

## Chapter 1 Introduction

RK3188 is a low power, high performance processor for mobile phones, personal mobile internet device and other digital multimedia applications, and integrates quad-core Cortex-A9 with separately NEON and FPU coprocessor.

Many embedded powerful hardware engines provide optimized performance for high-end application. RK3188 supports almost full-format video decoder by 1080p@60fps, also support H.264/MVC/VP8 encoder by 1080p@30fps, high-quality JPEG encoder/decoder, special image preprocessor and postprocessor.

Embedded 3D GPU makes RK3188 completely compatible with OpenGL ES2.0 and 1.1, OpenVG 1.1. Special 2D hardware engine with MMU will maximize display performance and provide very smoothly operation.

RK3188 has high-performance external memory interface(DDR3/LPDDR2/LVDDR3) capable of sustaining demanding memory bandwidths, also provides a complete set of peripheral interface to support very flexible applications as follows :

- 2 banks, 8bits/16bits Nor Flash/SRAM interface
- 4 banks, 8bits/16bits async Nand Flash, LBA Nand Flash and 8bits sync ONFI Nand Flash, all up to 60bits hardware ECC
- Totally 2GB memory space for 2 ranks, 16bits/32bits DDR3-800, LPDDR2-800, LVDDR3-800
- Totally 3-channels SD/MMC interface to support MMC4.41, SD3.0, SDIO3.0 or eMMC
- Dual-channels TFT LCD interface with 4-layers , 2048x1536 maximum display size
- One-channels, 8bits BT656 interface, 16bits BT601 DDR interface and 10bits/12bits raw data interface with image preprocessor
- Audio interface: one 2ch I2S/PCM interface and SPDIF tx interface
- One USB OTG 2.0 and one USB Host2.0 interface and HSIC interface
- 10M/100M RMI ethernet interface
- GPS interface
- High-speed ADC interface and TS stream interface
- Lots of low-speed peripheral interface : 5I2C, 4UART, 2SPI, 4 PWM

This document will provide guideline on how to use RK3188 correctly and efficiently. The chapter 1 and chapter 2 will introduce the features, block diagram, signal descriptions and system usage of RK3188, the chapter 3 through chapter 45 will describe the full function of each module in detail.

### 1.1 Features

#### 1.1.1 MicroProcessor

- Quad-core ARM Cortex-A9 MPCore processor, a high-performance, low-power and cached application processor
- Full implementation of the ARM architecture v7-A instruction set, ARM Neon Advanced SIMD (single instruction, multiple data) support for accelerated media and signal processing computation
- Superscalar, variable length, out-of-order pipeline with dynamic branch

- prediction, 8-stage pipeline
- Include VFPv3 hardware to support single and double-precision add, subtract, divide, multiply and accumulate, and square root operations
- SCU ensures memory coherency between the four CPUs
- Integrated timer and watchdog timer per CPU
- Integrated 32KB L1 instruction cache , 32KB L1 data cache with 4-way set associative
- 512KB unified L2 Cache
- Trustzone technology support
- Full coresight debug solution
  - Debug and trace visibility of whole systems
  - ETM trace support
  - Invasive and non-invasive debug
- Six separate power domains for every core to support internal power switch and externally turn on/off based on different application scenario
  - PD\_A9\_0: 1<sup>st</sup> Cortex-A9 + Neon + FPU + L1 I/D Cache
  - PD\_A9\_1: 2<sup>nd</sup> Cortex-A9 + Neon + FPU + L1 I/D Cache
  - PD\_A9\_2: 3<sup>rd</sup> Cortex-A9 + Neon + FPU + L1 I/D Cache
  - PD\_A9\_3: 4<sup>th</sup> Cortex-A9 + Neon + FPU + L1 I/D Cache
  - PD\_DBG: CoreSight-DK for Cortex-A9
  - PD\_SCU: SCU + L2 Cache controller + L2 Dataram, and including PD\_A9\_0, PD\_A9\_1, PD\_A9\_2, PD\_A9\_3, PD\_DGB
- One isolated voltage domain to support DVFS
- Maximum frequency can be up to 1GHz@0.9V(Worst Case) or 1.4GHz@1.0V(Typical Case).

