 0 in the Line Control Register, UART\_LCRH.
4. Reprogram the Control Register, UART\_CR.
5. Enable the UART.



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Bit(s)	Field Name	Description	Type	Reset
31:16		<i>Reserved - Write as 0, read as don't care</i>		
15	CTSEN	CTS hardware flow control enable. If this bit is set to 1, CTS hardware flow control is enabled. Data is only transmitted when the nUARTCTS signal is asserted.	RW	0x0
14	RTSEN	RTS hardware flow control enable. If this bit is set to 1, RTS hardware flow control is enabled. Data is only requested when there is space in the receive FIFO for it to be received.	RW	0x0
13	OUT2	Unsupported, write zero, read as don't care	RO	0x0
12	OUT1	Unsupported, write zero, read as don't care	RO	0x0
11	RTS	Request to send. This bit is the complement of the UART request to send, nUARTRTS, modem status output. That is, when the bit is programmed to a 1 then nUARTRTS is LOW.	RW	0x0
10	DTR	Unsupported, write zero, read as don't care	RO	0x0
9	RXE	Receive enable. If this bit is set to 1, the receive section of the UART is enabled. Data reception occurs for UART signals. When the UART is disabled in the middle of reception, it completes the current character before stopping.	RW	0x1
8	TXE	Transmit enable. If this bit is set to 1, the transmit section of the UART is enabled. Data transmission occurs for UART signals. When the UART is disabled in the middle of transmission, it completes the current character before stopping.	RW	0x1
7	LBE	Loopback enable. If this bit is set to 1, the UARTTXD path is fed through to the UARTRXD path. In UART mode, when this bit is set, the modem outputs are also fed through to the modem inputs. This bit is cleared to 0 on reset, to disable loopback.	RW	0x0



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6:3		<i>Reserved - Write as 0, read as don't care</i>		
2	SIRLP	Unsupported, write zero, read as don't care	RO	0x0
1	SIREN	Unsupported, write zero, read as don't care	RO	0x0
0	UARTEN	<u>UART enable:</u> 0 = UART is disabled. If the UART is disabled in the middle of transmission or reception, it completes the current character before stopping. 1 = the UART is enabled.	RW	0x0

## IFLS Register

**Synopsis** The UART\_IFLS Register is the interrupt FIFO level select register. You can use this register to define the FIFO level that triggers the assertion of the combined interrupt signal. The interrupts are generated based on a transition through a level rather than being based on the level. That is, the interrupts are generated when the fill level progresses through the trigger level. The bits are reset so that the trigger level is when the FIFOs are at the half-way mark.

Bit(s)	Field Name	Description	Type	Reset
31:12		<i>Reserved - Write as 0, read as don't care</i>		
11:9	RXIFPSEL	Unsupported, write zero, read as don't care	RO	0x0
8:6	TXIFPSEL	Unsupported, write zero, read as don't care	RO	0x0
5:3	RXIFLSEL	Receive interrupt FIFO level select. The trigger points for the receive interrupt are as follows: b000 = Receive FIFO becomes 1/8 full b001 = Receive FIFO becomes 1/4 full b010 = Receive FIFO becomes 1/2 full b011 = Receive FIFO becomes 3/4 full b100 = Receive FIFO becomes 7/8 full b101-b111 = reserved.	RW	0x0



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2:0	TXIFLSEL	Transmit interrupt FIFO level select. The trigger points for the transmit interrupt are as follows: b000 = Transmit FIFO becomes 1/8 full b001 = Transmit FIFO becomes 1/4 full b010 = Transmit FIFO becomes 1/2 full b011 = Transmit FIFO becomes 3/4 full b100 = Transmit FIFO becomes 7/8 full b101-b111 = reserved.	RW	0x0
-----	----------	---	----	-----

### IMSC Register

**Synopsis** The UART\_IMSC Register is the interrupt mask set/clear register. It is a read/write register. On a read this register returns the current value of the mask on the relevant interrupt. On a write of 1 to the particular bit, it sets the corresponding mask of that interrupt. A write of 0 clears the corresponding mask.

Bit(s)	Field Name	Description	Type	Reset
31:11		<i>Reserved - Write as 0, read as don't care</i>		
10	OEIM	Overrun error interrupt mask. A read returns the current mask for the interrupt. On a write of 1, the mask of the UARTOEINTR interrupt is set. A write of 0 clears the mask.	RW	0x0
9	BEIM	Break error interrupt mask. A read returns the current mask for the UARTBEINTR interrupt. On a write of 1, the mask of the interrupt is set. A write of 0 clears the mask.	RW	0x0
8	PEIM	Parity error interrupt mask. A read returns the current mask for the UARTPEINTR interrupt. On a write of 1, the mask of the interrupt is set. A write of 0 clears the mask.	RW	0x0
7	FEIM	Framing error interrupt mask. A read returns the current mask for the UARTFEINTR interrupt. On a write of 1, the mask of the interrupt is set. A write of 0 clears the mask.	RW	0x0



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6	RTIM	Receive timeout interrupt mask. A read returns the current mask for the UARTRTINTR interrupt. On a write of 1, the mask of the interrupt is set. A write of 0 clears the mask.	RW	0x0
5	TXIM	Transmit interrupt mask. A read returns the current mask for the UARTRXINTR interrupt. On a write of 1, the mask of the interrupt is set. A write of 0 clears the mask.	RW	0x0
4	RXIM	Receive interrupt mask. A read returns the current mask for the UARTRXINTR interrupt. On a write of 1, the mask of the interrupt is set. A write of 0 clears the mask.	RW	0x0
3	DSRMIM	Unsupported, write zero, read as don't care	RO	0x0
2	DCDMIM	Unsupported, write zero, read as don't care	RO	0x0
1	CTSMIM	nUARTCTS modem interrupt mask. A read returns the current mask for the UARTCTSINTR interrupt. On a write of 1, the mask of the interrupt is set. A write of 0 clears the mask.	RW	0x0
0	RIMIM	Unsupported, write zero, read as don't care	RO	0x0

## RIS Register

**Synopsis** The UART\_RIS Register is the raw interrupt status register. It is a read-only register. This register returns the current raw status value, prior to masking, of the corresponding interrupt.  
 NOTE: All the bits, except for the modem status interrupt bits (bits 3 to 0), are cleared to 0 when reset. The modem status interrupt bits are undefined after reset.

Bit(s)	Field Name	Description	Type	Reset
31:11		<i>Reserved - Write as 0, read as don't care</i>		



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10	OERIS	Overrun error interrupt status. Returns the raw interrupt state of the UARTOEINTR interrupt.	RW	0x0
9	BERIS	Break error interrupt status. Returns the raw interrupt state of the UARTBEINTR interrupt.	RW	0x0
8	PERIS	Parity error interrupt status. Returns the raw interrupt state of the UARTPEINTR interrupt.	RW	0x0
7	FERIS	Framing error interrupt status. Returns the raw interrupt state of the UARTFEINTR interrupt.	RW	0x0
6	RTRIS	Receive timeout interrupt status. Returns the raw interrupt state of the UARTRTINTR interrupt.	RW	0x0
5	TXRIS	Transmit interrupt status. Returns the raw interrupt state of the UARTRXINTR interrupt.	RW	0x0
4	RXRIS	Receive interrupt status. Returns the raw interrupt state of the UARTRXINTR interrupt.	RW	0x0
3	DSRRMIS	Unsupported, write zero, read as don't care	RW	0x0
2	DCDRMIS	Unsupported, write zero, read as don't care	RW	0x0
1	CTSRMIS	nUARTCTS modem interrupt status. Returns the raw interrupt state of the UARTCTSINTR interrupt.	RW	0x0
0	RIRMIS	Unsupported, write zero, read as don't care	RW	0x0

### MIS Register



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**Synopsis** The UART\_MIS Register is the masked interrupt status register. This register returns the current masked status value of the corresponding interrupt.

NOTE: All the bits, except for the modem status interrupt bits (bits 3 to 0), are cleared to 0 when reset. The modem status interrupt bits are undefined after reset.

Bit(s)	Field Name	Description	Type	Reset
31:11		<i>Reserved - Write as 0, read as don't care</i>		
10	OEMIS	Overrun error masked interrupt status. Returns the masked interrupt state of the UARTOEINTR interrupt.	RW	0x0
9	BEMIS	Break error masked interrupt status. Returns the masked interrupt state of the UARTBEINTR interrupt.	RW	0x0
8	PEMIS	Parity error masked interrupt status. Returns the masked interrupt state of the UARTPEINTR interrupt.	RW	0x0
7	FEMIS	Framing error masked interrupt status. Returns the masked interrupt state of the UARTFEINTR interrupt.	RW	0x0
6	RTMIS	Receive timeout masked interrupt status. Returns the masked interrupt state of the UARTRTINTR interrupt.	RW	0x0
5	TXMIS	Transmit masked interrupt status. Returns the masked interrupt state of the UARTTXINTR interrupt.	RW	0x0
4	RXMIS	Receive masked interrupt status. Returns the masked interrupt state of the UARTRXINTR interrupt.	RW	0x0
3	DSRMMIS	Unsupported, write zero, read as don't care	RW	0x0
2	DCDMMIS	Unsupported, write zero, read as don't care	RW	0x0
1	CTSMMIS	nUARTCTS modem masked interrupt status. Returns the masked interrupt state of the UARTCTSINTR interrupt.	RW	0x0
0	RIMMIS	Unsupported, write zero, read as don't care	RW	0x0



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### ICR Register

**Synopsis** The UART\_ICR Register is the interrupt clear register.

Bit(s)	Field Name	Description	Type	Reset
31:11		<i>Reserved - Write as 0, read as don't care</i>		
10	OEIC	Overrun error interrupt clear. Clears the UARTOEINTR interrupt.	RW	0x0
9	BEIC	Break error interrupt clear. Clears the UARTBEINTR interrupt.	RW	0x0
8	PEIC	Parity error interrupt clear. Clears the UARTPEINTR interrupt.	RW	0x0
7	FEIC	Framing error interrupt clear. Clears the UARTFEINTR interrupt..	RW	0x0
6	RTIC	Receive timeout interrupt clear. Clears the UARTRTINTR interrupt.	RW	0x0
5	TXIC	Transmit interrupt clear. Clears the UARTTXINTR interrupt.	RW	0x0
4	RXIC	Receive masked interrupt status. Returns the masked interrupt state of the UARTRXINTR interrupt.	RW	0x0
3	DSRMIC	Unsupported, write zero, read as don't care	RW	0x0
2	DCDMIC	Unsupported, write zero, read as don't care	RW	0x0
1	CTSMIC	nUARTCTS modem masked interrupt status. Returns the masked interrupt state of the UARTCTSINTR interrupt.	RW	0x0
0	RIMIC	Unsupported, write zero, read as don't care	RW	0x0





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### DMACR Register

**Synopsis** This is the disabled DMA Control Register, writing to it has not effect and reading returns 0.

Bit(s)	Field Name	Description	Type	Reset
31:3		<i>Reserved - Write as 0, read as don't care</i>		
2	DMAONERR	Unsupported, write zero, read as don't care	RW	0x0
1	TXDMAE	Unsupported, write zero, read as don't care	RW	0x0
0	RXDMAE	Unsupported, write zero, read as don't care	RW	0x0

### ITCR Register

**Synopsis** This is the Test Control Register UART\_ITCR.

Bit(s)	Field Name	Description	Type	Reset
31:2		<i>Reserved - Write as 0, read as don't care</i>		
1	ITCR1	Test FIFO enable. When this bit is 1, a write to the Test Data Register, UART_DR writes data into the receive FIFO, and reads from the UART_DR register reads data out of the transmit FIFO. When this bit is 0, data cannot be read directly from the transmit FIFO or written directly to the receive FIFO (normal operation).	RW	0x0
0	ITCR0	Integration test enable. When this bit is 1, the UART is placed in integration test mode, otherwise it is in normal operation.	RW	0x0



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### ITIP Register

**Synopsis** This is the Test Control Register UART\_ITIP.

Bit(s)	Field Name	Description	Type	Reset
31:4		<i>Reserved - Write as 0, read as don't care</i>		
3	ITIP3	Reads return the value of the nUARTCTS primary input.	RW	0x0
2:1		<i>Reserved - Write as 0, read as don't care</i>		
0	ITIP0	Reads return the value of the UARTRXD primary input.	RW	0x0

### ITOP Register

**Synopsis** This is the Test Control Register UART\_ITOP.

Bit(s)	Field Name	Description	Type	Reset
31:12		<i>Reserved - Write as 0, read as don't care</i>		
11	ITOP11	Intra-chip output. Writes specify the value to be driven on UARTMSINTR. Reads return the value of UARTMSINTR at the output of the test multiplexor.	RW	0x0
10	ITOP10	Intra-chip output. Writes specify the value to be driven on UARTRXINTR. Reads return the value of UARTRXINTR at the output of the test multiplexor.	RW	0x0
9	ITOP9	Intra-chip output. Writes specify the value to be driven on UARTRXINTR. Reads return the value of UARTRXINTR at the output of the test multiplexor.	RW	0x0



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8	ITOP8	Intra-chip output. Writes specify the value to be driven on UARTRTINTR. Reads return the value of UARTRTINTR at the output of the test multiplexor.	RW	0x0
7	ITOP7	Intra-chip output. Writes specify the value to be driven on UARTEINTR. Reads return the value of UARTEINTR at the output of the test multiplexor.	RW	0x0
6	ITIP6	Intra-chip output. Writes specify the value to be driven on UARTINTR. Reads return the value of UARTINTR at the output of the test multiplexor.	RW	0x0
5:4		<b>Reserved</b> - Write as 0, read as don't care		
3	ITIP3	Primary output. Writes specify the value to be driven on nUARTRTS.	RW	0x0
2:1		<b>Reserved</b> - Write as 0, read as don't care		
0	ITIP0	Primary output. Writes specify the value to be driven on UARTTXD.	RW	0x0

### TDR Register

**Synopsis** UART\_TDR is the test data register. It enables data to be written into the receive FIFO and read out from the transmit FIFO for test purposes. This test function is enabled by the ITCR1 bit in the Test Control Register, UART\_ITCR.

Bit(s)	Field Name	Description	Type	Reset
31:11		<b>Reserved</b> - Write as 0, read as don't care		
10:0	TDR10_0	When the ITCR1 bit is set to 1, data is written into the receive FIFO and read out of the transmit FIFO.	RW	0x0

## 14 Timer (ARM side)

### 14.1 Introduction

The ARM Timer is *based* on a ARM AP804, but it has a number of differences with the standard SP804:

- There is only one timer.
- It only runs in continuous mode.
- It has a extra clock pre-divider register.
- It has a extra stop-in-debug-mode control bit.
- It also has a 32-bit free running counter.

The clock from the ARM timer is derived from the system clock. This clock can change dynamically e.g. if the system goes into reduced power or in low power mode. Thus the clock speed adapts to the overall system performance capabilities. For accurate timing it is recommended to use the system timers.

### 14.2 Timer Registers:

The base address for the ARM timer register is 0x7E00B000.

Address offset <sup>8</sup>	Description
0x400	Load
0x404	Value (Read Only)
0x408	Control
0x40C	IRQ Clear/Ack (Write only)
0x410	RAW IRQ (Read Only)
0x414	Masked IRQ (Read Only)
0x418	Reload
0x41C	<i>Pre-divider (Not in real 804!)</i>
0x420	<i>Free running counter (Not in real 804!)</i>

#### ***Timer Load register***

The timer load register sets the time for the timer to count down. This value is loaded into the timer value register after the load register has been written or if the timer-value register has counted down to 0.

<sup>8</sup> This is the offset which needs to be added to the base address to get the full hardware address.



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## Timer Value register:

This register holds the current timer value and is counted down when the counter is running. It is counted down each timer clock until the value 0 is reached. Then the value register is re-loaded from the timer load register and the interrupt pending bit is set. The timer count down speed is set by the timer pre-divide register.

## Timer control register:

The standard SP804 timer control register consist of 8 bits but in the BCM implementation there are more control bits for the extra features. Control bits 0-7 are identical to the SP804 bits, albeit some functionality of the SP804 is not implemented. All new control bits start from bit 8 upwards. Differences between a real 804 and the BCM implementation are shown in italics.

