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**32-bit ARM® Cortex™-M3 Microcontroller, up to 64KB Flash and  
16KB SRAM with 1 MSPS ADC, USART, UART, SPI, I<sup>2</sup>C, I<sup>2</sup>S, MCTM,  
GPTM, BFTM, PDMA, SCI, CRC, EBI and USB2.0 FS**

## **HT32F1653/HT32F1654 Series Datasheet**

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## Table of Contents

<b>1 General Description.....</b>	<b>6</b>
<b>2 Features.....</b>	<b>7</b>
Core .....	7
On-chip Memory .....	7
Flash Memory Controller – FMC.....	7
Reset Control Unit – RSTCU .....	8
Clock Control Unit – CKCU.....	8
Power Management – PWRCU .....	8
External Interrupt/Event Controller – EXTI .....	9
Analog to Digital Converter – ADC .....	9
Analog Comparator – CMP .....	9
I/O Ports.....	10
PWM Generation and Capture Timers – GPTM .....	10
Motor Control Timer – MCTM .....	11
Basic Function Timer – BFTM .....	11
Watchdog Timer – WDT.....	12
Real Time Clock – RTC .....	12
Inter-integrated Circuit – I <sup>2</sup> C .....	13
Serial Peripheral Interface – SPI .....	13
Universal Synchronous Asynchronous Receiver Transmitter – USART.....	14
Universal Asynchronous Receiver Transmitter – UART .....	15
Smart Card Interface – SCI .....	15
Inter-IC Sound – I <sup>2</sup> S .....	16
Cyclic Redundancy Check – CRC .....	16
Peripheral Direct Memory Access – PDMA .....	17
External Bus Interface – EBI.....	17
Universal Serial Bus Device Controller – USB .....	18
Debug Support.....	18
Package and Operation Temperature .....	18
<b>3 Overview.....</b>	<b>19</b>
Device Information .....	19
Block Diagram .....	20
Memory Map .....	21
Clock Structure .....	22

<b>4 Pin Assignment.....</b>	<b>23</b>
<b>5 Electrical Characteristics .....</b>	<b>29</b>
Absolute Maximum Ratings .....	29
Recommended DC Operating Conditions .....	29
On-Chip LDO Voltage Regulator Characteristics.....	29
Power Consumption .....	30
Reset and Supply Monitor Characteristics.....	31
External Clock Characteristics.....	31
Internal Clock Characteristics .....	32
PLL Characteristics.....	33
Memory Characteristics .....	33
I/O Port Characteristics.....	34
ADC Characteristics .....	35
Comparator Characteristics .....	37
GPTM/MCTM Characteristics .....	37
I <sup>2</sup> C Characteristics .....	38
SPI Characteristics .....	39
I <sup>2</sup> S Characteristics .....	40
USB Characteristics.....	42
<b>6 Package Information .....</b>	<b>43</b>
48-pin LQFP (7mm×7mm) Outline Dimensions.....	44
64-pin LQFP (7mm×7mm) Outline Dimensions.....	45

## List of Tables

Table 1 HT32F1654/1653 Series Features and Peripheral List.....	19
Table 2 HT32F1654/1653 Series Pin Assignment for LQFP 64 / 48 Package.....	25
Table 3 HT32F1654/1653 Pin Description .....	27
Table 4 Absolute Maximum Ratings.....	29
Table 5 Recommended DC Operating Conditions.....	29
Table 6 LDO Characteristics .....	29
Table 7 Power Consumption Characteristics .....	30
Table 8 LVD/BOD Characteristics .....	31
Table 9 High Speed External Clock (HSE) Characteristics.....	31
Table 10 Low Speed External Clock (LSE) Characteristics .....	32
Table 11 High Speed Internal Clock (HSI) Characteristics.....	32
Table 12 Low Speed Internal Clock (LSI) Characteristics.....	33
Table 13 PLL Characteristics .....	33
Table 14 Flash Memory Characteristics.....	33
Table 15 I/O Port Characteristics .....	34
Table 16 ADC Characteristics .....	35
Table 17 Comparator Characteristics .....	37
Table 18 GPTM/MCTM Characteristics .....	37
Table 19 I <sup>2</sup> C Characteristics.....	38
Table 20 SPI Characteristics.....	39
Table 21 I <sup>2</sup> S Characteristics.....	40
Table 22 USB DC Electrical Characteristics .....	42
Table 23 USB AC Electrical Characteristics.....	42