### 1.1.2 Memory Organization

- Internal on-chip memory
  - 10KB BootRom
  - 32KB internal SRAM for security and non-security access, detailed size is programmable
- External off-chip memory<sup>®</sup>
  - DDR3-800, 16/32bits data widths, 2 ranks, totally 2GB(max) address space, maximum address space for one rank is also 2GB.
  - LPDDR2-800, 32bits data width, 2 ranks, totally 2GB(max) address space, maximum address space for one rank is also 2GB.
  - Async SRAM/Nor Flash, 8/16bits data width, 2banks
  - Async Nand Flash(include LBA Nand), 8/16bits data width, 4 banks, 60bits ECC
  - Sync ONFI Nand Flash , 8bits data width, 8 banks, 60bits ECC

### 1.1.3 Internal Memory

- Internal BootRom
  - Size : 10KB
  - Support system boot from the following device:
    - ◆ 8bits/16bits Async Nand Flash
    - ◆ 8bits ONFI Nand Flash
    - ◆ SPI0 interface
    - ◆ eMMC interface
    - ◆ SDMMC interface
  - Support system code download by the following interface:
    - ◆ USB OTG interface
    - ◆ UART2Interface

- Internal SRAM
  - Size : 32KB
  - Support security and non-security access
  - Security or non-security space is software programmable
  - Security space can be 0KB,4KB,8KB,12KB,16KB,32KB continuous size
- 1.1.4 External Memory or Storage device
  - Dynamic Memory Interface (DDR3/LPDDR2)
    - Compatible with JEDEC standard DDR3/LPDDR2 SDRAM
    - Data rates up to 800Mbps(400MHz) for DDR3/LPDDR2
    - Support up to 2 ranks (chip selects), totally 2GB(max) address space, maximum address space for one rank is also 2GB, which is software-configurable.
    - 16bits/32bits data width is software programmable
    - 7 host ports with 64bits AXI bus interface for system access, AXI bus clock is asynchronous with DDR clock
    - Programmable timing parameters to support DDR3/LPDDR2 SDRAM from various vendor
    - Advanced command reordering and scheduling to maximize bus utilization
    - Low power modes, such as power-down and self-refresh for DDR3/LPDDR2 SDRAM; clock stop and deep power-down for LPDDR2 SDRAM
    - Compensation for board delays and variable latencies through programmable pipelines
    - Embedded dynamic drift detection in the PHY to get dynamic drift compensation with the controller
    - Programmable output and ODT impedance with dynamic PVT compensation
    - Support one low-power work mode: power down DDR PHY and most of DDR IO except two cs and two cke output signals, make SDRAM still in self-refresh state to prevent data missing.
  - Static Memory Interface (ASRAM/Nor Flash)
    - Compatible with standard async SRAM or Nor Flash
    - Support up to 2 banks (chip selects)
    - For bank0, 8bits/16bits data width is software programmable; For bank1, 16bits data width is fixed
    - Support separately data and address bus, also support shared data and address bus to save IO numbers
  - Nand Flash Interface
    - Support 8bits/16bits async nand flash, up to 4 banks
    - Support 8bits sync DDR nand flash, up to 4 banks
    - Support LBA nand flash in async or sync mode
    - Up to 60bits hardware ECC
    - For DDR nand flash, support DLL bypass and 1/4 or 1/8 clock adjust, maximum clock rate is 75MHz
    - For async nand flash, support configurable interface timing , maximum data rate is 16bit/cycle
    - Embedded special DMA interface to do data transfer
    - Also support data transfer together with general DMAC1 in SoC system
  - eMMC Interface

- Compatible with standard iNAND interface
  - Support MMC4.41 protocol
  - Provide eMMC boot sequence to receive boot data from external eMMC device
  - Support combined single FIFO(32x32bits) for both transmit and receive operations
  - Support FIFO over-run and under-run prevention by stopping card clock automatically
  - Support CRC generation and error detection
  - Embedded clock frequency division control to provide programmable baud rate
  - Support block size from 1 to 65535Bytes
  - 8bits data bus width
- SD/MMC Interface
    - Compatible with SD3.0, MMC ver4.41
    - Support combined single FIFO(32x32bits) for both transmit and receive operations
    - Support FIFO over-run and under-run prevention by stopping card clock automatically
    - Support CRC generation and error detection
    - Embedded clock frequency division control to provide programmable baud rate
    - Support block size from 1 to 65535Bytes
    - Data bus width is 4bits

#### 1.1.5 System Component

- CRU (clock & reset unit)
  - Support clock gating control for individual components inside RK3188
  - One oscillator with 24MHz clock input and 4 embedded PLLs
  - Up to 2.2GHz clock output for all PLLs
  - Support global soft-reset control for whole SOC, also individual soft-reset for every components
- PMU(power management unit)
  - 6 work modes(slow mode, normal mode, idle mode, stop mode, sleep mode, power-off mode) to save power by different frequency or automatic clock gating control or power domain on/off control
  - Lots of wakeup sources in different mode
  - 3 separate voltage domains
  - 10 separate power domains, which can be power up/down by software based on different application scenes
- Timer
  - 7 on-chip 64bits Timers in SoC with interrupt-based operation
  - Provide two operation modes: free-running and user-defined count
  - Support timer work state checkable
  - Fixed 24MHz clock input
- PWM
  - Four on-chip PWMs with interrupt-based operation
  - Programmable 4-bit pre-scalar from apb bus clock
  - Embedded 32-bit timer/counter facility
  - Support single-run or continuous-run PWM mode