Name: Timer control		Address: base + 0x40C	Reset: 0x3E0020
Bit(s)	R/W	Function	
31:10	-	<Unused>	
23:16	R/W	Free running counter pre-scaler. Freq is $sys\_clk/(prescale+1)$ <b><i>These bits do not exists in a standard 804! Reset value is 0x3E</i></b>	
15:10	-	<Unused>	
9	R/W	0 : Free running counter Disabled 1 : Free running counter Enabled <b><i>This bit does not exists in a standard 804 timer!</i></b>	
8	R/W	0 : Timers keeps running if ARM is in debug halted mode 1 : Timers halted if ARM is in debug halted mode <b><i>This bit does not exists in a standard 804 timer!</i></b>	
7	R/W	0 : Timer disabled 1 : Timer enabled	
6	R/W	<b><i>Not used, The timer is always in free running mode.</i></b> <i>If this bit is set it enables periodic mode in a standard 804. That mode is not supported in the BC2835M.</i>	
5	R/W	0 : Timer interrupt disabled 1 : Timer interrupt enabled	
4	R/W	<Not used>	
3:2	R/W	Pre-scale bits: 00 : pre-scale is clock / 1 (No pre-scale) 01 : pre-scale is clock / 16 10 : pre-scale is clock / 256 11 : pre-scale is clock / 1 ( <i>Undefined in 804</i> )	
1	R/W	0 : 16-bit counters 1 : 23-bit counter	
0	R/W	<b><i>Not used, The timer is always in wrapping mode.</i></b> <i>If this bit is set it enables one-shot mode in real 804. That mode is not supported in the BCM2835.</i>	



## Timer IRQ clear register:

The timer IRQ clear register is write only. When writing this register the interrupt-pending bit is cleared.

When reading this register it returns 0x544D5241 which is the ASCII reversed value for "ARMT".

## Timer Raw IRQ register

The raw IRQ register is a read-only register. It shows the status of the interrupt pending bit.

Name: Raw IRQ		Address: base + 0x40C	Reset: 0x3E0020
Bit(s)	R/W	Function	
31:0	R	0	
0	R	0 : The interrupt pending bits is clear 1 : The interrupt pending bit is set.	

The interrupt pending bits is set each time the value register is counted down to zero. The interrupt pending bit can not by itself generates interrupts. Interrupts can only be generated if the interrupt enable bit is set.

## Timer Masked IRQ register:

The masked IRQ register is a read-only register. It shows the status of the interrupt signal. It is simply a logical AND of the interrupt pending bit and the interrupt enable bit.

Name: Masked IRQ		Address: base + 0x40C	Reset: 0x3E0020
Bit(s)	R/W	Function	
31:0	R	0	
0	R	0 : Interrupt line not asserted. 1 :Interrupt line is asserted, (the interrupt pending and the interrupt enable bit are set.)	

## Timer Reload register:

This register is a copy of the timer load register. The difference is that a write to this register does not trigger an immediate reload of the timer value register. Instead the timer load register value is only accessed if the value register has finished counting down to zero.

## The timer pre-divider register:

Name: pre-divide		Address: base + 0x41C	Reset: 0x07D
Bit(s)	R/W	Function	
31:10	-	<Unused>	
9:0	R/W	Pre-divider value.	

The Pre-divider register is not present in the SP804.



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The pre-divider register is 10 bits wide and can be written or read from. This register has been added as the SP804 expects a 1MHz clock which we do not have. Instead the pre-divider takes the APB clock and divides it down according to:

$$\text{timer\_clock} = \text{apb\_clock}/(\text{pre\_divider}+1)$$

The reset value of this register is 0x7D so gives a divide by 126.

### **Free running counter**

Name: Free running		Address: base + 0x420	Reset: 0x000
Bit(s)	R/W	Function	
31:0	R	Counter value	

The free running counter is not present in the SP804.

The free running counter is a 32 bits wide read only register. The register is enabled by setting bit 9 of the Timer control register. The free running counter is incremented immediately after it is enabled. The timer can not be reset but when enabled, will always increment and roll-over. The free running counter is also running from the APB clock and has its own clock pre-divider controlled by bits 16-23 of the timer control register.

This register will be halted too if bit 8 of the control register is set and the ARM is in Debug Halt mode.



## 15 USB

The USB core used in the Videocore is build from Synopsys IP. Details about the block can be found in [DWC\\_otg\\_databook.pdf](https://www.synopsys.com/dw/ipdir.php?ds=dwc_usb_2_0_hs_otg) (Which can also be downloaded from [https://www.synopsys.com/dw/ipdir.php?ds=dwc\\_usb\\_2\\_0\\_hs\\_otg](https://www.synopsys.com/dw/ipdir.php?ds=dwc_usb_2_0_hs_otg) ).

### 15.1 Configuration

A number of features of the block are specified before the block is build and thus can not be changed using software. The above mentioned document has a list of these under the chapter "Configuration Parameters". The following table list all configuration parameters mentioned in that chapter and the values which have been chosen.

Feature/Parameter	Selected value
Mode of Operation	0: HNP- and SRP-Capable OTG (Device and Host)
LPM Mode of Operation	0: Non-LPM-capable core
HSIC Mode of Operation	0: Non-HSIC-capable core
Architecture	2: Internal DMA
Point-to-Point Application Only	0: No
High-Speed PHY Interfaces	1: UTMI+
USB 1.1 Full-Speed Serial Transceiver Interface	1: Dedicated FS
USB IC_USB Transceiver Interface	0: Non-IC_USB-capable
Default (Power on) Interface selection: FS_USB/IC_USB	0 : FS_USB interface
Data Width of the UTMI+ Interface	0: 8 bits
Enable I2C Interface	0: None
Enable ULPI Carkit	0: No
Enable PHY Vendor Control Interface	0: No





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Feature/Parameter	Selected value
Number of Device Mode Endpoints in Addition to Control Endpoint 0	7
Enable Dedicated Transmit FIFOs for Device IN Endpoints	1: Yes
Enable descriptor based scatter/gather DMA	0: No
Enable Option for Endpoint- Specific Interrupt	0: No
Number of Device Mode Periodic IN Endpoints	0
Number of Device Mode IN Endpoints including Control Endpo 0	8
Number of Device Mode Control Endpoints in Addition to Endpoint 0	0
Number of Host Mode Channels	8
Is Periodic OUT Channel Support Needed in Host Mode	1: Yes
Total Data FIFO RAM Depth	4096
Enable Dynamic FIFO Sizing	1: Yes
Largest Rx Data FIFO Depth	4096
Largest Non-Periodic Host Tx Data FIFO Depth	1024
Largest Non-periodic Tx Data FIFO Depth	4096
Largest Host Mode Tx Periodic Data FIFO Dept	4096
Non-periodic Request Queue Depth	8
Host Mode Periodic Request Queue Depth	8
Device Mode IN Token Sequence Learning Queue Depth	8
Width of Transfer Size Counters	19



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Feature/Parameter	Selected value
Width of Packet Counters	10
Remove Optional Features	0: No
Power-on Value of User ID Register	0x2708A000
Enable Power Optimization	0: No
Is Minimum AHB Operating Frequency Less than 60 MHz	1: Yes
Reset Style of Clocked always Blocks in RTL	0: Asynchronous
Instantiate Double- Synchronization Flops	1: Yes
Enable Filter on "iddig" Signal from PHY	1: Yes
Enable Filter on "vbus_valid" Signal from PHY	1: Yes
Enable Filter on "a_valid" Signal from PHY	1: Yes
Enable Filter on "b_valid" Signal from PHY	1: Yes
Enable Filter on "session_end" Signal from PHY	1: Yes
Direction of Endpoints	Mode is {IN and OUT} for all endpoints
Largest Device Mode Periodic Tx Data FIFO n Depth	768 for all endpoints (Except 0)
Largest Device Mode IN Endpoint Tx FIFO n Depth (n = 0 to 15) when using dynamic FIFO sizing	0=32 1..5=512 6,7=768

## 15.2 Extra / Adapted registers.

Besides the registers as specified in the documentation of Synopsys a number of extra registers have been added. These control the Analogue USB Phy and the connections of the USB block into the Video core bus structure. Also the USB\_GAHBCFG register has an alternative function for the bits [4:1].

Base Address of the USB block – 0x7E98\_0000



Offset Address	Description		Size	Read/Write
0x080	USB_MDIO_CNTL	MDIO interface control		R/W
0x084	USB_MDIO_GEN	Data for MDIO interface	32	R/W
0x088	USB_VBUS_DRV	Vbus and other Miscellaneous controls		R/W

## USB MDIO Control (USB\_MDIO\_CNTL)

Address 0x 7E98 0080

Bit Number	Field Name	Description	Read/Write	Reset
31	mdio_busy	1= MDIO read or write in progress 0= MDIO Idle	R	0
30-24	-	Unused	-	0
23	bb_mdo	Direct write (bitbash) MDO output	R/W	0
22	bb_mdc	Direct write (bitbash) MDC output	R/W	0
21	bb_enbl	1= MDIO bitbash enable 0= MDIO under control of the phy	R/W	0
20	freerun	1= MDC is continuous active 0 = MDC only active during data transfer	R/W	0
19:16	mdc_ratio	MDC clock freq is sysclk/mdc_ratio	R/W	0
15:0	mdi	16-bit read of MDIO input shift register. Updates on falling edge of MDC	RO	0

**Table 15-1 MDIO Control**

## USB MDIO Data (USB\_MDIO\_DATA)

Address 0x 7E98 0084

Bit Number	Field Name	Description	Read/Write	Reset
31-0	mdio_data	32-bit sequence to send over MDIO bus	W	0
31-0	mdio_data	32-bit sequence received from MDIO bus	R	0

**Table 15-2 USB MDIO data**

A Preamble is not auto-generated so any MDIO access must be preceded by a write to this register of 0xFFFFFFFF. Furthermore, a bug in the USB PHY requires an extra clock edge so a write of 0x00000000 must follow the actual access.



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## USB VBUS (USB\_VBUS)

**Address** 0x 7E98 0088

Bit Number	Field Name	Description	Read/Write	Reset
31-20	-	Unused	-	0
19-16	axi_priority	Sets the USB AXI priority level	R/W	0
15:10	-	Unused	-	0
9	vbus_irq	1=one or more bits of [6:4] have changed since last read. This bit is cleared when the register is read.	RC	0
8	vbus_irq_en	1=Enable IRQ on VBUS status change	R/W	0
7	afe_non_driving	1=USB PHY AFE pull ups/pull downs are off 0=Normal USB AFE operation (Has no effect if MDIO mode is enabled in the phy)	R/W	0
6	utmisrp_dischrgvbus	Drive VBUS	R	0
5	utmisrp_chrgvbuses	Charge VBUS	R	0
4	utmiothg_drvvbus	Discharge VBUS	R	0
3	utmiothg_avalid	A session Valid	R/W	0
2	utmiothg_bvalid	B session Valid	R/W	0
1	utmiothg_vbusvalid	VBUS valid	R/W	0
0	utmisrp_sessend	Session end	R/W	0

**Table 15-3 USB MDIO data**

The RW bits in this register are fed into the USB2.0 controller and the RO bits are coming out of it. In the real device, it will be up to the software to communicate this information between the USB2.0 controller and external VBUS device (some of these have I2C control, others will have to interface via GPIO).

## USB AHB configuration (USB\_GAHBCFG)

**Address** 0x 7E98 0008

The USB\_GAHBCFG register has been adapted. Bits [4:1] which are marked in the Synopsys documentation as "Burst Length/Type (HBstLen)" have been used differently.

- [4] 1 = Wait for all outstanding AXI writes to complete before signalling (internally) that DMA is done.  
0 = don't wait.
- [3] Not used
- [2:1] Sets the maximum AXI burst length, but the bits are inverted,  
00 = maximum AXI burst length of 4,  
01 = maximum AXI burst length of 3,  
10 = maximum AXI burst length of 2  
11 = maximum AXI burst length of 1



# BCM2835 ARM Peripherals

**Personal Notes:**

# Samsung SD & MicroSD Card product family

## SDA 3.0 specification compliant-Up to UHS-I mode

# datasheet

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## Revision History

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## 1.0 PRODUCT LINE-UP

[Table 1] : PRODUCT LINE-UP

Model Number	Capacities	Remarks
MMBTR04GUDCH-xMLxx	4GB	microSD Card (x : Refer to the Ordering Information)
MMCTR08GUBCH-xMLxx	8GB	
MMCTR16GUBCJ-xMLxx	16GB	

## 2.0 INTRODUCTION

### 2.1 General Description

The microSD is a memory card that is specifically designed to meet the security, capacity, performance and environment requirements inherent in newly emerging audio and video consumer electronic devices. The microSD will include a copyright protection mechanism that complies with the security of the SDMI standard and will be faster and capable for higher Memory capacity. The microSD security system uses mutual authentication and a "new cipher algorithm" to protect from illegal usage of the card content. A none secured access to the user's own content is also available.

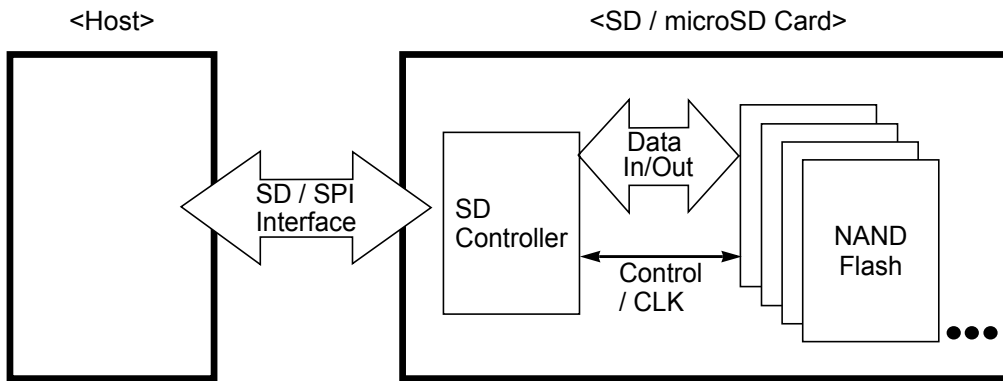
The microSD communication is based on an advanced 9 and 8-pin interface (SD:9pin, microSD:8pin)) designed to operate in at maximum operating frequency of 208MHz and 2.7V ~ 3.6V operating voltage range with 2 Type signaling(1.8V & 3.3V). More detail informations on the interface, and mechanical description is defined as a part of this specification.

UHS-I and High Speed mode Limited on this Specification.

### 2.2 System Features

- Compliant with SD Memory Card Specifications PHYSICAL LAYER SPECIFICATION Version 3.0
  - Based on SD Memory Card Specification 3.0 compatible Test Device.
  - Bus speed support up to SDR104(1.8V signaling, frequency up to 208MHz)
  - Bus speed support High Speed Mode for backward compatible(3.3V signaling, frequency up to 50MHz)
- Targeted for portable and stationary applications
- Memory capacity:
  - 1) Standard Capacity SD Memory Card(SDSC) : Up to and including 2 GB
  - 2) High Capacity SD Memory Card(SDHC) : More than 2GB and up to and including 32GB
  - 3) Extended Capacity SD Memory Card(SDXC) : More than 32GB and up to and including 2TB
- Voltage range:
  - High Voltage SD Memory Card – Operating voltage range: 2.7-3.6 V
- Designed for read-only and read/write cards.
- Bus Speed Mode (using 4 parallel data lines)
  - 1) Default mode: Variable clock rate 0 - 25 MHz, up to 12.5 MB/sec interface speed
  - 2) High-Speed mode: Variable clock rate 0 - 50 MHz, up to 25 MB/sec interface speed
  - 3) SDR12: 1.8V signaling, Frequency up to 25 MHz, up to 12.5MB/sec
  - 4) SDR25: 1.8V signaling, Frequency up to 50 MHz, up to 25MB/sec
  - 5) SDR50: 1.8V signaling, Frequency up to 100 MHz, up to 50MB/sec
  - 6) SDR104: 1.8V signaling, Frequency up to 208 MHz, up to 104MB/sec
  - 7) DDR50: 1.8V signaling, Frequency up to 50 MHz, sampled on both clock edges, up to 50MB/sec
- Switch function command supports Bus Speed Mode and future functions
- Correction of memory field errors
- Card removal during read operation will never harm the content
- Content Protection Mechanism - Complies with highest security of SDMI standard.
- Password Protection of cards (CMD42 - LOCK\_UNLOCK)
- Write Protect feature using mechanical switch
- Built-in write protection features (permanent and temporary)
- Card Detection (Insertion/Removal)
- Application specific commands
- Comfortable erase mechanism
- Weight : SD Card Max. 2.5g / microSD Card Max. 1g

### 2.3 System Block Diagram



## 3.0 PRODUCT SPECIFICATION

### 3.1 Current Consumption

This information table below provides current consumption of Samsung microSD Card. Current consumption is measured by averaging over 1 second.  
[Table 2] : Current Consumption Table

Mode	Max. Interface Frequency	Operations	Max.
Default Mode	25Mhz	Read	100mA
		Write	
High Speed Mode	50Mhz	Read	200mA
		Write	
SDR 12	25Mhz	Read	100mA
		Write	
SDR 25	50Mhz	Read	200mA
		Write	
DDR 50	50Mhz	Read	400mA
		Write	
SDR50	100Mhz	Read	400mA
		Write	
SDR 104	208Mhz	Read	400mA
		Write	

**NOTE:**

Current consumption on each device can be varied by NAND Flash, . of chips, test conditions and Etc. For specific information, refer to Samsung microSD Card Qualification report.