## List of Figures

Figure 1 HT32F1654/1653 Block Diagram .....	20
Figure 2 HT32F1654/1653 Memory Map.....	21
Figure 3 HT32F1654/1653 Clock Structure .....	22
Figure 4 HT32F1654/1653 LQFP-48 Pin Assignment .....	23
Figure 5 HT32F1654/1653 LQFP-64 Pin Assignment .....	24
Figure 6 ADC Sampling Network Model .....	36
Figure 7 I <sup>2</sup> C Timing Diagrams.....	38
Figure 8 SPI Timing Diagrams - SPI Master Mode .....	39
Figure 9 SPI Timing Diagrams - SPI Slave Mode with CPHA=1 .....	40
Figure 10 Timing of I <sup>2</sup> S Master Mode .....	41
Figure 11 Timing of I <sup>2</sup> S Slave Mode.....	41
Figure 12 USB Signal Rise Time and Fall Time and Cross-Point Voltage (VCRS) Definition .....	42

# 1 General Description

The Holtek HT32F1654/1653 devices are high performance, low power consumption 32-bit microcontrollers based around an ARM® Cortex™-M3 processor core. The Cortex™-M3 is a next-generation processor core which is tightly coupled with a Nested Vectored Interrupt Controller (NVIC), SysTick timer and which includes advanced debug support.

The devices operate at a frequency of up to 72MHz with a Flash accelerator to obtain maximum efficiency. They provide up to 64KB of embedded Flash memory for code/data storage and 16KB of embedded SRAM memory for system operation and application program usage. A variety of peripherals, such as ADC, I<sup>2</sup>C, USART, UART, SPI, I<sup>2</sup>S, PDMA, GPTM, MCTM, SCI, EBI, CRC-16/32, USB2.0 FS, SW-DP (Serial Wire Debug Port), etc., are also implemented in the devices. Several power saving modes provide the flexibility for maximum optimisation between wakeup latency and power consumption, an especially important consideration in low power applications.

The above features ensure that the devices are suitable for use in a wide range of applications, especially in areas such as white goods application control, power monitors, alarm systems, consumer products, handheld equipment, data logging applications, motor control, fingerprint recognition and so on.



## 2 Features

### Core

- 32-bit ARM® Cortex™-M3 processor core
- Up to 72 MHz operating frequency
- 1.25 DMIPS/MHz - Dhrystone 2.1
- Single-cycle multiplication and hardware division
- Integrated Nested Vectored Interrupt Controller - NVIC
- 24-bit SysTick timer

The Cortex™-M3 processor is a general-purpose 32-bit processor core especially suitable for products requiring high performance and low power consumption microcontrollers. It offers many special features such as a Thumb-2 instruction set, hardware divider, low latency interrupt response time, atomic bit-banding access and multiple buses for simultaneous accesses. The Cortex™-M3 processor is based on the ARMv7 architecture and supports both Thumb and Thumb-2 instruction sets.

### On-chip Memory

- Up to 64 KB on-chip Flash memory for instruction/data and option storage
- 16 KB on-chip SRAM
- Supports multiple boot modes

The ARM® Cortex™-M3 processor is structured using Harvard architecture which implements a separate bus structure to fetch instructions and load/store data. The instruction code and data are both located in the same memory address space but in different address ranges. The maximum address range of the Cortex™-M3 is 4 GB due to its 32-bit bus address width. Additionally, a pre-defined memory map is provided by the Cortex™-M3 processor to reduce the software complexity of repeated implementation for different device vendors. However, some regions are used by the ARM® Cortex™-M3 system peripherals. Refer to the ARM® Cortex™-M3 Technical Reference Manual for more information. Figure 2 shows the memory map of the HT32F1654/53 series of devices, including Code, SRAM, peripheral, and other pre-defined regions.