- Provides reference mode and output various duty-cycle waveform
- WatchDog
  - 32 bits watchdog counter width
  - Counter clock is from apb bus clock
  - Counter counts down from a preset value to 0 to indicate the occurrence of a timeout
  - WDT can perform two types of operations when timeout occurs:
    - ◆ Generate a system reset
    - ◆ First generate an interrupt and if this is not cleared by the service routine by the time a second timeout occurs then generate a system reset
  - Programmable reset pulse length
  - Totally 16 defined-ranges of main timeout period
- Bus Architecture
  - 64-bit multi-layer AXI/AHB/APB composite bus architecture
  - 5 embedded AXI interconnect
    - ◆ CPU interconnect with three 64-bits AXI masters, two 64-bits AXI slaves, one 32-bits AHB master and lots of 32-bits AHB/APB slaves
    - ◆ PERI interconnect with two 64-bits AXI masters, one 64-bits AXI slave, one 32-bits AXI slave, four 32-bits AHB masters and lots of 32-bits AHB/APB slaves
    - ◆ Display interconnect with six 64-bits AXI masters and one 32-bits AHB slave
    - ◆ GPU interconnect with one 128-bits AXI master and 64-bits AXI slave ,they are point-to-point AXI-lite architecture
    - ◆ VCODEC interconnect also with one 64-bits AXI master and one 32-bits AHB slave ,they are point-to-point AXI-lite architecture
  - For each interconnect with AXI/AHB/APB composite bus, clocks for AXI/AHB/APB domains are always synchronous, and different integer ratio is supported for them.
  - Flexible different QoS solution to improve the utility of bus bandwidth
- Interrupt Controller
  - Support 3 PPI interrupt source and 76 SPI interrupt sources input from different components inside RK3188
  - Support 16 software-triggered interrupts
  - Input interrupt level is fixed , only high-level sensitive
  - Two interrupt outputs (nFIQ and nIRQ) separately for each Cortex-A9, both are low-level sensitive
  - Support different interrupt priority for each interrupt source, and they are always software-programmable
- DMAC
  - Micro-code programming based DMA
  - The specific instruction set provides flexibility for programming DMA transfers
  - Linked list DMA function is supported to complete scatter-gather transfer
  - Support internal instruction cache
  - Embedded DMA manager thread
  - Support data transfer types with memory-to-memory, memory-to-peripheral, peripheral-to-memory

- Signals the occurrence of various DMA events using the interrupt output signals
- Mapping relationship between each channel and different interrupt outputs is software-programmable
- Two embedded DMA controller , DMAC0 is for cpu system, DMAC1 is for peri system
- DMAC0 features:
  - ◆ 6 channels totally
  - ◆ 11 hardware request from peripherals
  - ◆ 2 interrupt output
  - ◆ Dual APB slave interface for register configure, designated as secure and non-secure
  - ◆ Support Trustzone technology and programmable secure state for each DMA channel
- DMAC1 features:
  - ◆ 7 channels totally
  - ◆ 13 hardware request from peripherals
  - ◆ 2 interrupt outputs
  - ◆ Not support trustzone technology
- Security system
  - Support trustzone technology for the following components inside RK3188
    - ◆ Cortex-A9, support security and non-security mode, switch by software
    - ◆ DMAC0, support some dedicated channels work only in security mode
    - ◆ eFuse, only accessed by Cortex-A9 in security mode
    - ◆ Internal memory , part of space is addressed only in security mode, detailed size is software-programmable together with TZMA(trustzone memory adapter) and TZPC(trustzone protection controller)

#### 1.1.6 Video CODEC

- Shared internal memory and bus interface for video decoder and encoder<sup>®</sup>
- Video Decoder
  - Real-time video decoder of MPEG-1, MPEG-2, MPEG-4, H.263, H.264 , AVS , VC-1 , RV , VP6/VP8 , Sorenson Spark, MVC
  - Error detection and concealment support for all video formats
  - Output data format is YUV420 semi-planar, and YUV400(monochrome) is also supported for H.264
  - H.264 up to HP level 4.2 : 1080p@60fps (1920x1088)<sup>®</sup>
  - MPEG-4 up to ASP level 5 : 1080p@60fps (1920x1088)
  - MPEG-2 up to MP : 1080p@60fps (1920x1088)
  - MPEG-1 up to MP : 1080p@60fps (1920x1088)
  - H.263 : 576p@60fps(720x576)
  - Sorenson Spark : 1080p@60fps (1920x1088)
  - VC-1 up to AP level 3 : 1080p@30fps (1920x1088)
  - RV8/RV9/RV10 : 1080p@60fps (1920x1088)
  - VP6/VP8 : 1080p@60fps (1920x1088)
  - AVS : 1080p@60fps (1920x1088)
  - MVC : 1080p@60fps (1920x1088)
  - For AVS, 4:4:4 sampling not supported
  - For H.264, Image cropping not supported