### 3.2 System Performance

#### 3.2.1 Product Performance

Product Performance is based on TestMetrix compliance Tool. Note that the performance measured by TestMetrix does not represent real performance in various circumstances.

[Table 3] : Performance Information

Product Number	Write Performance (MB/s)	Read Performance (MB/s)
MMBTR04GUDCH-xMLxx	7	90
MMCTR08GUBCH-xMLxx		
MMCTR16GUBCJ-xMLxx		

#### 3.2.2 Read, Write Timeout Error Conditions

SEC microSD Card shall complete the command within the time period defined as follows or give up and return and error message. If the host does not get any response with the given timeout it should assume that the card is not going to respond and try recover. For more information, refer to Section 4.6 of the SDA Physical Layer Specification, Version 3.0

[Table 4] : Timeout Error Conditions

Timing	Max. Value
Block Read Access Time	100ms
Block Write Access Time	250ms(SDSC/SDHC), 500ms(SDXC)
Initialization Time out(ACMD 41) <sup>1</sup>	1s

**NOTE:**

1) The host shall set ACMD41 timeout more than 1 second to abort repeat of issuing ACMD41 when the card does not indicate ready. The timeout count starts from the first ACMD41 which is set voltage window in the argument.

### 3.3 SD Mode Card Registers

•Six registers are defined within the card interface: OCR, CID, CSD, RCA, DSR and SCR. These can be accessed only by corresponding commands. The OCR, CID, CSD and SCR registers carry the card/content specific information, while the RCA and DSR registers are configuration registers storing actual configuration parameters. **OCR Register** The 32-bit operation conditions register stores the VDD voltage profile of the card. Additionally, this register includes status information bits.

See Section 5.1 of the SDA Physical Layer Specification, Version 3.00 for more information.

[Table 5] : OCR Register Definition

OCR bit	VDD Voltage Window	OCR Value
0-3	reserved	0
4	reserved	0
5	reserved	0
6	reserved	0
7	reserved for Low Voltage Range	0
8	reserved	0
9	reserved	0
10	reserved	0
11	reserved	0
12	reserved	0
13	reserved	0
14	reserved	0
15	2.7 - 2.8	1
16	2.8 - 2.9	1
17	2.9 - 3.0	1
18	3.0 - 3.1	1
19	3.1 - 3.2	1
20	3.2 - 3.3	1
21	3.3 - 3.4	1
22	3.4 - 3.5	1
23	3.5 - 3.6	1
24 <sup>3</sup>	Switching to 1.8V Accepted (S18A)	0 or 1
24 - 29	reserved	0
30	Card Capacity Staus(CCS) <sup>1</sup>	-
31	Card power up status bit(busy) <sup>2</sup>	-

**NOTE:**

1) This bit is valid only when the card power up status bit is set.

2) This bit is set to LOW if the card has not finished the power up routine.

3) S18A = 0 means voltage switch is not allowed .

S18A = 1 means Votage switch is allowed and host issue CMD to invoke voltage switch sequence.

### 3.3.1 CID Register

The Card Identification (CID) register is 128 bits wide. It contains the card identification information used during the card identification phase. Every individual Read/Write (RW) card shall have a unique identification number. It is programmed during manufacturing and cannot be changed by card hosts. The structure of the CID register is defined in the following paragraphs:

[Table 6] : CID Register Fields

Name	Field	Type	Width	CID Value		
				4GB	8GB	16GB
Manufacturer ID	MID	Binary	8	CID Register Value can be provided by Customer Request		
OEM/Application ID	OID	ASCII	16			
Product name	PNM	ASCII	40			
Product revision	PRV	BCD	8			
Product serial number	PSN	Binary	32			
Reserved	-	-	4			
Manufacturing date	MDT	BCD	12			
CRC7 checksum	CRC	Binary	7			
not used, always '1'	-	-	1			

## 3.3.2 CSD Register (CSD Version 1.0)

The Card-Specific Data register provides information on how to access the card contents. The CSD defines the data format, error correction type, maximum data access time, data transfer speed, whether the DSR register can be used etc. The programmable part of the register (entries marked by W or E, see below) can be changed by CMD27. The type of the entries in the table below is coded as follows: R = readable, W(1) = writable once, W= multiple writable.

[Table 7] : The CSD Register Fields (CSD Version 1.0)

Name	Field	Width	Cell Type	CSD-slice	CSD Value		
					4GB	8GB	16GB
CSD structure	CSD_STRUCTURE	2	R	[127:126]	Version 1.0		
Reserved	-	6	R	[125:120]	-		
Data read access-time 1	TAAC	8	R	[119:112]	N/A		
Data read access-time 2 in CLK cycles (NSAC*100)	NSAC	8	R	[111:104]	N/A		
Max. Data transfer rate	TRAN_SPEED	8	R	[103:96]	N/A		
Card command classes	CCC	12	R	[95:84]	N/A		
Max. read data block length	READ_BLK_LEN	4	R	[83:80]	N/A		
Partial blocks for read allowed	READ_BLK_PARTIAL	1	R	[79:79]	N/A		
Write block misalignment	WRITE_BLK_MISALIGN	1	R	[78:78]	N/A		
Read block misalignment	READ_BLK_MISALIGN	1	R	[77:77]	N/A		
DSR implemented	DSR_IMP	1	R	[76:76]	N/A		
Reserved	-	2	R	[75:74]	-		
Device size	C_SIZE	12	R	[73:62]	N/A		
Max. read current @ V <sub>DD</sub> min	VDD_R_CURR_MIN	3	R	[61:59]	N/A		
Max. read current @ V <sub>DD</sub> max	VDD_R_CURR_MAX	3	R	[58:56]	N/A		
Max. write current @ V <sub>DD</sub> min	VDD_W_CURR_MIN	3	R	[55:53]	N/A		
Max. write current @ V <sub>DD</sub> max	VDD_W_CURR_MAX	3	R	[52:50]	N/A		
Device size multiplier	C_SIZE_MULT	3	R	[49:47]	N/A		
Erase single block enable	ERASE_BLK_EN	1	R	[46:46]	N/A		
Erase sector size	SECTOR_SIZE	7	R	[45:39]	N/A		
Write protect group size	WP_GRP_SIZE	7	R	[38:32]	N/A		
Write protect group enable	WP_GRP_ENABLE	1	R	[31:31]	N/A		
Reserved (Do Not Use)		2	R	[30:29]	-		
Write speed factor	R2W_FACTOR	3	R	[28:26]	N/A		
Max. write data block length	WRITE_BLK_LEN	4	R	[25:22]	N/A		
Partial blocks for write allowed	WRITE_BLK_PARTIAL	1	R	[21:21]	N/A		
Reserved	-	5	R	[20:16]	-		
File format group	FILE_FORMAT_GRP	1	R/W(1)	[15:15]	N/A		
Copy flag (OTP)	COPY	1	R/W(1)	[14:14]	N/A		
Permanent write protection	PERM_WRITE_PROTECT	1	R/W(1)	[13:13]	N/A		
Temporary write protection	TMP_WRITE_PROTECT	1	R/W	[12:12]	N/A		
File format	FILE_FORMAT	2	R/W(1)	[11:10]	N/A		
Reserved		2	R/W	[9:8]	-		
CRC	CRC	7	R/W	[7:1]	N/A		
Not used, always '1'	-	1	-	[0:0]	-		

### 3.3.3 CSD Register (CSD Version 2.0)

The following Table shows Definition of the CSD Version 2.0 for the High Capacity SD Memory Card and Extended Capacity SD Memory Card. The following sections describe the CSD fields and the relevant data types for the High Capacity SD Memory Card.

CSD Version 2.0 is applied to only the High Capacity SD Memory Card. The field name in parenthesis is set to fixed value and indicates that the host is not necessary to refer these fields. The fixed values enables host, which refers to these fields, to keep compatibility to CSD Version 1.0. The Cell Type field is coded as follows: R = readable, W(1) = writable once, W = multiple writable.

[Table 8] : The CSD Register Fields (CSD Version 2.0)

Name	Field	Width	Cell Type	CSD-slice	CSD Value		
					4GB	8GB	16GB
CSD structure	CSD_STRUCTURE	2	R	[127:126]	CSD Version 2.0		
Reserved	-	6	R	[125:120]	-		
Data read access-time	(TAAC)	8	R	[119:112]	1000.00 us		
Data read access-time in CLK cycles (NSAC*100)	(NSAC)	8	R	[111:104]	0 cycles		
Max. Data transfer rate	(TRAN_SPEED)	8	R	[103:96]	25 Mbit/s or 50 Mbit/s		
Card command classes	CCC	12	R	[95:84]	class 0 2 4 5 7 8 10		
Max. read data block length	(READ_BLK_LEN)	4	R	[83:80]	512 bytes		
Partial blocks for read allowed	(READ_BLK_PARTIAL)	1	R	[79:79]	0		
Write block misalignment	(WRITE_BLK_MISALIGN)	1	R	[78:78]	0		
Read block misalignment	(READ_BLK_MISALIGN)	1	R	[77:77]	0		
DSR implemented	DSR_IMP	1	R	[76:76]	0		
Reserved	-	6	R	[75:70]	-		
Device size	C_SIZE	22	R	[69:48]	7525	15053	30173
Reserved	-	1	R	[47:47]	-		
Erase single block enable	(ERASE_BLK_EN)	1	R	[46:46]	1		
Erase sector size	(SECTOR_SIZE)	7	R	[45:39]	128 blocks		
Write protect group size	(WP_GRP_SIZE)	7	R	[38:32]	1 sectors		
Write protect group enable	(WP_GRP_ENABLE)	1	R	[31:31]	0		
Reserved	-	2	R	[30:29]	-		
Write speed factor	(R2W_FACTOR)	3	R	[28:26]	4		
Max. write data block length	(WRITE_BLK_LEN)	4	R	[25:22]	512 bytes		
Partial blocks for write allowed	(WRITE_BLK_PARTIAL)	1	R	[21:21]	0		
Reserved	-	5	R	[20:16]	-		
File format group	(FILE_FORMAT_GRP)	1	R	[15:15]	0		
Copy flag (OTP)	COPY	1	R/W(1)	[14:14]	0		
Permanent write protection	PERM_WRITE_PROTECT	1	R/W(1)	[13:13]	0		
Temporary write protection	TMP_WRITE_PROTECT	1	R/W	[12:12]	0		
File format	(FILE_FORMAT)	2	R	[11:10]	0		
Reserved	-	2	R	[9:8]	-		
CRC	CRC	7	R/W	[7:1]	-		
Not used, always '1'	-	1	-	[0:0]	-		

### 3.3.4 RCA Register

The writable 16-bit relative card address register carries the card address that is published by the card during the card identification. This address is used for the addressed host-card communication after the card identification procedure. The default value of the RCA register is 0x0000. The value 0x0000 is reserved to set all cards into the Stand-by State with CMD7.



### 3.3.5 SCR Register

In addition to the CSD register, there is another configuration register named SD CARD Configuration Register (SCR). SCR provides information on the SD Card's special features that were configured into the given card. The size of SCR register is 64bits. The register shall be set in the factory by the SD Card manufacturer. The following table describes the SCR register content.

[Table 9] : The SCR Fields

Name	Field	Width	Cell Type	SCR-slice	SCR Value		
					4GB	8GB	16GB
SCR structure	SCR_STRUCTURE	4	R	[63:60]	SCR Version 1.0		
SD Memory Card - Spec. Version	SD_SPEC	4	R	[59:56]	Version 2.00 or Version 3.0x		
data_status_after erases	DATA_STAT_AFTER_ERASE	1	R	[55:55]	0		
SD Security Support	SD_SECURITY	3	R	[54:52]	SDHC Card (Security Version 2.00)		
DAT Bus widths supported	SD_BUS_WIDTHS	4	R	[51:48]	1 bit(DAT0) + 4 bit(DAT0-3)		
Spec. Version 3.00 or Higher	SD_SPEC3	1	R	[47]	Version 3.0X or later		
Reserved		13	R	[46:34]	-		
Command Support bits	CMD_SUPPORT	14	R	[33:32]	Speed Class Control (CMD20) & Set Block Count (CMD23)		
Reserved for manufacturer usage-		32	R	[31:0]	-		

### 3.3.6 SD Status Register

The SD Status contains status bits that are related to the SD Memory Card proprietary features and may be used for future application specific usage. The size of the SD Status is one data block of 512bit. The content of this register is transmitted to the Host over the DAT bus along with 16bit CRC. The SD Status is sent to the host over the DAT bus if ACMD13 is sent (CMD55 followed with CMD13). ACMD13 can be sent to a card only in 'tran\_state' (card is selected). SD Status structure is described in below. Unused reserved bits shall be set to 0.

[Table 10] : SD Status Register

Bits	Field	Cell Type	Data			Value		
			4GB	8GB	16GB	4GB	8GB	16GB
511:510	DATA_BUS_WIDTH	S R	0x00			1bit width or 4bit width		
509	SECURED_MODE	S R	0x00			-		
508:502	Reserved for Security Functions (Refer to Part 3 Security Specification)							
501:496	Reserved							
495:480	SD_CARD_TYPE	S R	0x0000			Regular SD RD/WR Card		
479:448	SIZE_OF_PROTECTED_AREA	S R	0x2000000	0x3000000	0x4000000	-		
447:440	SPEED_CLASS	S R	0x3		0x4	Class 6		Class 10
439:432	PERFORMANCE_MOVE	S R	0x3		0x0	3 [MB/sec]		Sequential Write (SPEC 3.0)
431:428	AU_SIZE	S R	0x9			4MB		
427:424	Reserved							
423:408	ERASE_SIZE	S R	0x8			8 AU		
407:402	ERASE_TIMEOUT	S R	0x4			4 sec		
401:400	ERASE_OFFSET	S R	0x1			1 sec		
399:396	UHS_SPEED_GRADE	S R	0x0		0x1	Less than 10MB/sec		10MB/sec and above
395:392	UHS_AU_SIZE	S R	0x9			4 MB		
391:312	Reserved							
311:0	Reserved for Manufacturer							

**NOTE:**

- Speed Class that supports Class 10 shall not use the Pm value stored in the SD Status to calculate performance in any fragmented AU.
- Class 10 Performance is defined only for entirely free AUs
- In contrast with speed Class , Pm is not supported in UHS-1 card. which means Pm shall be set to '0' in SD status of UHS-1 card.

### 3.4 SPI Mode Card Registers

Unlike the SD Memory card protocol (where the register contents is sent as command response), reading the contents of the CSD and CID registers in SPI mode is a simple read-block transaction. The card will respond with a standard response token followed by data block of 16 bytes suffixed with a 16-bit CRC.

The data timeout for the CSD command cannot be set to the cards TAAC since this value is stored in the card's CSD. Therefore, the standard response timeout value(NcR) is used for read latency of the CSD register.

### 3.5 User Capacity

This information table below provides user capacity of Samsung microSD Card.

Product user density is based on SD Formatter 3.1 tool with FAT File system.