### Flash Memory Controller – FMC

- Flash accelerator for maximum efficiency
- 32-bit word programming with In System Programming Interface (ISP) and In Application Programming (IAP)
- Flash protection capability to prevent illegal access

The Flash Memory Controller, FMC, provides all the necessary functions and pre-fetch buffer for the embedded on-chip Flash Memory. Since the access speed of the Flash Memory is slower than the CPU, a wide access interface with a pre-fetch buffer and cache are provided for the Flash Memory in order to reduce the CPU waiting time which will cause CPU instruction execution delays. Flash Memory word program/page erase functions are also provided.

## Reset Control Unit – RSTCU

- Supply supervisor:
  - Power-on Reset - POR
  - Brown-out Detector - BOD
  - Programmable Low Voltage Detector - LVD

The Reset Control Unit, RSTCU, has three kinds of reset, a power on reset, a system reset and an APB unit reset. The power on reset, known as a cold reset, resets the full system during power up. A system reset resets the processor core and peripheral IP components with the exception of the SW-DP controller. The resets can be triggered by an external signal, internal events and the reset generators.

## Clock Control Unit – CKCU

- External 4 to 16 MHz crystal oscillator
- External 32,768 Hz crystal oscillator
- Internal 8MHz RC oscillator trimmed to  $\pm 2\%$  accuracy at 3.3V operating voltage and 25°C operating temperature
- Internal 32 kHz RC oscillator
- Integrated system clock PLL
- Independent clock divider and gating bits for peripheral clock sources

The Clock Control unit, CKCU, provides a range of oscillator and clock functions. These include a High Speed Internal RC oscillator (HSI), a High Speed External crystal oscillator (HSE), a Low Speed Internal RC oscillator (LSI), a Low Speed External crystal oscillator (LSE), a Phase Lock Loop (PLL), a HSE clock monitor, clock prescalers, clock multiplexers, APB clock divider and gating circuitry. The clocks of the AHB, APB and Cortex™-M3 are derived from the system clock (CK\_SYS) which can come from the HSI, HSE or PLL. The Watchdog Timer and Real Time Clock (RTC) use either the LSI or LSE as their clock source. The maximum operating frequency of the system core clock (CK\_AHB) can be up to 72 MHz.

## Power Management – PWRCU

- Single 3.3 V power supply: 2.7 V to 3.6 V
- Integrated 1.8 V LDO regulator for core and peripheral power supply
- $V_{BAT}$  battery power supply for RTC and backup registers
- Three power domains: 3.3 V, 1.8 V and Backup
- Four power saving modes: Sleep, Deep-Sleep1, Deep-Sleep2, Power-Down

Power consumption can be regarded as one of the most important issues for many embedded system applications. Accordingly the Power Control Unit, PWRCU, in these devices provides many types of power saving modes such as Sleep, Deep-Sleep1, Deep-Sleep2 and Power-Down mode. These operating modes reduce the power consumption and allow the application to achieve the best trade-off between the conflicting demands of CPU operating time, speed and power consumption.

## External Interrupt/Event Controller – EXTI

- Up to 16 EXTI lines with configurable trigger source and type
- All GPIO pins can be selected as EXTI trigger source
- Source trigger type includes high level, low level, negative edge, positive edge, or both edge
- Individual interrupt enable, wakeup enable and status bits for each EXTI line
- Software interrupt trigger mode for each EXTI line
- Integrated deglitch filter for short pulse blocking

The External Interrupt/Event Controller, EXTI, comprises 16 edge detectors which can generate a wake-up event or interrupt requests independently. Each EXTI line can also be masked independently.

## Analog to Digital Converter – ADC

- 12-bit SAR ADC engine
- Up to 1 Msps conversion rate - 1  $\mu$ s at 56 MHz, 1.17  $\mu$ s at 72 MHz
- Up to 12 external analog input channels
- Supply voltage range: 2.7 V ~ 3.6 V
- Conversion range:  $V_{REF+} \sim V_{REF-}$

A 12-bit multi-channel ADC is integrated in the device. There are up to 12 multiplexed channels, which include external channels on which the external analog signals can be measured, and 2 internal channels. If the input voltage is required to remain within a specific threshold window, an Analog Watchdog function will monitor and detect these signals. An interrupt will then be generated to inform the device that the input voltage is not within the preset threshold levels. There are three conversion modes to convert an analog signal to digital data. The ADC can be operated in one shot, continuous and discontinuous conversion modes.