- For MPEG-4, GMC(global motion compensation) not supported
- For VC-1, upscaling and range mapping are supported in image post-processor
- For MPEG-4 SP/H.263/Sorenson spark, using a modified H.264 in-loop filter to implement deblocking filter in post-processor unit
- Video Encoder
  - Support video encoder for H.264 (BP@level4.0, MP@level4.0, HP@level4.0), MVC and VP8
  - Only support I and P slices, not B slices
  - Support error resilience based on constrained intra prediction and slices
  - Input data format :
    - ◆ YCbCr 4:2:0 planar
    - ◆ YCbCr 4:2:0 semi-planar
    - ◆ YCbYCr 4:2:2
    - ◆ CbYCrY 4:2:2 interleaved
    - ◆ RGB444 and BGR444
    - ◆ RGB555 and BGR555
    - ◆ RGB565 and BGR565
    - ◆ RGB888 and BRG888
    - ◆ RGB101010 and BRG101010
  - Image size is from 96x96 to 1920x1088(Full HD)
  - Maximum frame rate is up to 30fps@1920x1080<sup>®</sup>
  - Bit rate supported is from 10Kbps to 20Mbps

#### 1.1.7 JPEG CODEC

- JPEG decoder
  - Input JPEG file : YCbCr 4:0:0, 4:2:0, 4:2:2, 4:4:0, 4:1:1 and 4:4:4 sampling formats
  - Output raw image : YCbCr 4:0:0, 4:2:0, 4:2:2, 4:4:0, 4:1:1 and 4:4:4 semi-planar
  - Decoder size is from 48x48 to 8176x8176(66.8Mpixels)
  - Maximum data rate<sup>®</sup> is up to 76million pixels per second
- JPEG encoder
  - Input raw image :
    - ◆ YCbCr 4:2:0 planar
    - ◆ YCbCr 4:2:0 semi-planar
    - ◆ YCbYCr 4:2:2
    - ◆ CbYCrY 4:2:2 interleaved
    - ◆ RGB444 and BGR444
    - ◆ RGB555 and BGR555
    - ◆ RGB565 and BGR565
    - ◆ RGB888 and BRG888
    - ◆ RGB101010 and BRG101010
  - Output JPEG file : JFIF file format 1.02 or Non-progressive JPEG
  - Encoder image size up to 8192x8192(64million pixels) from 96x32
  - Maximum data rate<sup>®</sup> up to 90million pixels per second

#### 1.1.8 Image Enhancement

- Image pre-processor
  - Only used together with HD video encoder inside RK3188, not support

- stand-alone mode
    - Provides RGB to YCbCr 4:2:0 color space conversion, compatible with BT601, BT709 or user defined coefficients
    - Provides YCbCr4:2:2 to YCbCr4:2:0 color space conversion
    - Support cropping operation from 8192x8192 to any supported encoding size
    - Support rotation with 90 or 270 degrees
- Video stabilization
  - Work in combined mode with HD video encoder inside RK3188 and stand-alone mode
  - Adaptive motion compensation filter
  - Support scene detection from video sequence, encodes key frame when scene change noticed
- Image Post-Processor(embedded inside video decoder)
  - Combined with HD video decoder and JPEG decoder, post-processor can read input data directly from decoder output to reduce bus bandwidth
  - Also work as a stand-alone mode, its input data is from a camera interface or other image data stored in external memory
  - Input data format :
    - ◆ Any format generated by video decoder in combined mode
    - ◆ YCbCr 4:2:0 semi-planar
    - ◆ YCbCr 4:2:0 planar
    - ◆ YCbYCr 4:2:2
    - ◆ YCrYCb 4:2:2
    - ◆ CbYCrY 4:2:2
    - ◆ CrYCbY 4:2:2
  - Output data format:
    - ◆ YCbCr 4:2:0 semi-planar
    - ◆ YCbYCr 4:2:2
    - ◆ YCrYCb 4:2:2
    - ◆ CbYCrY 4:2:2
    - ◆ CrYCbY 4:2:2
    - ◆ Fully configurable ARGB channel lengths and locations inside 32bits, such as ARGB8888,RGB565,ARGB4444 etc.
  - Input image size:
    - ◆ Combined mode : from 48x48 to 8176x8176 (66.8Mpixels)
    - ◆ Stand-alone mode : width from 48 to 8176,height from 48 to 8176, and maximum size limited to 16.7Mpixels
    - ◆ Step size is 16 pixels
  - Output image size: from 16x16 to 1920x1088 (horizontal step size 8,vertical step size 2)
  - Support image up-scaling :
    - ◆ Bicubic polynomial interpolation with a four-tap horizontal kernel and a two-tap vertical kernel
    - ◆ Arbitrary non-integer scaling ratio separately for both dimensions
    - ◆ Maximum output width is 3x input width
    - ◆ Maximum output height is 3x input height
  - Support image down-scaling:
    - ◆ Arbitrary non-integer scaling ratio separately for both dimensions
    - ◆ Unlimited down-scaling ratio
  - Support YUV to RGB color conversion, compatible with BT.601-5, BT.709 and user definable conversion coefficient