SD Formatter 3.1 software formats all SD Cards and SDHC Cards using a formatting program that complies with official SD memory card requirements.

[Table 11] : User Capacity

Product Number	File System	Tot. Sector No.	User Capacity[Byte]
MMBTR04GUDCH-xMLxx	FAT 32	7,690,240	3,937,402,880
MMCTR08GUBCH-xMLxx		15,398,912	7,884,242,944
MMCTR16GUBCJ-xMLxx		30,881,792	15,811,477,504

**NOTE :**

SD or SDHC Card file systems form attached with generic operating system formatting software do not comply with official SD memory card requirement and optimum performance may not be experienced

## 4.0 INTERFACE DESCRIPTION

### 4.1 microSD SD mode Bus Topology / microSD SPI Bus Topology

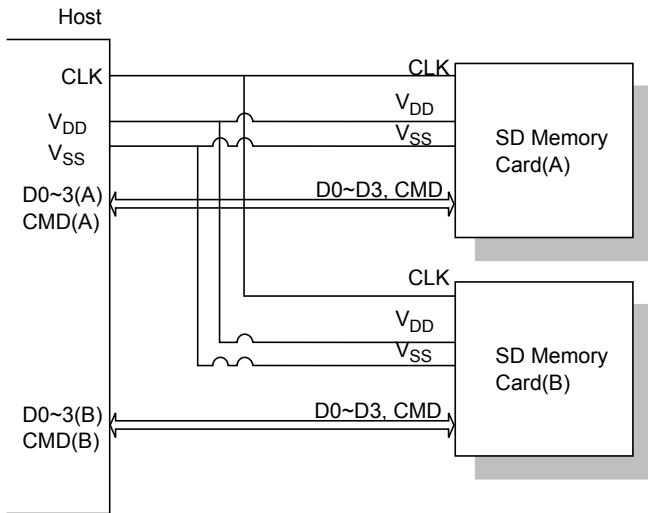


Figure 1. SD Memory Card System Bus Topology

The microSD Memory Card system defines two alternative communication protocols: SD and SPI. The host system can choose either one of modes. The card detects which mode is requested by the host when the reset command is received and expects all further communication to be in the same communication mode. Common bus signals for multiple card slots are not recommended. A single SD bus should connect a single SD card. Where the host system supports a high-speed mode, a single SD bus shall be connected to a single SD card.

The microSD bus includes the following signals:

- CMD : Bidirectional Command/Response signal
- DAT0 - DAT3 : 4 Bidirectional data signals
- CLK : Host to card clock signal
- V<sub>DD</sub>, V<sub>SS1</sub>, V<sub>SS2</sub>: Power and ground signals

The microSD Card bus has a single master (application), multiple slaves (cards), synchronous start topology (refer to Figure 1, Figure 2). Clock, power and ground signals are common to all cards. Command (CMD) and data (DAT0-DAT3) signals are dedicated to each card providing continuous point to point connection to all the cards.

During initialization process, commands are sent to each card individually, allowing the application to detect the cards and assign logical addresses to the physical slots. Data is always sent (received) to (from) each card individually. However, in order to simplify the handling of the card stack, after initialization process, all commands may be sent concurrently to all cards. Addressing information is provided in the command packet.

SD Bus allows dynamic configuration of the number of data lines. After power-up, by default, the microSD Card will use only DAT0 for data transfer. After initialization, the host can change the bus width (number of active data lines). This feature allows an easy trade off between hardware cost and system performance. Note that while DAT1-DAT3 are not in use, the related Host's DAT lines should be in tri-state (input mode). For SDIO cards DAT1 and DAT2 are used for signaling.

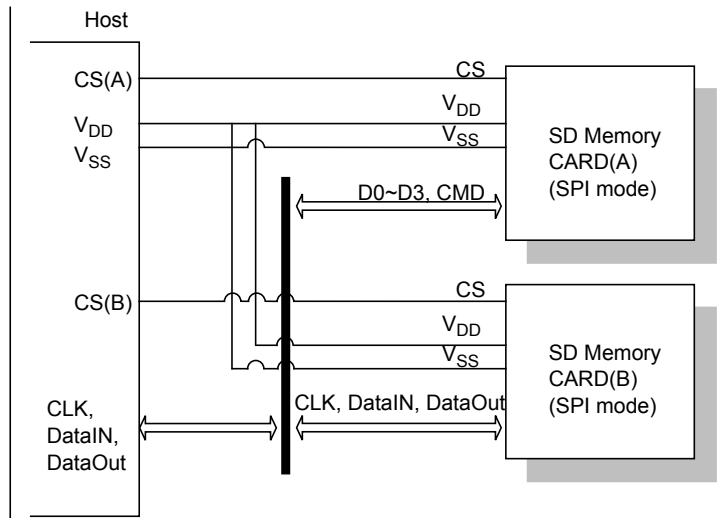


Figure 2. SD Memory Card system (SPI mode) Bus Topology

The SPI compatible communication mode of the microSD Memory Card is designed to communicate with a SPI channel, commonly found in various microcontrollers in the market. The interface is selected during the first reset command after power up and cannot be changed as long as the part is powered on.

The SPI standard defines the physical link only, and not complete data transfer protocol. The microSD Card SPI implementation uses the same command set of the SD mode. From the application point of view, the advantage of the SPI mode is the capability of using an off-the-shelf host, hence reducing the design-in effort to minimum. The disadvantage is the loss of performance, relatively to the SD mode which enables the wide bus option.

The microSD Card SPI interface is compatible with SPI hosts available on the market. As any other SPI device the microSD Card SPI channel consists of the following four signals:

- CS : Host to card Chip Select signal
- CLK : Host to card clock signal
- DataIN : Host to card data signal
- DataOut: Card to host data signal

Another SPI common characteristic is byte transfers, which is implemented in the card as well. All data tokens are multiples of bytes (8 bit) and always byte aligned to the CS signal.

The card identification and addressing methods are replaced by a hardware Chip Select (CS) signal. There are no broadcast commands. For every command, a card (slave) is selected by asserting (active low) the CS signal.

The CS signal must be continuously active for the duration of the SPI transaction (command, response and data). The only exception occurs during card programming, when the host can de-assert the CS signal without affecting the programming process.

## 4.2 Bus Protocol

### 4.2.1 SD Bus

For more details, refer to Section 3.6.1 of the SDA Physical Layer Specification, Version 3.0

### 4.2.2 SPI Bus

For more details, refer to Chapter 7 of the SDA Physical Layer Specification, Version 3.0

## 4.3 microSD Card Pin Assignment

### 4.3.1 SD Card Pin Assignment

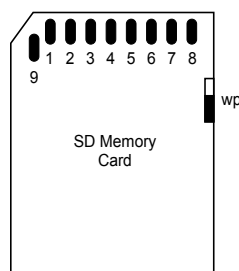


Figure 3. SD Memory Card shape and interface (top view)

The SD Memory Card has the form factor 24 mm x 32 mm x 2.1 mm or 24 mm x 32 mm x 1.4 mm.

Figure 3 shows the general shape of the shape and interface contacts of the SD Memory Card. The detailed physical dimensions and mechanical description are given in section 5.4.

The following Table defines the card contacts:

[Table 12] : SD Memory Card Pad Assignment

Pin #	Name	Type <sup>1</sup>	Description	Name	Type	Description
SD Mode				SPI Mode		
1	CD/DAT3 <sup>2</sup>	I/O/PP <sup>3</sup>	Card Detect / Data Line [Bit 3]	CS	I <sup>3</sup>	Chip Select (neg true)
2	CMD	I/O/PP	Command/Response	DI	I	Data In
3	VSS1	S	Supply voltage ground	VSS	S	Supply voltage ground
4	VDD	S	Supply voltage	VDD	S	Supply voltage
5	CLK	I	Clock	SCLK	I	Clock
6	VSS2	S	Supply voltage ground	VSS2	S	Supply voltage ground
7	DAT0	I/O/PP	Data Line [Bit 0]	DO	O/PP	Data Out
8	DAT1 <sup>4</sup>	I/O/PP	Data Line [Bit 1]	RSV		
9	DAT2 <sup>5</sup>	I/O/PP	Data Line [Bit 2]	RSV		

**NOTE:**

- 1) S: power supply; I: input; O: output using push-pull drivers; PP: I/O using push-pull drivers;
- 2) The extended DAT lines (DAT1-DAT3) are input on power up. They start to operate as DAT lines after SET\_BUS\_WIDTH command. The Host shall keep its own DAT1-DAT3 lines in input mode, as well, while they are not used.
- 3) At power up this line has a 50KOhm pull up enabled in the card. This resistor serves two functions Card detection and Mode Selection. For Mode Selection, the host can drive the line high or let it be pulled high to select SD mode. If the host wants to select SPI mode it should drive the line low. For Card detection, the host detects that the line is pulled high. This pull-up should be disconnected by the user, during regular data transfer, with SET\_CLR\_CARD\_DETECT (ACMD42) command
- 4) DAT1 line may be used as Interrupt Output (from the Card) in SDIO mode during all the times that it is not in use for data transfer operations (refer to "SDIO Card Specification" for further details).
- 5) DAT2 line may be used as Read Wait signal in SDIO mode (refer to "SDIO Card Specification" for further details).

## 4.3.2 microSD Card Assignment

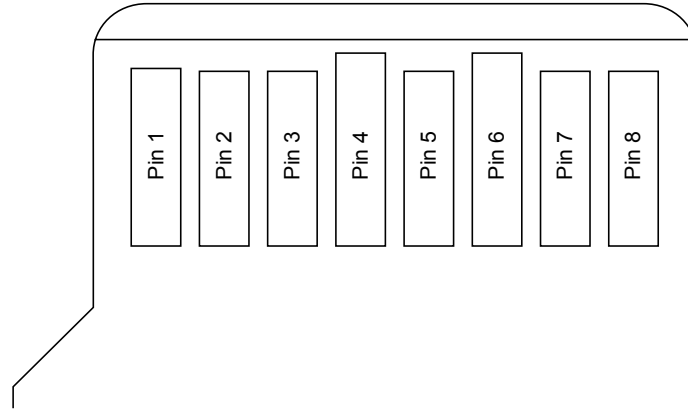


Figure 4. Contact Area

[Table 13] : microSD Contact Pad Assignment

Pin #	SD Mode			SPI Mode		
	Name	Type <sup>1</sup>	Description	Name	Type <sup>1</sup>	Description
1	DAT2 <sup>2,5</sup>	I/O/PP	Data Line [Bit 2]	RSV		Reserved
2	CD/DAT3 <sup>2</sup>	I/O/PP <sup>3</sup>	Card Detect / Data Line [Bit 3]	CS	⌋ <sup>3</sup>	Chip Select (neg true)
3	CMD	PP	Command/Response	DI	I	Data In
4	VDD	S	Supply voltage	VDD	S	Supply voltage
5	CLK	I	Clock	SCLK	I	Clock
6	VSS	S	Supply voltage ground	VSS	S	Supply voltage ground
7	DAT0	I/O/PP	Data Line [Bit 0]	DO	O/PP	Data Out
8	DAT1 <sup>2,4</sup>	I/O/PP	Data Line [Bit 1]	RSV <sup>4</sup>		

## NOTE:

- 1) S: power supply; I: input; O: output using push-pull drivers; PP: I/O using push-pull drivers ;
- 2) The extended DAT lines (DAT1-DAT3) are input on power up. They start to operate as DAT lines after SET\_BUS\_WIDTH command. The Host shall keep its own DAT1-DAT3 lines in input mode, as well, while they are not used.
- 3) At power up this line has a 50KOhm pull up enabled in the card. This resistor serves two functions Card detection and Mode Selection. For Mode Selection, the host can drive the line high or let it be pulled high to select SD mode. If the host wants to select SPI mode it should drive the line low. For Card detection, the host detects that the line is pulled high. This pull-up should be disconnected by the user, during regular data transfer, with SET\_CLR\_CARD\_DETECT (ACMD42)
- 4) DAT1 line may be used as Interrupt Output (from the Card) in SDIO mode during all the times that it is not in use for data transfer operations (refer to "SDIO Card Specification" for further details).
- 5) DAT2 line may be used as Read Wait signal in SDIO mode (refer to "SDIO Card Specification" for further details).

### 4.4 Mechanical Specification

This section describes the mechanical and electrical features, as well as SEC microSD Card environmental reliability and durability specifications. For more details you can refer to SDA Physical Layer Specification Version 2.00, Section 8.1. For more details and Section 3.0 Mechanical Specification for microSD Memory Card.