## Analog Comparator – CMP

- Dual rail-to-rail comparators
- Each comparator has configurable negative inputs used for flexible voltage selection
- Dedicated I/O pin or internal voltage reference provided by an internal 6-bit scaler
- Programmable hysteresis
- Programming speed and consumption
- Comparator outputs can be routed to I/O pins, to timers or to ADC trigger inputs
- 6-bit scaler can be configured to dedicated I/O pins for a voltage reference
- Comparators have interrupt generation capability with wakeup function from within the Sleep or Deep Sleep modes through the EXTI controller
- Supply voltage range: 2.7 V ~ 3.6 V

Two general purpose comparators – CMP - are implemented within the devices. These can be configured either as standalone comparators or combined with the different kinds of peripheral functions. Each comparator is capable of generating an interrupt to the NVIC and waking up the MCU from the Deep Sleep mode through EXTI wakeup event management unit.

## I/O Ports

- Up to 51 GPIOs
- Port A, B, C, D are mapped as 16 external interrupts - EXTI
- Almost all I/O pins are 5 V-tolerant except for pins shared with analog inputs

There are up to 51 General Purpose I/O pins, GPIO, named from PA0~PA15 to PD0~PD2 for the implementation of logic input/output functions. Each of the GPIO ports has a series of related control and configuration registers to maximize flexibility and to meet the requirements of a wide range of applications.

The GPIO ports are pin-shared with other alternative functions to obtain maximum functional flexibility on the package pins. The GPIO pins can be used as alternative functional pins by configuring the corresponding registers regardless of the input or output pins.

The external interrupts on the GPIO pins of the device have related control and configuration registers in the External Interrupt Control Unit, EXTI.

## PWM Generation and Capture Timers – GPTM

- Two 16-bit up, down, up/down auto-reload counters
- 16-bit programmable prescaler allowing counter clock frequency division ratio between 1 and 65536
- Input Capture function
- Compare Match Output
- PWM waveform generation with Edge-aligned and Center-aligned Counting Modes
- Single Pulse Mode Output
- Encoder interface controller with two inputs using a quadrature decoder

The General Purpose Timers consists of one 16-bit up/down-counter, four 16-bit Capture/Compare Registers (CCRs), one 16-bit Counter Reload Register (CRR) and several control/status registers. They can be used for a variety of purposes including general time measurement, input signal pulse width measurement and output waveform generation such as that for single pulse generation or for PWM output generation. The GPTM includes an Encoder Interface using a decoder with two inputs.

## Motor Control Timer – MCTM

- Two 16-bit up, down, up/down auto-reload counters
- 16-bit programmable prescaler allowing counter clock frequency division ratio between 1 and 65536
- Input Capture function
- Compare Match Output
- PWM waveform generation with edge aligned and centre-aligned Counting Modes
- Single Pulse Mode Output
- Complementary Outputs with programmable dead-time insertion
- Encoder interface controller with two inputs using a quadrature decoder
- Includes a 3-phase motor control and hall sensor interface
- Brake input to force the timer's output signals into a reset or fixed condition

The Motor Control Timer consists of a single 16-bit up/down counter; four 16-bit CCRs (Capture/Compare Registers), single one 16-bit counter-reload register (CRR), single 8-bit repetition counter and several control/status registers. It can be used for a variety of purposes including measuring the pulse widths of input signals or generating output waveforms such as compare match outputs, PWM outputs or complementary PWM outputs with dead-time insertion. The MCTM supports an Encoder interface controller to an incremental encoder with two inputs. The MCTM is capable of offering full functional support for motor control, hall sensor interfacing and brake input.