- Support dithering (2x2 ordered spatial dithering) for 4,5,6bit RGB channel precision
  - Support programmable alpha channel and alpha blending operation with the following overlay input formats:
    - ◆ 8bit alpha +YUV444, big endian channel order with AYUV8888
    - ◆ 8bit alpha +24bit RGB, big endian channel order with ARGB8888
  - Support deinterlacing with conditional spatial deinterlace filtering, only compatible with YUV420 input format
  - Support RGB image contrast / brightness / color saturation adjustment
  - Support image cropping & digital zoom only for JPEG or stand-alone mode
  - Support picture in picture
  - Support image rotation (horizontal flip, vertical flip, rotation 90,180 or 270 degrees)
- Image Post-Processor (IPP) (standalone)
    - memory to memory mode
    - input data format and size
      - ◆ RGB888 : 16x16 to 8191x8191
      - ◆ RGB565 : 16x16 to 8191x8191
      - ◆ YUV422/YUV420 : 16x16 to 8190x8190
      - ◆ YUV444 : 16x16 to 8190x8190
    - pre scaler
      - ◆ integer down-scaling(ratio: 1/2,1/3,1/4,1/5,1/6,1/7,1/8) with linear filter
      - ◆ deinterlace(up to 1080i) to support YUV422&YUV420 input format
    - post scaler
      - ◆ down-scaling with 1/2 ~ 1 arbitrary non-integer ratio
      - ◆ up-scaling with 1~4 arbitrary non-integer ratio
      - ◆ 4-tap vertical, 2-tap horizontal filter
      - ◆ The max output image width of post scaler is 4096
    - Support rotation with 90/180/270 degrees and x-mirror,y-mirror

### 1.1.9 Graphics Engine

- 3D Graphics Engine :
  - High performance OpenGL ES1.1 and 2.0, OpenVG1.1 etc.
  - Embedded 4 shader cores with shared hierarchical tiler
  - Seperate vertex(geometry) and fragment(pixel) processing for maximum parallel throughput
  - Provide MMU and L2 Cache with 128KB size
  - Triangle rate: 30M triangles/s
  - Pixel rate: 1.4G pixels/s @ 400MHz
  - Max frequency can up to 380MHz@0.9V (Worst Case) and 500MHz@1.0V (Typical Case)
- 2D Graphics Engine :
  - Max frequency : 400MHz@0.9V(Worst Case)
  - BitBlit with Stretch Blit, Simple Blit and Filter Blit
  - Color fill with gradient fill, and pattern fill
  - Line drawing with anti-aliasing and specified width
  - High-performance stretch and shrink
  - Monochrome expansion for text rendering
  - ROP2,ROP3,ROP4

- Alpha blending modes including global alpha, per\_pixel alpha, porter-duff and fading
- 8K x 8K input and 2K x 2K output raster 2D coordinate system
- Arbitrary degrees rotation with anti-aliasing on every 2D primitive
- Blending, scaling and rotation are supported in one pass for Bitbilt
- Source format:
  - ◆ ABGR8888, XBGR888, ARGB8888, XRGB888
  - ◆ RGB888, RGB565
  - ◆ RGBA5551, RGBA4444
  - ◆ YUV420 planar, YUV420 semi-planar
  - ◆ YUV422 planar, YUV422 semi-planar
  - ◆ BPP8, BPP4, BPP2, BPP1
- Destination formats:
  - ◆ ABGR8888, XBGR888, ARGB8888, XRGB888
  - ◆ RGB888, RGB565
  - ◆ RGBA5551, RGBA4444
  - ◆ YUV420 planar, YUV420 semi-planar only in filter and pre-scale mode
  - ◆ YUV422 planar, YUV422 semi-planar only in filter and pre-scale mode