#### 4.4.1 Mechanical Form Factor of microSD

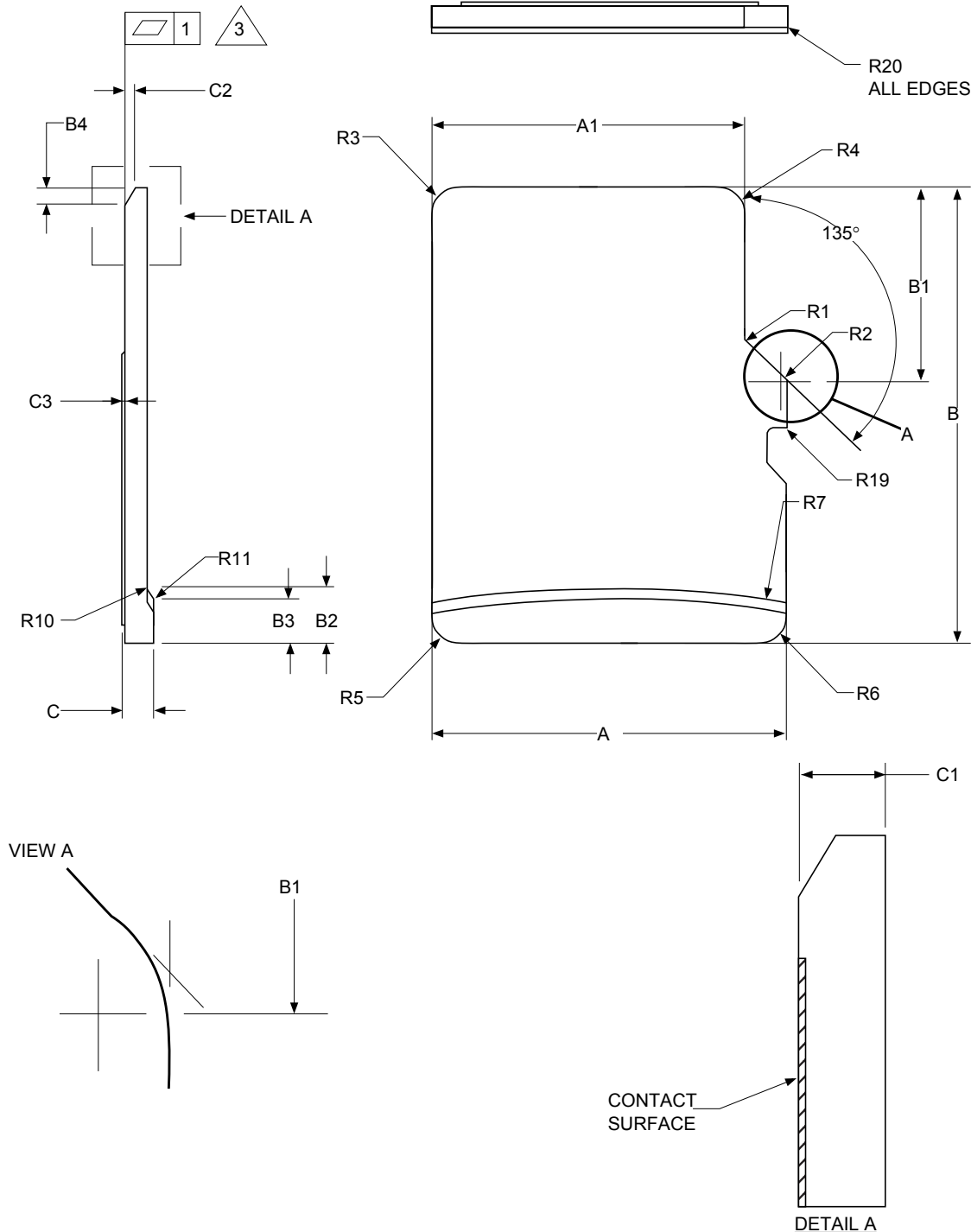


Figure 5. Mechanical Description: Top View

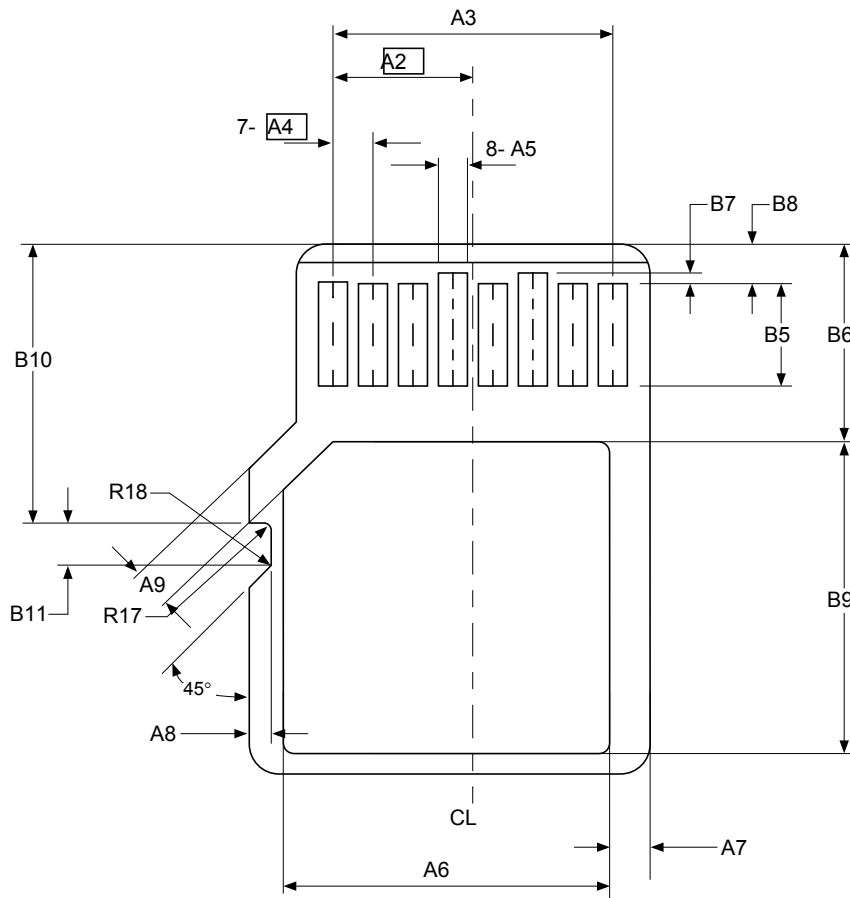


Figure 6. : Mechanical Description: Bottom View

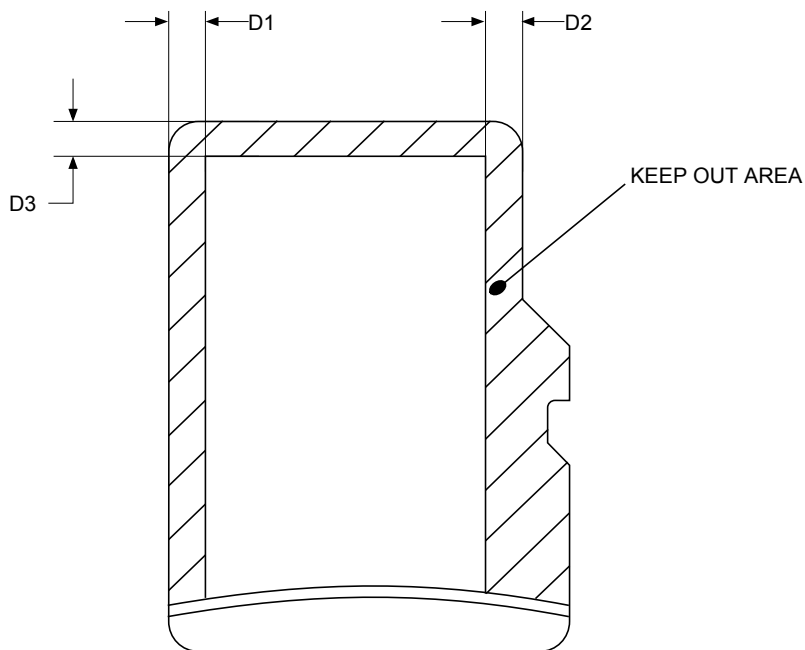


Figure 7. Mechanical Description: Keep Out Area

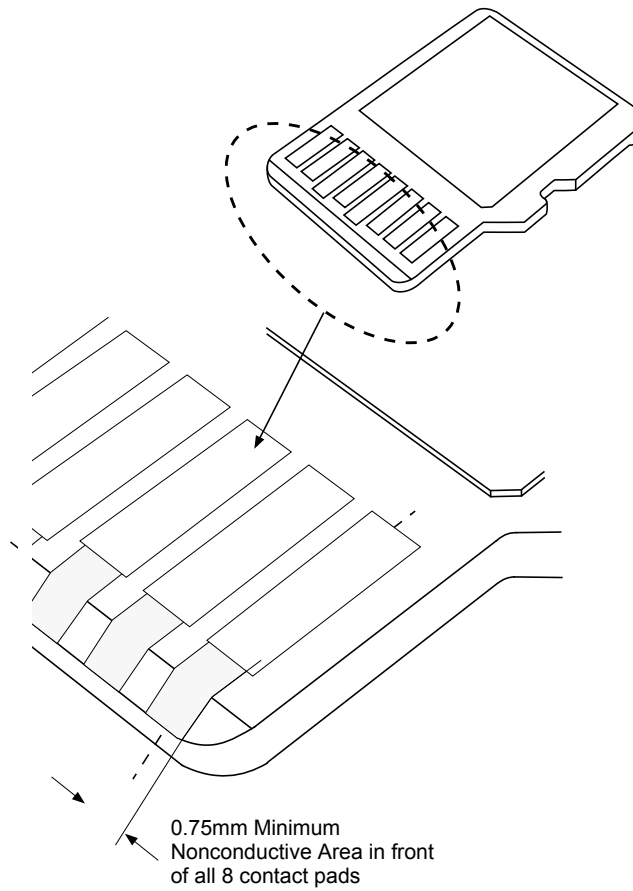


Figure 8. Nonconductive Area in Front of Contact Pad

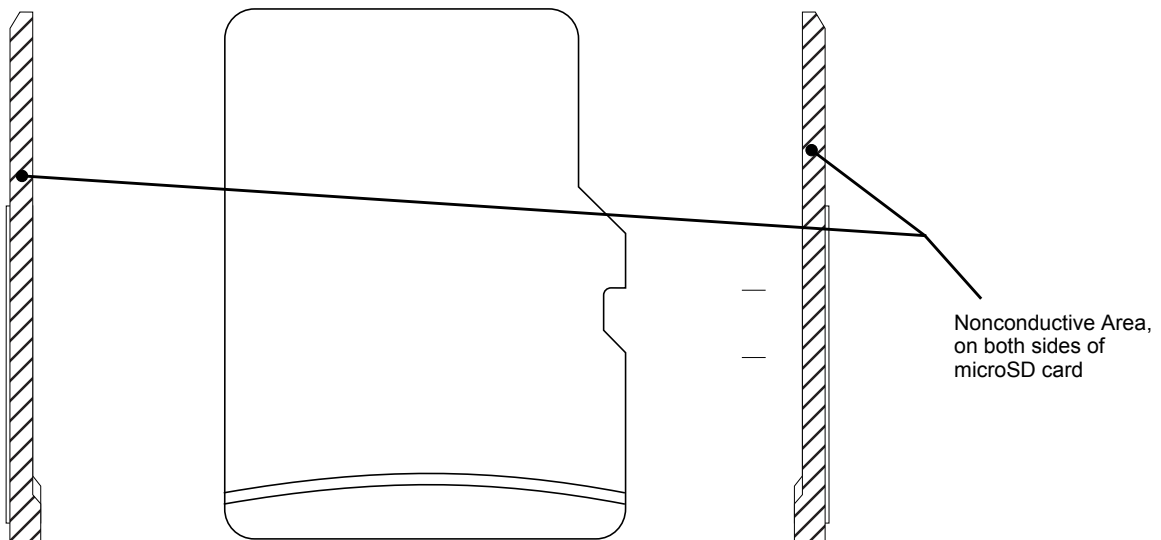


Figure 9. Nonconductive Area on Sides of Card



[Table 14]: microSD Package: Dimensions

SYMBOL	COMMON DIMENSIONS			NOTE
	MIN	NOM	MAX	
A	10.90	11.00	11.10	
A1	9.60	9.70	9.80	
A2	-	3.85	-	BASIC
A3	7.60	7.70	7.80	
A4	-	1.10	-	BASIC
A5	0.75	0.80	0.85	
A6	-	-	8.50	
A7	0.90	-	-	
A8	0.60	0.70	0.80	
A9	0.80	-	-	
B	14.90	15.00	15.10	
B1	6.30	6.40	6.50	
B2	1.64	1.84	2.04	
B3	1.30	1.50	1.70	
B4	0.42	0.52	0.62	
B5	2.80	2.90	3.00	
B6	5.50	-	-	
B7	0.20	0.30	0.40	
B8	1.00	1.10	1.20	
B9	-	-	9.00	
B10	7.80	7.90	8.00	
B11	1.10	1.20	1.30	
C	0.90	1.00	1.10	
C1	0.60	0.70	0.80	
C2	0.20	0.30	0.40	
C3	0.00	-	0.15	
D1	1.00	-	-	
D2	1.00	-	-	
D3	1.00	-	-	
R1	0.20	0.40	0.60	
R2	0.20	0.40	0.60	
R3	0.70	0.80	0.90	
R4	0.70	0.80	0.90	
R5	0.70	0.80	0.90	
R6	0.70	0.80	0.90	
R7	29.50	30.00	30.50	
R10	-	0.20	-	
R11	-	0.20	-	
R17	0.10	0.20	0.30	
R18	0.20	0.40	0.60	
R19	0.05	-	0.20	
R20	0.02	-	0.15	

**NOTE:**

- 1) DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994.
- 2) DIMENSIONS ARE IN MILLIMETERS.
- 3) COPLANARITY IS ADDITIVE TO C1 MAX THICKNESS.

#### 4.4.2 Electrical features, Environmental Reliability and Durability

SEC microSD Card Electrical features, Environmental Reliabilities and Durabilities conform to SDA Physical Layer Specification Version 2.00, Section 8.1. For more details and informations of SEC microSD Card Data, refer to Product Qualification Report.

## 4.5 Electrical Interface

The following sections provide valuable information about the electrical interface. See Chapter 6 of the SDA Physical Layer Specification, Version 3.00 for more detail information.

### 4.5.1 Power Up

The power-up of the microSD Card bus is handled locally in each SD Card and in the host

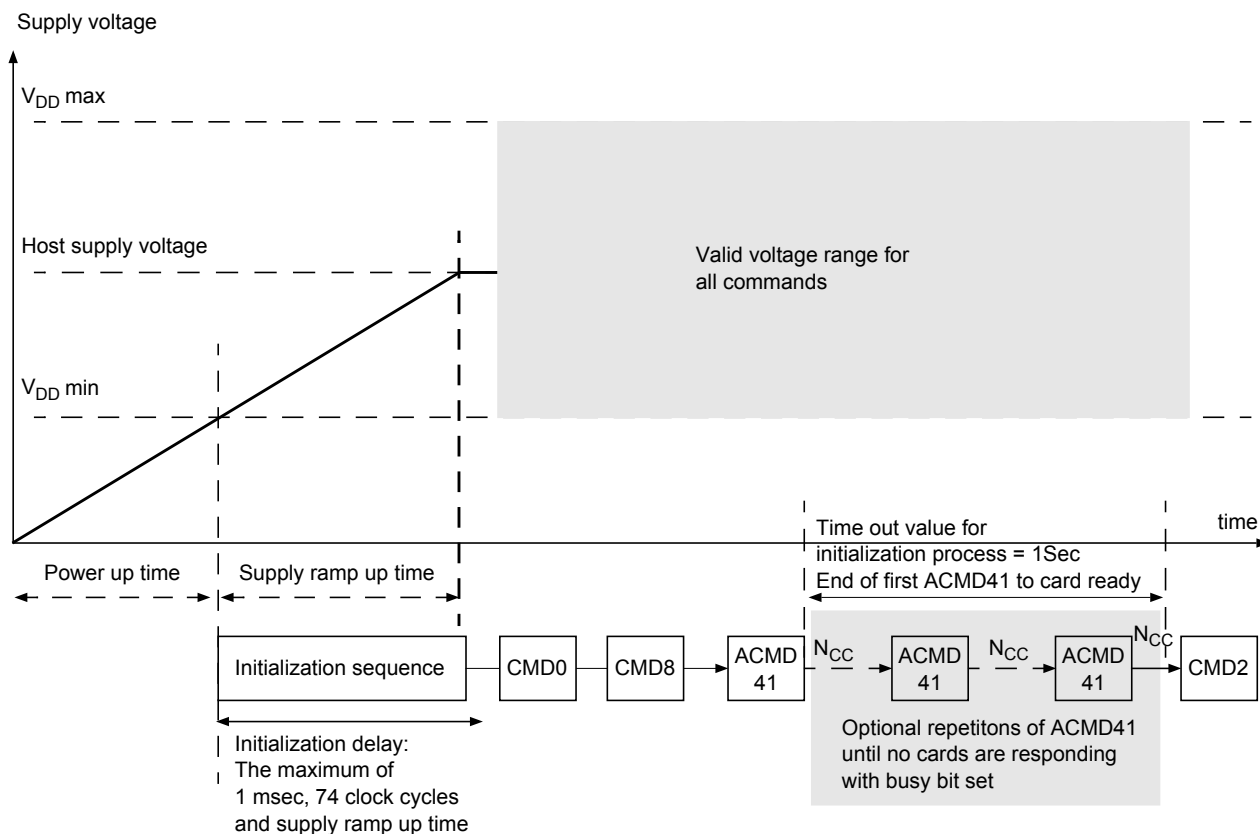


Figure 10. Power-up Diagram

- Power up time is defined as voltage rising time from 0 volt to  $V_{DD\ (min.)}$  and depends on application parameters such as the maximum number of SD Cards, the bus length and the characteristic of the power supply unit.
- Supply ramp up time provides the time that the power is built up to the operating level (the host supply voltage) and the time to wait until the SD card can accept the first command,
- The host shall supply power to the card so that the voltage is reached to  $V_{DD\ (min.)}$  within 250ms and start to supply at least 74 SD clocks to the SD card with keeping CMD line to high. In case of SPI mode, CS shall be held to high during 74 clock cycles.
- After power up (including hot insertion, i.e. inserting a card when the bus is operating) the SD Card enters the *idle state*. In case of SD host, CMD0 is not necessary. In case of SPI host, CMD0 shall be the first command to send the card to SPI mode.
- CMD8 is added in the Physical Layer Specification Version 2.00 to support multiple voltage ranges and used to check whether the card supports supplied voltage. The version 2.00 host shall issue CMD8 and verify voltage before card initialization. The host that does not support CMD8 shall supply high voltage range.
- ACMD41 is a synchronization command used to negotiate the operation voltage range and to poll the cards until they are out of their power-up sequence. In case the host system connects multiple cards, the host shall check that all cards satisfy the supplied voltage. Otherwise, the host should select one of the cards and initialize.

#### 4.5.2 Reset Level Power Up

Host needs to keep power line level less than 0.5V and more than 1ms before power ramp up.