## Basic Function Timer – BFTM

- Two 32-bit compare/match count-up counters - no I/O control features
- One shot mode - counting stops after a match condition
- Repetitive mode - restart counter after a match condition

The Basic Function Timer is a simple count-up 32-bit counter designed to measure time intervals and generate a one shot or repetitive interrupts. The BFTM operates in two functional modes, repetitive or one shot mode. In the repetitive mode the BFTM restarts the counter when a compare match event occurs. The BFTM also supports a one shot mode which forces the counter to stop counting when a compare match event occurs.

## Watchdog Timer – WDT

- 12-bit down counter with 3-bit prescaler
- Interrupt or reset event for the system
- Programmable watchdog timer window function
- Register write protection function

The Watchdog Timer is a hardware timing circuit that can be used to detect system failures due to software malfunctions. It includes a 12-bit count-down counter, a prescaler, a WDT counter value register, a WDT delta value register, interrupt related circuits, WDT operation control circuitry and a WDT protection mechanism. The Watchdog Timer can be operated in an interrupt mode or a reset mode. The Watchdog Timer will generate an interrupt or a reset when the counter counts down and reaches a zero value. If the software does not reload the counter value before a Watchdog Timer underflow occurs, an interrupt or a reset will be generated when the counter underflows. In addition, an interrupt or reset is also generated if the software reloads the counter when the counter value is greater than or equal to the WDT delta value. This means the counter must be reloaded within a limited timing window using a specific method. The Watchdog Timer counter can be stopped while the processor is in the debug mode. There is a register write protect function which can be enabled to prevent it from changing the Watchdog Timer configuration unexpectedly.

## Real Time Clock – RTC

- 32-bit up-counter with a programmable prescaler
- Alarm function
- Interrupt and Wake-up event

The Real Time Clock, RTC for short, includes an APB interface, a 32-bit count-up counter, a control register, a prescaler, a compare register and a status register. Most of the RTC circuits are located in the Backup Domain except for the APB interface. The APB interface is located in the V<sub>DD18</sub> power domain. Therefore, it is necessary to be isolated from the ISO signal that comes from the power control unit when the V<sub>DD18</sub> power domain is powered off, that is when the device enters the Power-Down mode. The RTC counter is used as a wakeup timer to generate a system resume signal from the Power-Down mode.

## Inter-integrated Circuit – I<sup>2</sup>C

- Supports both master and slave modes with a frequency of up to 1 MHz
- Provide an arbitration function and clock synchronization
- Supports 7-bit and 10-bit addressing modes and general call addressing
- Supports slave multi-addressing mode with maskable address

The I<sup>2</sup>C Module is an internal circuit allowing communication with an external I<sup>2</sup>C interface which is an industry standard two line serial interface used for connection to external hardware. These two serial lines are known as a serial data line, SDA, and a serial clock line, SCL. The I<sup>2</sup>C module provides three data transfer rates: 1. 100 kHz in the Standard mode, 2. 400 kHz in the Fast mode and 3. 1 MHz in the Fast mode plus mode. The SCL period generation register is used to setup different kinds of duty cycle implementations for the SCL pulse.

The SDA line which is connected directly to the I<sup>2</sup>C bus is a bi-directional data line between the master and slave devices and is used for data transmission and reception. The I<sup>2</sup>C module also has an arbitration detect function and clock synchronization to prevent situations where more than one master attempts to transmit data to the I<sup>2</sup>C bus at the same time.

## Serial Peripheral Interface – SPI

- Supports both master and slave mode
- Frequency of up to  $f_{PCLK}/2$  MHz for master mode and  $f_{PCLK}/3$  MHz for slave mode
- FIFO Depth: 8 levels
- Multi-master and multi-slave operation

The Serial Peripheral Interface, SPI, provides an SPI protocol data transmit and receive function in both master and slave mode. The SPI interface uses 4 pins, which are the serial data input and output lines MISO and MOSI, the clock line, SCK, and the slave select line, SEL. One SPI device acts as a master device which controls the data flow using the SEL and SCK signals to indicate the start of data communication and the data sampling rate. To receive a data byte, the streamed data bits are latched on a specific clock edge and stored in the data register or in the RX FIFO. Data transmission is carried out in a similar way but in a reverse sequence. The mode fault detection provides a capability for multi-master applications.