#### 1.1.10 Video IN/OUT

- Camera Interface
  - Support up to 5M pixels
  - 8bits BT656(PAL/NTSC) interface
  - 16bits BT601 DDR interface
  - 8bits/10bits/12bits raw data interface
  - YUV422 data input format with adjustable YUV sequence
  - YUV422,YUV420 output format with separately Y and UV space
  - Support picture in picture (PIP)
  - Support simple image effects such as Arbitrary(sepia), Negative, Art freeze, Embossing etc.
  - Support static histogram statistics and white balance statistics
  - Support image crop with arbitrary windows
  - Support scale up/down from 1/8 to 8 with arbitrary non-integer ratio
- Display Interface
  - Two independent display controllers
  - Support LCD or TFT interfaces up to 2048x1536
  - Parallel RGB LCD Interface :  
RGB888(24bits),RGB666(18bits),RGB565(15bits)
  - Serial RGB LCD Interface: 3x8bits with RGB delta support, 3x8bits followed by dummy data, 16bits followed by 8bits
  - MCU LCD interface : i-8080 with up to 24bits RGB
  - Support DDR output mode with differential clocks output
  - Support DDR output mode with single clock output
  - Four display layers :
    - ◆ One background layer with programmable 24bits color
    - ◆ One video layer (win0)
      - RGB888, ARGB888, RGB565, YUV422, YUV420
      - 1/8 to 8 scaling up/down engine with arbitrary non-integer ratio
      - Support virtual display
      - 256 level alpha blending
      - Support transparency color key

- Support 3D display
- ◆ One video layer (win1)
  - RGB888, ARGB888, RGB565, 1/2/4/8BPP
  - Support virtual display
  - 256 level alpha blending
  - Support transparency color key
- ◆ Hardware cursor(hwc)
  - 2BPP
  - Maximum resolution 64x64
  - 3-color and transparent mode
  - 2-color + transparency + tran\_invert mode
  - 16 level alpha blending
- 3 x 256 x 8 bits display LUTs
- Win0 and Win1 layer overlay exchangeable
- Support color space conversion:  
YUV2RGB(rec601-mpeg/rec601-jpeg/rec709) and RGB2YUV
- Deflicker support for interlace output
- 24bits to 16bits/18bitsditheringoperation
- Blank and black display
- Standby mode

#### 1.1.11 Audio Interface

- I2S/PCM with 2ch
  - Up to 2 channels (2xTX, 2xRX)
  - Audio resolution from 16bits to 32bits
  - Sample rate up to 192KHz
  - Provides master and slave work mode, software configurable
  - Support 3 I2S formats (normal, left-justified, right-justified)
  - Support 4 PCM formats(early, late1, late2, late3)
  - I2S and PCM mode cannot be used at the same time
- SPDIF
  - Audio resolution: 16bits/20bits/24bits
  - Software configurable sample rates (48KHz, 44.1KHz, 32KHz)
  - Stereo voice replay with 2 channels

#### 1.1.12 Connectivity

- SDIO interface
  - Compatible with SDIO 3.0 protocol
  - Support FIFO over-run and under-run prevention by stopping card clock automatically
  - 4bits data bus widths
- High-speed ADC stream interface
  - Support single-channel 8bits/10bits interface
  - DMA-based and interrupt-based operation
  - Support 8bits TS stream interface
  - Support PID filter operation
    - ◆ Combined with high-speed ADC interface to implement filter from original TS data
    - ◆ Provide PID filter up to 64 channels PID simultaneously
    - ◆ Support sync-byte detection in transport packet head
    - ◆ Support packet lost mechanism in condition of limited bandwidth

- MAC 10/100MEthernet Controller
  - IEEE802.3u compliant Ethernet Media Access Controller(MAC)
  - Support only RMI(Reduced MII) mode
  - 10Mbps and 100Mbps compatible
  - Automatic retry and automatic collision frame deletion
  - Full duplex support with flow-control
  - Address filtering(broadcast, multicast, logical, physical)
  
- GPS Interface
  - Single chip, integrate GPS bb with cpu.
  - 32 DMA channels for ahb master access
  - Complete l1-band, C/A, and NMEA-0183 compatibility.
  - Support reference frequencies 16.368MHz.
  - High sensitivity for indoor fixes.
  - Low power consumption.
  - Low cost with smaller size.
  - Multi modes support both standalone GPS and A\_GPS
  
- SPI Controller
  - 2 on-chip SPI controller inside RK3188
  - Support serial-master and serial-slave mode, software-configurable
  - DMA-based or interrupt-based operation
  - Embedded two 32x16bits FIFO for TX and RX operation respectively
  - Support 2 chip-selects output in serial-master mode
  