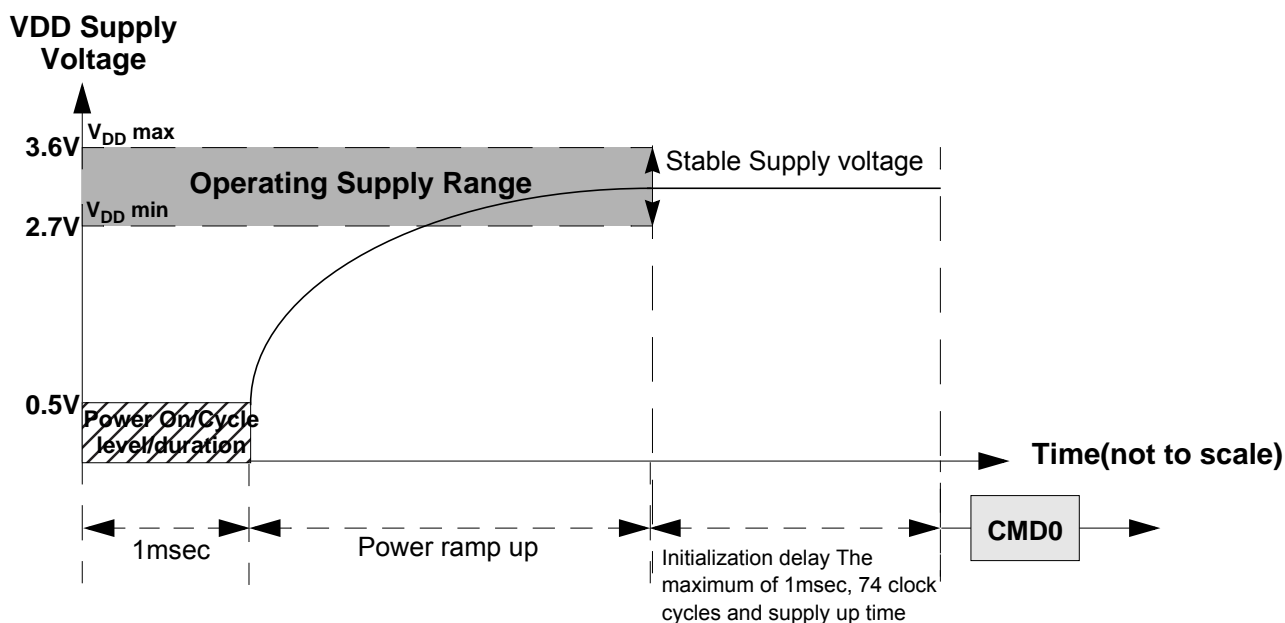


Figure 11. change of Figure for power up

- To assure a reliable SD Card hard reset of Power On and Power Cycle, Voltage level shall be below 0.5V and Time duration shall be at least 1ms.
- The power ramp up time is defined from 0.5V threshold level up to the operating supply voltage which is stable between  $V_{DD}(min.)$  and  $V_{DD}(max.)$  and host can supply SDCLK.

Followings are recommendation of Power ramp up:

- (1) Voltage of power ramp up should be monotonic as much as possible.
- (2) The minimum ramp up time should be 0.1ms.
- (3) The maximum ramp up time should be 35ms for 2.7~3.6V power supply.

#### 4.5.3 Power Down and Power Cycle

- When the host shuts down the power, the card VDD shall be lowered to less than 0.5Volt for a minimum period of 1ms. During power down, DAT, CMD, and CLK should be disconnected or driven to logical 0 by the host to avoid a situation that the operating current is drawn through the signal lines.
- If the host needs to change the operating voltage, a power cycle is required. Power cycle means the power is turned off and supplied again. Power cycle is also needed for accessing cards that are already in *Inactive State*. To create a power cycle the host shall follow the power down description before power up the card (i.e. the card VDD shall be once lowered to less than 0.5Volt for a minimum period of 1ms).

#### 4.5.4 Bus Operating Conditions for 3.3V Signaling

SPI Mode bus operating conditions are identical to SD Card mode bus operating conditions.

##### 4.5.4.1 Threshold Level for High Voltage Range

[Table 15] : Threshold Level for High Voltage

Parameter	Symbol	Min	Max.	Unit	Remark
Supply Voltage	V <sub>DD</sub>	2.7	3.6	V	
Output High Voltage	V <sub>OH</sub>	0.75*V <sub>DD</sub>		V	I <sub>OH</sub> = -2mA V <sub>DD</sub> min
Output Low Voltage	V <sub>OL</sub>		0.125*V <sub>DD</sub>	V	I <sub>OL</sub> = 2mA V <sub>DD</sub> min
Input High Voltage	V <sub>IH</sub>	0.625*V <sub>DD</sub>	V <sub>DD</sub> +0.3	V	
Input Low Voltage	V <sub>IL</sub>	V <sub>SS</sub> -0.3	0.25 *V <sub>DD</sub>	V	
Power Up Time	=		250	ms	From 0V to V <sub>DD</sub> min

##### 4.5.4.2 Bus Signal Line Load

The total capacitance of the SD Memory Card bus is the sum of the bus host capacitance C<sub>HOST</sub>, the bus capacitance C<sub>BUS</sub> itself and the capacitance C<sub>CARD</sub> of each card connected to this line:

$$\text{Total bus capacitance} = C_{\text{HOST}} + C_{\text{BUS}} + N * C_{\text{CARD}}$$

Where N is the number of connected cards.

[Table 16] : Bus Operating Conditions - Signal Line's Load

Parameter	Symbol	Min	Max.	Unit	Remark
Pull-up resistance	R <sub>CMD</sub> R <sub>DAT</sub>	10	100	KOhm	to prevent bus floating
Total bus capacitance for each signal line	C <sub>L</sub>		40	pF	1 card C <sub>HOST</sub> +C <sub>BUS</sub> shall not exceed 30 pF
Capacitance of the card for each signal pin	C <sub>CARD</sub>		10	pF	
Maximum signal line inductance			16	nH	f <sub>pp</sub> <= 20 MHz
Pull-up resistance inside card (pin1)	R <sub>DAT3</sub>	10	90	KOhm	May be used for card detection
Capacity Connected to Power Line	CC		5	uF	To Prevent inrush current

Note that the total capacitance of CMD and DAT lines will be consist of C<sub>HOST</sub>, C<sub>BUS</sub> and one C<sub>CARD</sub> only because they are connected separately to the SD Memory Card host.

Host should consider total bus capacitance for each signal as the sum of C<sub>HOST</sub>, C<sub>BUS</sub>, and C<sub>CARD</sub>, these parameters are defined by per signal. The host can determine C<sub>HOST</sub> and C<sub>BUS</sub> so that total bus capacitance is less than the card estimated capacitance load (C<sub>L</sub>=40 pF). The SD Memory Card guarantees its bus timing when total bus capacitance is less than maximum value of C<sub>L</sub> (40 pF). To limit inrush current caused by host insertion, card maximum capacitance between V<sub>DD</sub> - V<sub>SS</sub> is defined as 5uF. To support host hot insertion, the host should consider decoupling capacitor connected to power line. As microSD card C<sub>c</sub> is 5uF(Max.), 45uF(min.) is recommended for Decoupling capacitor. For more details, please refer to Appendix E of the SDA Physical Layer Specification 3.00.

## 4.5.5 Driver Strength for 1.8V Signaling

### 4.5.5.1 I/O Drive Strength Types

[Table 17] : I/O Driver Strength Types

Driver Type	Nominal Impedance	Driving capability	UHS50 Card	UHS104 Card
A	33Ω	x1.5	Optional	Mandatory
B	50Ω	x1	Mandatory	Mandatory
C	66Ω	x0.75	Optional	Mandatory
D	100Ω	x0.5	Optional	Mandatory

**NOTE :**

Nominal impedance is defined by I-V characteristics of output driver at 0.9V.

(1) Driver Type A

Type A driver is the x15 driver, defined as 33 ohm nominal driver, and supporting up to 208MHz operation.

(2) Driver Type B

Type B driver is the default driver strength, targeted for a fixed impedance distributed system with 50 ohm transmission line, at all available frequencies. Therefore, it is defined as 50 ohm nominal driver. This driver can support total  $C_L$  of about 15pF for UHS104 card and about 30pF for UHS50 card. Driver strength B is the reference driver for definitions of all the rest of the driver strengths.

(3) Driver Type C

Type C driver is the x0.75 driver, it is the weakest driver that supports 208MHz operation, and is defined as 66 ohm nominal driver

(4) Driver Type D

Type D driver is a x0.5 driver, it is best for a system which the speed is not critical, but the more important is low noise / low EMI.

Type D generates the slowest rise / fall time. Using a very slow rise time, the system usually will be considered as a lumped load system.

Type D is defined as 100 ohm nominal driver, and the maximum operating frequency is depends on th host design.

### 4.5.5.2 I/O Driver Target AC Characteristics

The characteristics of output driver are measured by under all maximum to minimum delay conditions.

### 4.5.5.3 Requirement for Rise/Fall Time

[Table 18] : I/O Driver Design Target

Driver Type	Symbol	Driver Rise / Fall Time Requirements				Condition
		Min.	Typ.	Max.	Units	
Type B for UHS104	$T_{RB}, T_{FB}$	0.40	0.88	1.32	ns	15pF
Type B for UHS50	$T_{RB}, T_{FB}$	0.70	1.83	2.75	ns	30pF

**NOTE:**

1. Typical rise / fall time values are a design target. Any actual rise / fall time that is between the minimum and the maximum is conforming to this specification.

2. Output rise time is measured between  $V_{OL}$  (0.45V) to  $V_{OH}$  (1.4V), output fall time is measured between  $V_{OH}$  (1.4V) to  $V_{OL}$  (0.45V).

3. The I-V curve(current-voltage characteristics) of drivers types A,C and D are approximately x1.5,x0.75 and x0.5 from the default driver type B

### 4.5.5.4 Requirement for Rise/Fall Time

[Table 19] : Design Target for Ratio of Rise / Fall Time

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
The Ratio of Rise / Fall Time	$R_{RF}$	0.7	1.0	1.4	-	$R_{RF}=T_R/T_F$

## 4.5.5.5 Output Driver Test Circuit

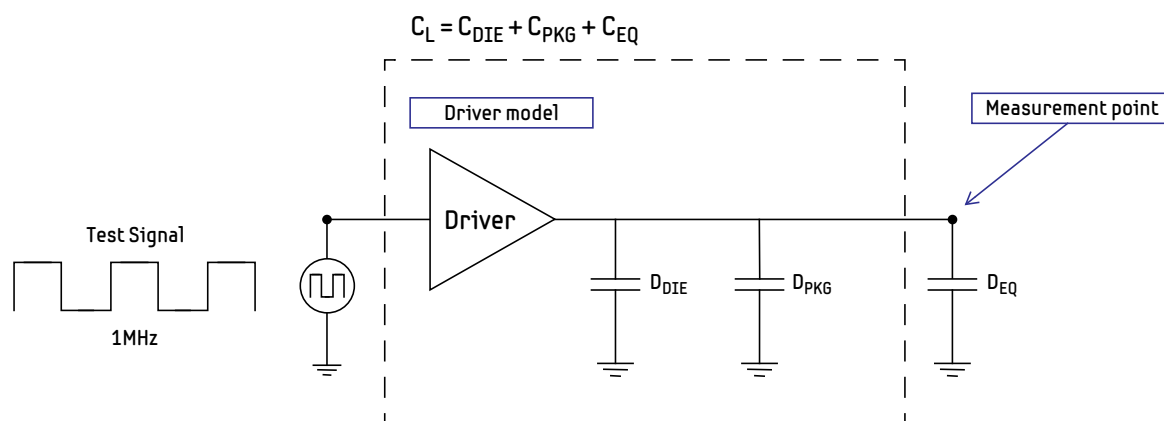


Figure 12. Outputs Test Circuit for Rise/Fall Time Measurement

## NOTE :

- 1) The ratio of rise time to fall time is specified for the same temperature and voltage, over the entire temperature and voltage range. For a given temperature and voltage combination, it represents the maximum difference between rise and fall time due to process variation.
- 2) Terminology is defined as follows:

[Table 20] : Card Capacitance Range

Capacitance	Min	Max	Units	Notes
$C_{CARD} (C_{DIE} + C_{PKG})$	5	10	pF	---

## 4.5.5.6 Driver Strength Selection

[Table 21] : Output Driver Type Support Bits

CMD6 Status Bit	Meaning
432	Support bit of Type B Driver (Always 1 as default)
433	Support bit of Type A Driver
434	Support bit of Type C Driver
435	Support bit of Type D Driver

[Table 22] : Approximation of Total Capacitance for Each of Drive Strength

Driver Type	Type A	Type B	Type C	Type D
$C_L$ at 208MHz	21pF	15pF	11pF	Note1
$C_L$ at 100MHz SDR $C_L$ at 50 MHz DDR	43pF	30pF	23pF	Note1

## NOTE :

- 1) Type D support total  $C_L$  of about 22pF or more, for slower rise / fall time than at 100MHz SDR operation. When selecting type D driver, the maximum frequency is determined by the host system.

## 4.5.6 Bus Operating Condition for 1.8V Signaling

## 4.5.6.1 Threshold Level for 1.8V Signaling

[Table 23] : Threshold Level for 1.8V Signaling

Parameter	Symbol	Min.	Max.	Unit	Remark
Supply Voltage	$V_{DD}$	2.70	3.60	V	
Regulator Voltage	$V_{DDIO}$	1.70	1.95	V	Generated by $V_{DD}$
Output High Voltage	$V_{OH}$	1.40	-	V	$I_{OH} = -2mA$
Output Low Voltage	$V_{OL}$	-	0.45	V	$I_{OL} = 2mA$
Input High Voltage	$V_{IH}$	1.27	2.00	V	
Input Low Voltage	$V_{IL}$	$V_{SS}-0.30$	0.58V	V	

## 4.5.6.2 Leakage Current

[Table 24] : Input Leakage Current

Parameter	Symbol	Min.	Max.	Unit	Remark
Input Leakage Current		-2	2	$\mu A$	DAT3 pull-up is disconnected.

## 4.6 Bus Signal Levels

As the bus can be supplied with a variable supply voltage, all signal levels are related to the supply voltage.

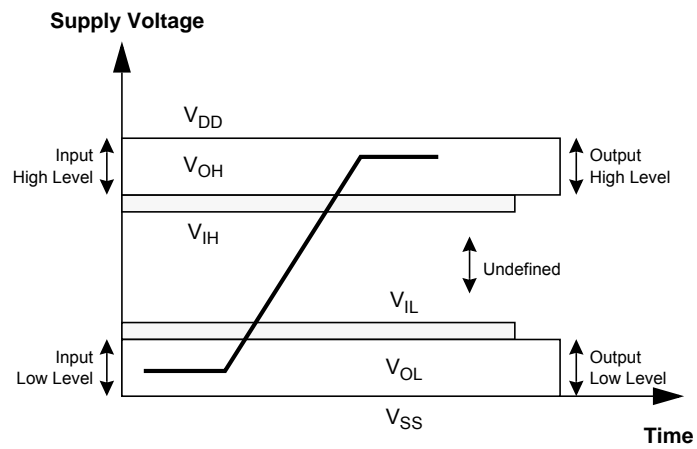
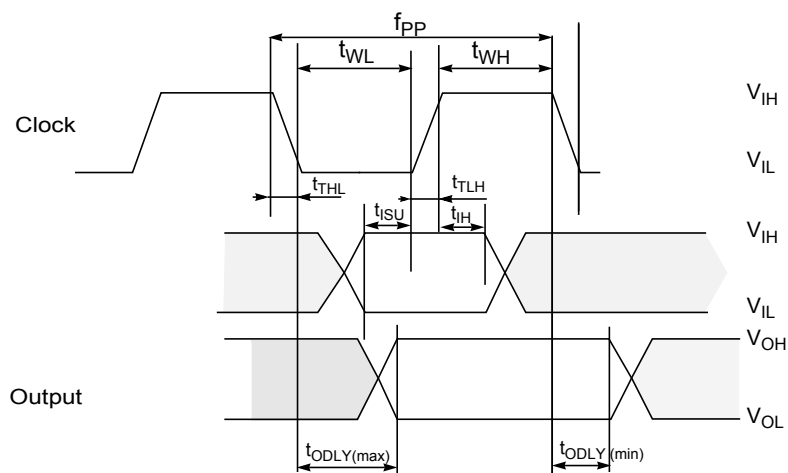


Figure 13. Bus Signal Levels

To meet the requirements of the JEDEC specification JESD8-1A and JESD8-7, the card input and output voltages shall be within the specified ranges shown in Table 5-2 for any VDD of the allowed voltage range.



## 4.6.1 Bus Timing (Default Mode)



Shaded areas are not valid

Figure 14. Timing diagram data input/output referenced to clock (Default)

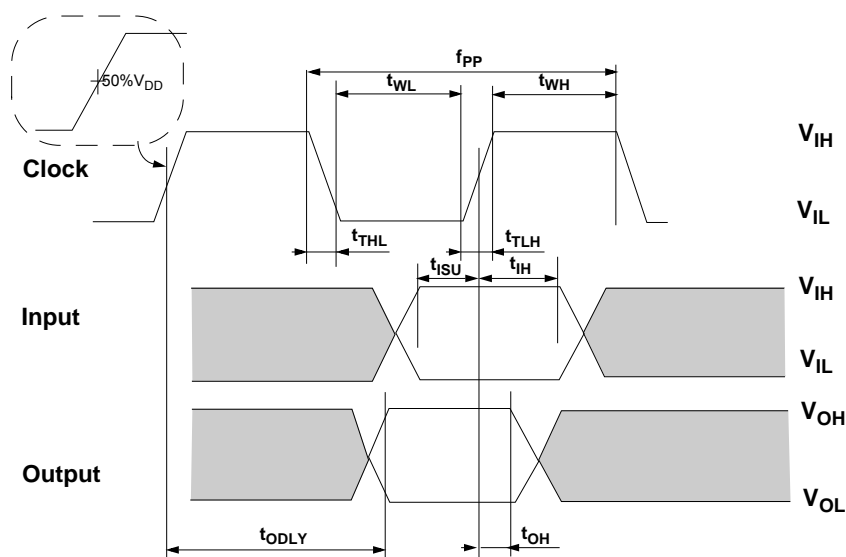
[Table 25] : Bus Timing - Parameter Values (Default)

Parameter	Symbol	Min	Max.	Unit	Remark
Clock CLK ( All values are referred to min. ( $V_{IH}$ ) and max. ( $V_{IL}$ ) )					
Clock frequency Data Transfer Mode	$f_{PP}$	0	25	MHz	$C_{CARD} \leq 10$ pF (1 card)
Clock frequency Identification Mode	$f_{OD}$	0 <sup>1)</sup> / 100	400	kHz	$C_{CARD} \leq 10$ pF (1 card)
Clock low time	$t_{WL}$	10		ns	$C_{CARD} \leq 10$ pF (1 card's)
Clock high time	$t_{WH}$	10		ns	$C_{CARD} \leq 10$ pF (1 card)
Clock rise time	$t_{TLH}$		10	ns	$C_{CARD} \leq 10$ pF (1 card)
Clock fall time	$t_{THL}$		10	ns	$C_{CARD} \leq 10$ pF (1 card)
Inputs CMD, DAT (referenced to CLK)					
Input set-up time	$t_{ISU}$	5		ns	$C_{CARD} \leq 10$ pF (1 card)
Input hold time	$t_{IH}$	5		ns	$C_{CARD} \leq 10$ pF (1 card)
Outputs CMD, DAT (referenced to CLK)					
Output delay time during Data Transfer Mode	$t_{ODLY}$	0	14	ns	$C_L \leq 40$ pF (1 card)
Output delay time during Identification Mode	$t_{ODLY}$	0	50	ns	$C_L \leq 40$ pF (1 card)

## NOTE:

1) 0Hz means to stop the clock. The given minimum frequency range is for cases where a continuous clock is required

## 4.6.2 Bus Timing (High-speed Mode)



Shaded areas are not valid

Figure 15. Timing Diagram data Input/Output Referenced to Clock (High-Speed)

[Table 26] : Bus Timing - Parameter Values (High-Speed)

Parameter	Symbol	Min	Max.	Unit	Remark
Clock CLK ( All values are referred to min. ( $V_{IH}$ ) and max. ( $V_{IL}$ ) )					
Clock frequency Data Transfer Mode	$f_{PP}$	0	50	MHz	$C_{CARD} \leq 10$ pF (1 card)
Clock low time	$t_{WL}$	7		ns	$C_{CARD} \leq 10$ pF (1 card)
Clock high time	$t_{WH}$	7		ns	$C_{CARD} \leq 10$ pF (1 card)
Clock rise time	$t_{TLH}$		3	ns	$C_{CARD} \leq 10$ pF (1 card)
Clock fall time	$t_{THL}$		3	ns	$C_{CARD} \leq 10$ pF (1 card)
Inputs CMD, DAT (referenced to CLK)					
Input set-up time	$t_{ISU}$	6		ns	$C_{CARD} \leq 10$ pF (1 card)
Input hold time	$t_{IH}$	2		ns	$C_{CARD} \leq 10$ pF (1 card)
Outputs CMD, DAT (referenced to CLK)					
Output delay time during Data Transfer Mode	$t_{ODLY}$		14	ns	$C_L \leq 40$ pF (1 card)
Output Hold time	$t_{OH}$	2.5		ns	$C_L \leq 15$ pF (1 card)
Total System capacitance for each line <sup>1)</sup>	$C_L$		40	pF	1 card

## NOTE:

1) In order to satisfy severe timing, host shall drive only one card.

4.6.3 Bus Timing Specification in SDR12, SDR25, SDR50 and SDR104 Modes

4.6.3.1 Clock Timing

SDCLK input shall satisfy the clock timing over all variable conditions, and is measured as close as possible to SD socket pins to the card while CMD and DAT[3:0] are in quiet state(not toggling).  $V_{IH}$  denotes  $V_{IH}$  (min.) and  $V_{IL}$  denotes  $V_{IL}$ (max.) in Figure 19.

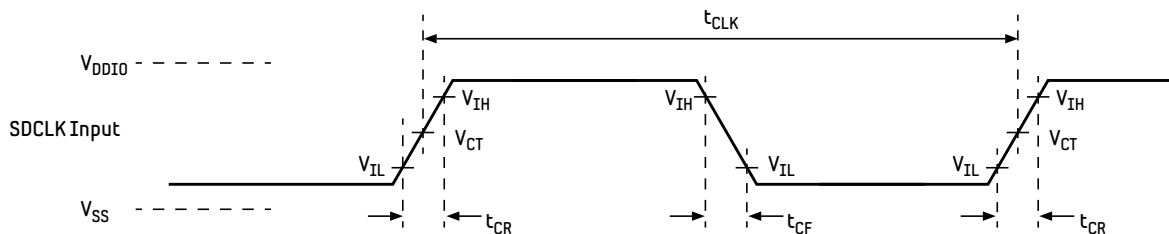


Figure 16. Clock Signal Timing

[Table 27] : Clock Signal Timing

Symbol	Min.	Max.	Unit	Remark
$t_{CLK}$	4.80	-	ns	208MHz (Max.), Between rising edge, $V_{CT}= 0.975V$
$t_{CR}, t_{CF}$	-	$0.2 * t_{CLK}$	ns	$t_{CR}, t_{CF} < 0.96ns$ (max.) at 208MHz, $C_{CARD}=10pF$ $t_{CR}, t_{CF} < 2.00ns$ (max.) at 100MHz, $C_{CARD}=10pF$ The absolute maximum value of $t_{CR}, t_{CF}$ is 10ns regardless of clock frequency.
Clock Duty	30	70	%	

4.6.3.2 Card Input Timing

The new parameter Clock Threshold( $V_{CT}$ ) is introduced to indicate clock reference point and is defined as 0.975V. Data setup time and hold time are measure at Data Threshold( $V_{IH}$ (min.) and  $V_{IL}$ (max.)).  $V_{IH}$  denotes  $V_{IH}$  (min.) and  $V_{IL}$  denotes  $V_{IL}$ (max.) in Figure 20

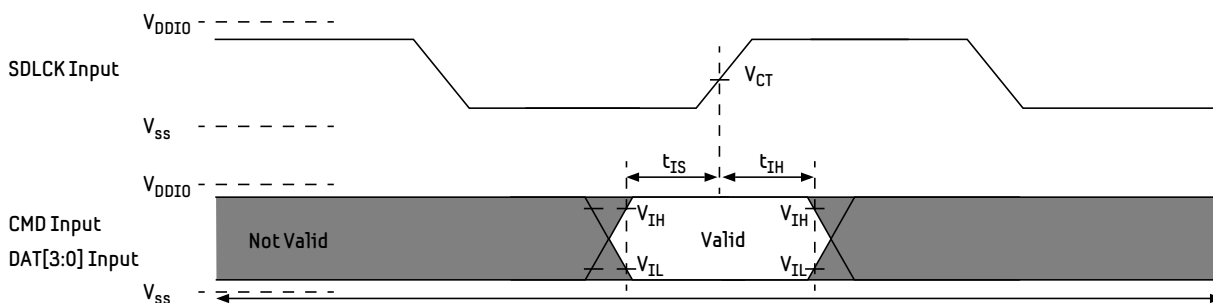


Figure 17. Card Input Timing

[Table 28] : SDR50 and SDR104 Input Timing

Symbol	Min.	Max.	Unit	SDR104 mode
$t_{IS}$	1.40	-	ns	$C_{CARD}=10pF, V_{CT}= 0.975V$
$t_{IH}$	0.80	-	ns	$C_{CARD}=5pF, V_{CT}= 0.975V$
Symbol	Min.	Max.	Unit	SDR50 mode
$t_{IS}$	3.00	-	ns	$C_{CARD}=10pF, V_{CT}= 0.975V$
$t_{IH}$	0.80	-	ns	$C_{CARD}=5pF, V_{CT}= 0.975V$

## 4.6.4 Card Output Timing

### 4.6.4.1 Frequency Range Consideration

The maximum frequency of UHS-I is 208MHz. Hosts can use any frequency less than the UHS-I card supported. Considering the relation between clock period and output delay time, there is a border frequency around 100MHz. Therefore, two output timing diagrams are defined in this document.

(1) Fixed Output Data Window Case (SDR12, SDR25, SDR50 and DDR50)

If output delay is less than clock period ( $t_{ODLY(max.)} < t_{CLK}$ ), DAT[3:0] can be sampled by SDCLK because fixed data window synchronized to SDCLK is always available. Considering  $t_{ODLY}$  (delay from SDCLK input to CMD and DAT[3:0] output), overlapped area of valid window is available under all maximum and minimum delay conditions (Variation of Temperature and voltage). Refer to Figure 21. Fixed Output Data Window Timing (Figure 22) defines overlapped area of valid data window.

Host can create sampling clock by loopback SDCLK method (refer to Appendix C.1). This timing mode enables the host to configure a simple data receiver circuit. The Fixed Output Data window case is supported in SDR12, SDR25, SDR50 and DDR50. The frequency range is up to 100MHz.

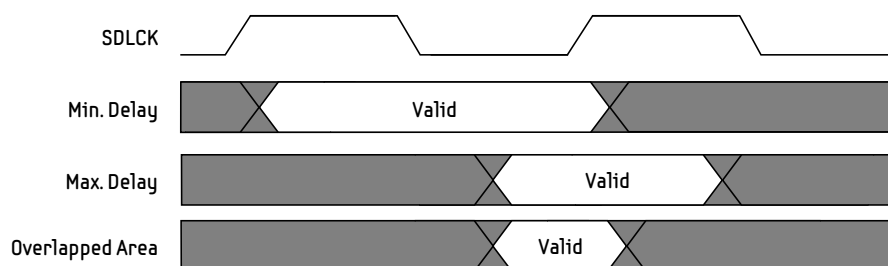


Figure 18. Fixed Output Data Window

(2) Variable Output Data Window Case(SDR104)

Output delay may be bigger than one clock period. In this case, another timing parameter  $t_{OP}$  is adopted.  $t_{OP}$  is the momentary output phase from SDCLK input to CMD and DAT[3:0] output. After initialization, the  $t_{OP}$  can start at any phase in relation to the clock. At the initialization step the host should take care to find the optimal sampling point for the card outputs. The Variable Output Data Window is supported in SDR104. The frequency range is up to 208MHz.

#### Application Notes:

The fixed timing supported host can use SDR12, SDR25 and SDR50 modes and cannot use SDR104 mode.

### 4.6.4.2 Output Timing of Fixed Data Window (SDR12, SDR25 and SDR50)

Figure 22 shows card output timing of fixed data window and Table 29 shows required values of this timing for SDR12, SDR25 and SDR50. A valid window is specified by the minimum and maximum of output delay ( $t_{ODLY}$ ). The valid data window synchronized to SDCLK is available regardless of all temperature and voltage variation. Output valid window is calculated by  $t_{CLK} - t_{ODLY} + t_{OH}$ . Host can create sampling clock by delayed SDCLK.  $V_{OH}$  denote  $V_{OH(min.)}$  and  $V_{OL}$  denotes  $V_{OL(max.)}$  in Figure 22

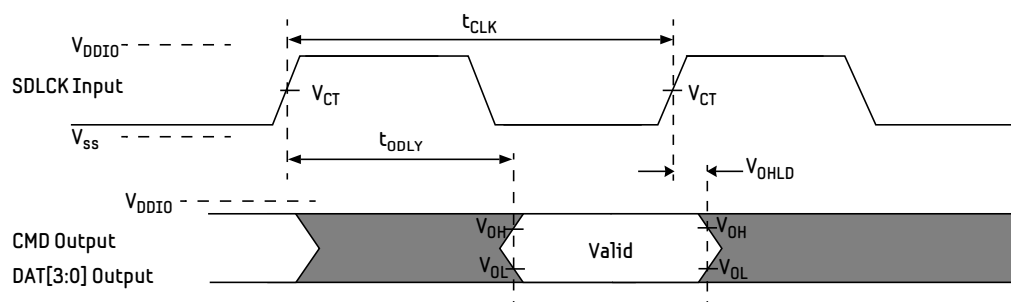


Figure 19. Output Timing of Fixed Data Window

[Table 29]: Output Timing of Fixed Data Window

Symbol	Min.	Max.	Unit	Remark
$t_{ODLY}$	-	7.5	ns	$t_{CLK} \geq 10.0\text{ns}$ , $C_L = 30\text{pF}$ , using driver Type B. for SDR50,
$t_{ODLY}$	-	14	ns	$t_{CLK} \geq 20.0\text{ns}$ , $C_L = 40\text{pF}$ , using driver Type B. for SDR25 and SDR12,
$t_{OH}$	1.5	-	ns	Hold time at the $t_{ODLY}$ (min.), $C_L = 15\text{pF}$

4.6.4.3 Output Timing of Variable Window (SDR104)

Figure 23 shows card output timing of variable data window and Table 30 shows required values of this timing.  $t_{OP}$  is introduced to express output delay.  $t_{OP}$  does not include a long term temperature drift in contrast  $t_{ODLY}$  which includes all delay variation. The temperature drift is expressed by  $\Delta t_{OP}$ .  $t_{OP}$  after initialization, can be in range from 0 to 2UI. On determining sampling point of data, a long term drift, which is mainly depends on temperature drift, should be considered. Output valid data window( $t_{ODW}$ ) is available regardless of the drift ( $\Delta t_{OP}$ ) but position of data window varies by the drift.  $V_{OH}$  denotes  $V_{OH}(\min.)$  and  $V_{OL}$  denotes  $V_{OL}(\max.)$  in Figure 23

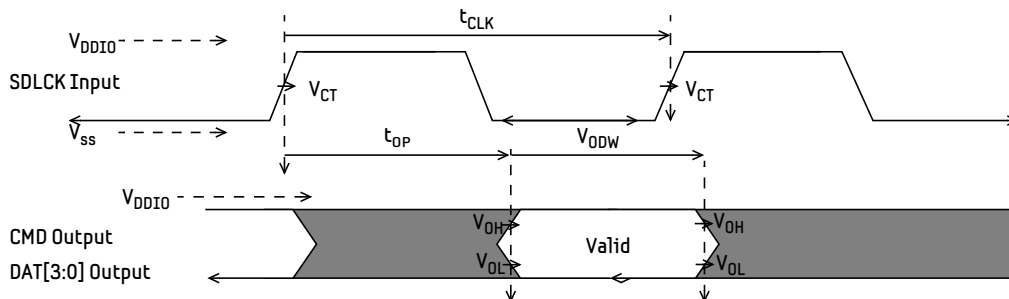


Figure 20. Output Timing of Variable Data Window

[Table 30] : Output Timing of Variable Data Window

Symbol	Min.	Max.	Unit	Remark
$t_{OP}$	0	2	UI	Card Output Phase
$\Delta t_{OP}$	-350	+1550	ps	Delay variation due to temperature change after tuning
$t_{ODW}$	0.60	-	UI	$t_{ODW} = 2.88ns$ at 208MHz

Card  $\Delta t_{OP}$  is the total allowable shift of output valid window ( $T_{ODW}$ ) from last system Tuning procedure.