- Uart Controller
  - 4 on-chip uart controller inside RK3188
  - DMA-based or interrupt-based operation
  - For UART1/UART2/UART3, Embedded two 32Bytes FIFO for TX and RX operation respectively
  - For UART0, two 64Bytes FIFOs are embedded for TX/RX operation
  - Support 5bit,6bit,7bit,8bit serial data transmit or receive
  - Standard asynchronous communication bits such as start,stop and parity
  - Support different input clock for uart operation to get up to 4Mbps or other special baud rate
  - Support non-integer clock divides for baud clock generation
  - Auto flow control mode is only for UART0, UART1, UART3
  
- I2C controller
  - 5 on-chip I2C controller in RK3188
  - Multi-master I2C operation
  - Support 7bits and 10bits address mode
  - Software programmable clock frequency and transfer rate up to 400Kbit/s in the fast mode
  - Serial 8bits oriented and bidirectional data transfers can be made at up to 100Kbit/s in the standard mode
  
- GPIO
  - 4 groups of GPIO (GPIO0~GPIO3,) , 32 GPIOs per group, totally have 128 GPIOs
  - All of GPIOs can be used to generate interrupt to Cortex-A9
  - GPIO0 can be used to wakeup system from stop/sleep/power-off mode
  - All of pullup GPIOs are software-programmable for pullup resistor or not

- All of pulldown GPIOs are software-programmable for pulldown resistor or not
- All of GPIOs are always in input direction in default after power-on-reset
- The drive strength for all of GPIOs is software-programmable
- USB Host2.0
  - Compatible with USB Host2.0 specification
  - Supports high-speed(480Mbps), full-speed(12Mbps) and low-speed(1.5Mbps) mode
  - Provides 16 host mode channels
  - Support periodic out channel in host mode
- USB OTG2.0
  - Compatible with USB OTG2.0 specification
  - Supports high-speed(480Mbps), full-speed(12Mbps) and low-speed(1.5Mbps) mode
  - Support up to 9 device mode endpoints in addition to control endpoint 0
  - Support up to 6 device mode IN endpoints including control endpoint 0
  - Endpoints 1/3/5/7 can be used only as data IN endpoint
  - Endpoints 2/4/6 can be used only as data OUT endpoint
  - Endpoints 8/9 can be used as data OUT and IN endpoint
  - Provides 9 host mode channels
  - Provides UART support to receive and transmit asynchronous, serial data by reusing DP/DM ports
- HSIC Interface
  - Compliant with the USB2.0 Specification and Enhanced Host Controller Interface Specification 2.0
  - 1 Port HSIC PHY Interface Operates in host mode
  - Built-in one 840x35 bits FIFO
  - Internal DMA with scatter/gather function

#### 1.1.13 Others

- SAR-ADC(Successive Approximation Register)
  - 3-channel single-ended 10-bit SAR analog-to-digital converter
  - Conversion speed range is up to 1 MSPS
  - SAR-ADC clock must be less than 1MHz
  - DNL is less than  $\pm 1$  LSB , INL is less than  $\pm 2.0$  LSB
  - Power down current is about 0.5uA for analog and digital logic
  - Power supply is 1.8V ( $\pm 10\%$ ) for analog interface
- eFuse
  - 256bits (32x8) high-density electrical Fuse
  - Programming condition : VQPS must be 1.5( $\pm 10\%$ )
  - Program time is about 10us( $\pm 1$ us)
  - Read condition : VQPS must be 0V
  - Support standby mode
- Operation Temperature Range
  - -40°C to +85°C
- Operation Voltage Range
  - Core supply: 1.0V ( $\pm 10\%$ )

- IO supply : 3.3V or 2.5V or 1.8V ( $\pm 10\%$ )
- Process
  - GlobalFoundry28nmSLP
- Package Type
  - TFBGA453LD (body: 19mm x 19mm ; ball size : 0.4mm ; ball pitch : 0.8mm)
- Power
  - TBA
- Notes :<sup>①</sup> *DDR3/LPDDR2 are not used simultaneously as well as async and sync ddr nand flash. DDR3/LPDDR2 could support 533/1066Hz under typical corner if chip operating environment, such as the power supply in PCB board is well design.*
- <sup>②</sup> *In RK3188, Video decoder and encoder are not used simultaneously because of shared internal buffer*
- <sup>③</sup> *Actual maximum frame rate will depend on the clock frequency and system bus performance*
- <sup>④</sup> *Actual maximum data rate will depend on the clock frequency and JPEG compression rate*

## 1.2 Block Diagram

The following diagram shows the basic block diagram for RK3188.