Card  $\Delta t_{OP} = 1550pS$  for junction temperature of  $\Delta T = 90$  deg.C during operation.

Card  $\Delta t_{OP} = -350pS$  for junction temperature of  $\Delta T = -20$  deg.C during operation.

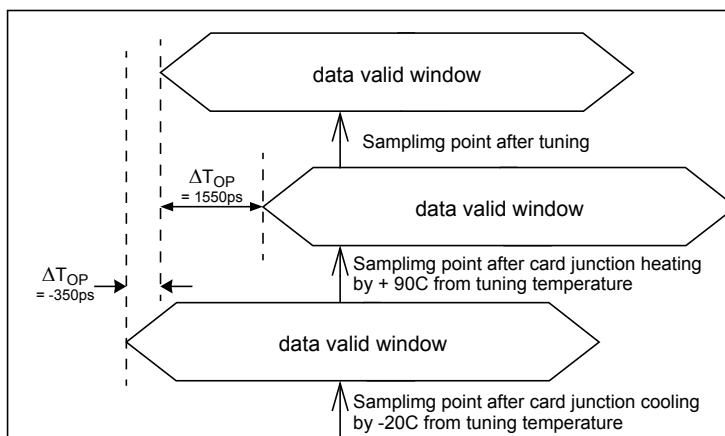


Figure 21.  $\Delta t_{OP}$  Consideration for Variable Data Window Mode

The range of  $\Delta t_{OP}$  is 2600ps when card junction temperature changes from -25 deg. C to 125 deg. C during operation.

It is important note that Figure 22 and Figure 23 are output timings of the same output circuit expressed under different conditions. Two output timing figures are required because two types of read data sampling methods are presumed depends on host implementation. These output timings are defined at the test circuit measurement point.  $T_{ODW}$  for card is defined in this table, using an external noise free test circuit. The valid window defined by output timings include skew among CMD and DAT[3:0] created by the card.

The host designer should consider the host transmission path which will add some Signal Integrity induced noise, skew between bus members, and timing errors. Expected  $T_{ODW}$  at host input is larger than 0.50UI.

Application Notes:

The host needs to consider drift of data window. A temperature drift after tuning procedure completes translates into a limited output valid window drift ( $\Delta t_{OP}$ ). The Host designer should take into consideration this drift, and design correctly to avoid being affected by this drift.

It is good practice to activate tuning procedure after sleep.

Host can use different techniques to overcome temperature effect (include reducing operating frequency).

4.6.5 Bus Timing specification in DDR50 Mode

4.6.5.1 Clock Timing

Figure 25 shows clock signal timing and Table 31 shows required values of this timing. Clock timing is requirement for the host.  $t_{CLK}$  is used to define rise / fall timing. Rise and fall time shall be less than  $0.2 * t_{CLK}$ . SDCLK input shall satisfy the clock timing over all variable Conditions, and is measured as close as possible to SD socket pins to the card while CMD and DAT[3:0] are in quiet state (not toggling).  $V_{IH}$  denote  $V_{IH}(\min.)$  and  $V_{IL}$  denotes  $V_{IL}(\max.)$  in Figure 25

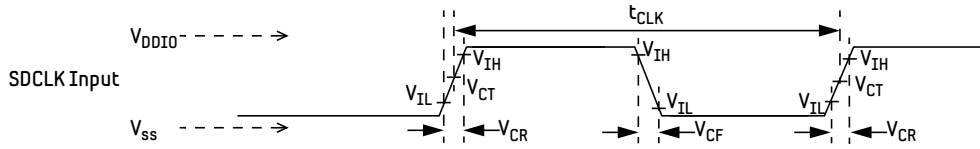


Figure 22. Clock Signal Timing

[Table 31] : Clock Signal Timing

Symbol	Min.	Max.	Unit	Remark
$t_{CLK}$	20	-	ns	50MHz (Max.), Between rising edge
$t_{CR}, t_{CF}$	-	$0.2 * t_{CLK}$	ns	$t_{CR}, t_{CF} < 4.00ns$ (max.) at 50MHz, $C_{CARD}=10pF$
Clock Duty	45	55	%	

CMD signal timings are not shown in Figure 26. For CMD Signal timing refers to Figure 20 and Figure 22 (Timing Diagram of SDR mode).

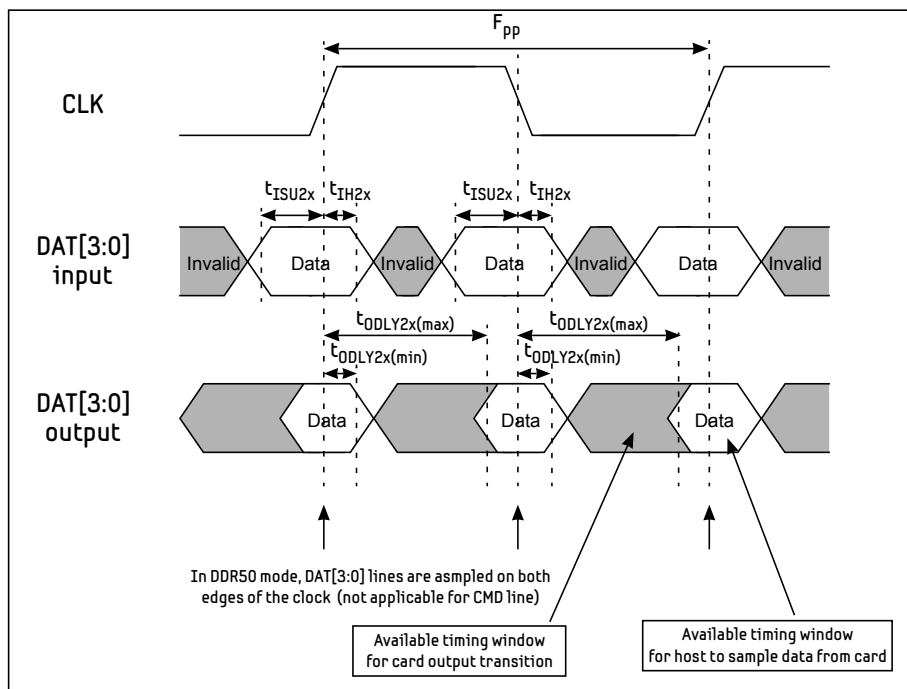


Figure 23. Timing Diagram DAT Inputs/Outputs Referenced to CLK in DDR50 Mode

[Table 32] : Bus Timings - Parameters Values (DDR50 mode)

Parameter	Symbol	Min	Max	Unit	Remark
<b>Input CMD (referenced to CLK rising edge)</b>					
Input set-up time	$t_{ISU}$	6	-	ns	$C_{CARD} \leq 10\text{pF}$ (1 card)
Input hold time	$t_{IH}$	0.8	-	ns	$C_{CARD} \leq 10\text{pF}$ (1 card)
<b>Output CMD (referenced to CLK rising edge)</b>					
Output Delay time during Data Transfer Mode	$t_{ODLY}$	-	13.7	ns	$C_L \leq 30\text{pF}$ (1 card)
Output hold time	$t_{OH}$	1.5	-	ns	$C_L \geq 15\text{pF}$ (1 card)
<b>Inputs DAT (referenced to CLK rising and falling edges)</b>					
Input set-up time	$t_{ISU2x}$	3	-	ns	$C_{CARD} \leq 10\text{pF}$ (1 card)
Input hold time	$t_{IH2x}$	0.8	-	ns	$C_{CARD} \leq 10\text{pF}$ (1 card)
<b>Outputs DAT (referenced to CLK rising and falling edges)</b>					
Output Delay time during Data Transfer Mode	$t_{ODLY2x}$	-	7.0	ns	$C_L \leq 25\text{pF}$ (1 card)
Output hold time	$t_{ODLY2x}$	1.5	-	ns	$C_L \geq 15\text{pF}$ (1 card)

## 5.0 MICROSD CARD FUNCTIONAL DESCRIPTION

### 5.1 General

SEC microSD Card Functional Description contained in this chapter; Section 6.2~6.14; basically, conform to SDA Physical Layer Specification, Version 3.00. See Chapter 4 of the SDA Physical Layer Specification, Version 3.00 for detail information and guide.

### 5.2 Card Identification Mode

While in Card Identification mode the host resets all the cards that are in card identification mode, validates operation voltage range, identifies cards and asks them to publish Relative Card Address(RCA). This operation is done to each card separately on its own CMD line. Refer to Section 4.2 of the SDA Physical Layer Specification, Version 3.00 for detail information and guide<sup>1)</sup>

**NOTE :**

The products on this specification support UHS-1 mode. For correct identification flow, please refer to Section 4.2 of the SDA Physical Layer Specification, Version 2.00.

### 5.3 Clock Control

The microSD Memory Card bus clock signal can be used by the host to change the cards to energy saving mode or to control the data flow(to avoid under-run or over-run conditions) on the bus. Refer to Section 4.4 of the SDA Physical Layer Specification, Version 3.00 for detail information and guide

### 5.4 Cyclic Redundancy Code

The CRC is intended for protecting SD Card commands, responses and data transfer against transmission errors on the SD Card bus. One CRC is generated for every command and checked for every response on the CMD line. For data blocks one CRC per transferred block, per data line, is generated. The CRC is generated and checked as described in the Section 4.5 of the SDA Physical Layer Specification, Version 3.0

### 5.5 Command

There are four kinds of commands defined to control the SD Card:

- \* Broadcast commands (bc), no response - The broadcast feature is only if all the CMD lines are connected together in the host. If they are separated then each card will accept it separately on his turn.
- \* Broadcast commands with response (bcr) - response from all cards simultaneously. Since there is no Open Drain mode in SD Card, this type of command is used only if all the CMD lines are separated. The command will be accepted and responded to by every card separately.
- \* Addressed (point-to-point) commands (ac) - no data transfer on DAT lines
- \* Addressed (point-to-point) data transfer commands (adtc), data transfer on DAT lines

All commands and responses are sent over the CMD line of the SD Card bus. The command transmission always starts with the left bit of the bitstring corresponding to the command code word. For more details, refer to the Section 4.7 of the SDA Physical Layer Specification, Version 3.0.

**NOTE:**

Limited Vendor CMD information, only for certain customer and application, can be provided under appropriate purpose of usage.



## 5.6 Memory Array Partitioning

The basic unit of data transfer to/from the SD Card is one byte. All data transfer operations which require a block size always define block lengths as integer multiples of bytes. Some special functions need other partition granularity.

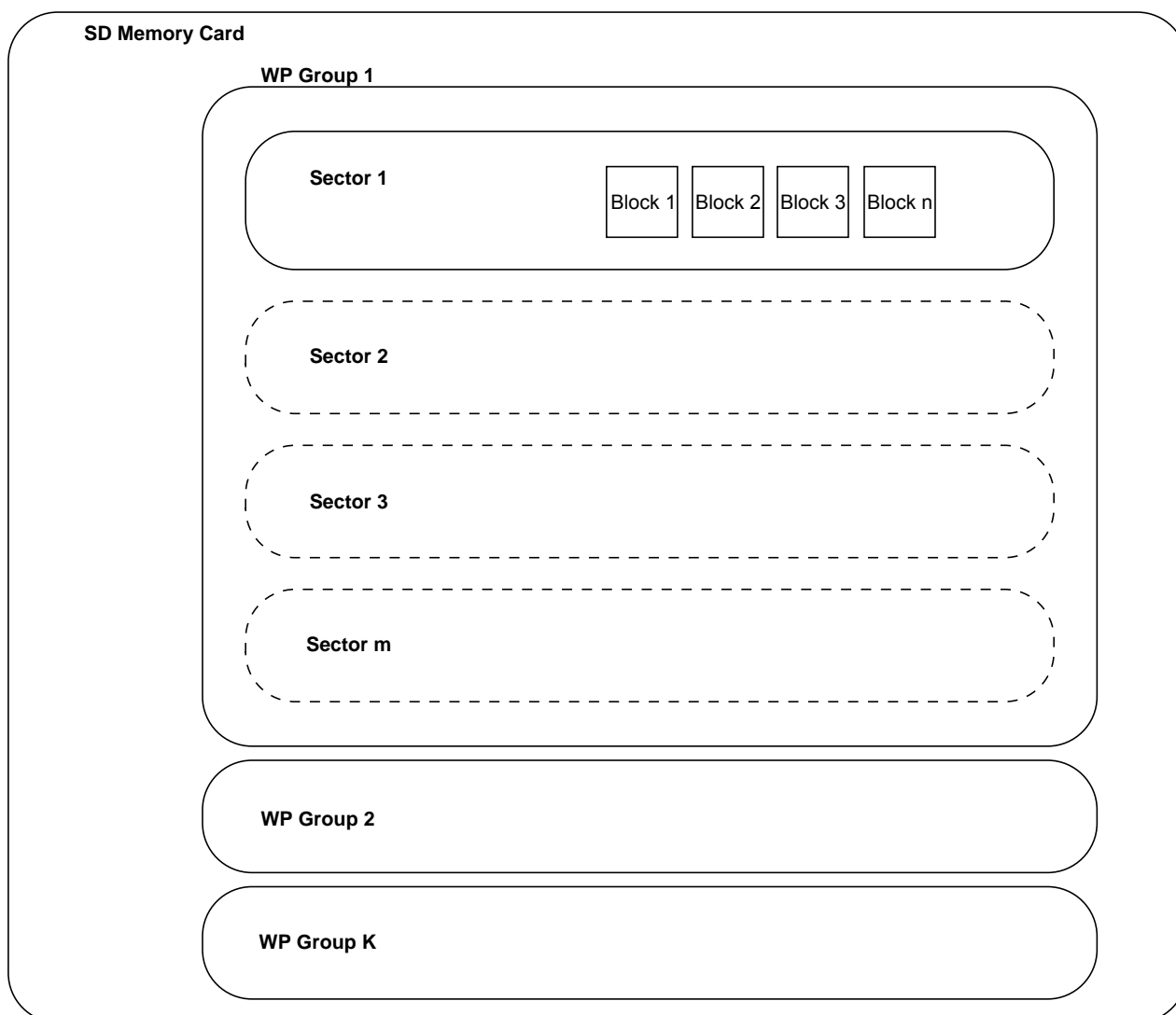


Figure 24. Write Protection Hierarchy

For block oriented commands, the following definition is used:

- **Block:** is the unit that is related to the block oriented read and write commands. Its size is the number of bytes that will be transferred when one block command is sent by the host. The size of a block is either programmable or fixed. The information about allowed block sizes and the programmability is stored in the CSD.
- For devices that have erasable memory cells, special erase commands are defined. The granularity of the erasable units is in general not the same as for the block oriented commands:
- **Sector:** is the unit that is related to the erase commands. Its size is the number of blocks that will be erased in one portion. The size of a sector is fixed for each device. The information about the sector size (in blocks) is stored in the CSD. Note that if the card specifies AU size, sector size should be ignored.
- **AU (Allocation Unit):** is a physical boundary of the card and consists of one or more blocks and its size depends on each card. The maximum AU size is defined for memory capacity. Furthermore AU is the minimal unit in which the card guarantees its performance for devices which complies with Speed Class Specification. The information about the size and the Speed Class are stored in the SD Status. AU is also used to calculate the erase timeout and UHS speed Grade
- **WP-Group:** is the minimal unit that may have individual write protection for devices which support write-protected group. Its size is the number of groups that will be write-protected by one bit. The size of a WP-group is fixed for each device. The information about the size is stored in the CSD. The High Capacity SD Memory Card does not support the write protect group command.

## 5.7 Timings

Refer to Section 4.12 of the SDA Physical Layer Specification, Version 3.0 for detail information and guide<sup>1)</sup>

**NOTE :**

1) The product on this specification supports UHS-1 mode.

## 5.8 Speed Class Specification

Refer to Section 4.13 of the SDA Physical Layer Specification, Version 3.0 for detail information and guide<sup>1)</sup>

**NOTE :**

1) The product on this specification supports UHS-1 mode.

## 5.9 Erase Timeout Calculation

Refer to Section 4.14 of the SDA Physical Layer Specification, Version 3.0 for detail information and guide<sup>1)</sup>

**NOTE :**

1) The product on this specification supports UHS-1 mode.