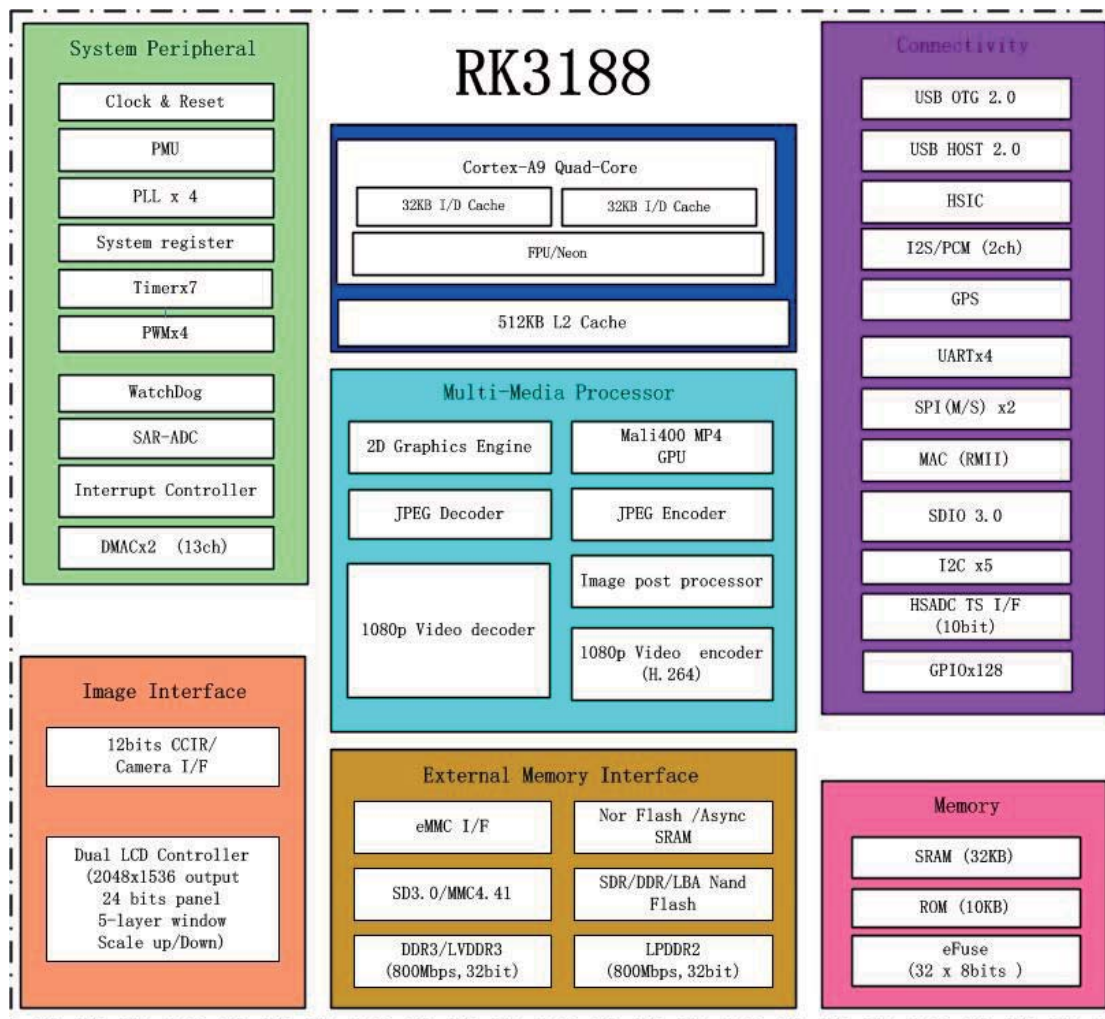


Fig. 1-1 RK3188 Block Diagram

## 1.3 Pin Description

In this chapter, the pin description will be divided into two parts, one is all power/ground descriptions in Table 1-1, include analog power/ground, another is all the function signals descriptions in Table 1-2, also include analog power/ground.

### 1.3.1 RK3188 power/ground IO descriptions

Table 1-1 RK3188 Power/Ground IO informations

Group	Ball #	Min(V)	Typ(V)	Max(V)	Descriptions
GND	C2, D4, D7, D10, D13, D16, D19, C21, E21, G9, G14, H8, H9, H10, H11, H12, H13, H14, H15, H16, J8, J9, J10, J11, J12, J13, J14, J15, J16, K8, K9, K10, K11, K12, K13, K14, K15, K16, L8, L9, L10, L11, L12, L13, L14, L15, L16,	N/A	N/A	N/A	Internal Core Ground and Digital IO Ground