## Universal Synchronous Asynchronous Receiver Transmitter – USART

- Supports both asynchronous and clocked synchronous serial communication modes
- Asynchronous operating baud rate up to  $f_{PCLK}/16$  MHz and synchronous operating rate up to  $f_{PCLK}/8$  MHz
- Full duplex communication
- Fully programmable serial communication characteristics including:
  - Word length: 7, 8, or 9-bit character
  - Parity: Even, odd, or no-parity bit generation and detection
  - Stop bit: 1 or 2 stop bit generation
  - Bit order: LSB-first or MSB-first transfer
- Error detection: Parity, overrun, and frame error
- Auto hardware flow control mode - RTS, CTS
- IrDA SIR encoder and decoder
- RS485 mode with output enable control
- FIFO Depth: 16 x 9 bits for both receiver and transmitter

The Universal Synchronous Asynchronous Receiver Transceiver, USART, provides a flexible full duplex data exchange using synchronous or asynchronous transfer. The USART is used to translate data between parallel and serial interfaces, and is commonly used for RS232 standard communication. The USART peripheral function supports four types of interrupt including Line Status Interrupt, Transmitter FIFO Empty Interrupt, Receiver Threshold Level Reaching Interrupt and Time Out Interrupt. The USART module includes a 16-byte transmitter FIFO, (TX\_FIFO) and a 16-byte receiver FIFO (RX\_FIFO). The software can detect a USART error status by reading the Line Status Register, LSR. The status includes the type and the condition of transfer operations as well as several error conditions resulting from Parity, Overrun, Framing and Break events.

## Universal Asynchronous Receiver Transmitter – UART

- Asynchronous serial communication operating baud-rate up to  $f_{PCLK}/16$  MHz
- Full duplex communication
- Fully programmable serial communication characteristics including:
  - Word length: 7, 8, or 9-bit character
  - Parity: Even, odd, or no-parity bit generation and detection
  - Stop bit: 1 or 2 stop bit generation
  - Bit order: LSB-first or MSB-first transfer
- Error detection: Parity, overrun, and frame error
- FIFO Depth: 16 x 9 bits for both receiver and transmitter

The Universal Asynchronous Receiver Transceiver, UART, provides a flexible full duplex data exchange using asynchronous transfer. The UART is used to translate data between parallel and serial interfaces, and is commonly used for RS232 standard communication. The UART peripheral function supports four types of interrupt including Line Status Interrupt, Transmitter FIFO Empty Interrupt, Receiver Threshold Level Reaching Interrupt and Time Out Interrupt. The UART module includes a 16-byte transmitter FIFO, (TX\_FIFO) and a 16-byte receiver FIFO (RX\_FIFO). The software can detect a UART error status by reading the Line Status Register, LSR. The status includes the type and the condition of transfer operations as well as several error conditions resulting from Parity, Overrun, Framing and Break events.

## Smart Card Interface – SCI

- Supports ISO 7816-3 standard
- Character mode
- Single transmit buffer and single receive buffer
- 11-bit ETU (elementary time unit) counter
- 9-bit guard time counter
- 24-bit general purpose waiting time counter
- Parity generation and checking
- Automatic character retry on parity error detection in transmission and reception modes

The Smart Card Interface is compatible with the ISO 7816-3 standard. This interface includes Card Insertion/Removal detection, SCI data transfer control logic and data buffers, internal Timer Counters and corresponding control logic circuits to perform all the necessary Smart Card operations. The Smart Card interface acts as a Smart Card Reader to facilitate communication with the external Smart Card. The overall functions of the Smart Card interface are controlled by a series of registers including control and status registers together with several corresponding interrupts which are generated to get the attention of the microcontroller for SCI transfer status.

## Inter-IC Sound – I<sup>2</sup>S

- Master or slave mode
- Mono and stereo
- I<sup>2</sup>S-justified, Left-justified, and Right-justified mode
- 8/16/24/32-bit sample size with 32-bit channel extended
- 8 x 32-bit Tx & Rx FIFO with PDMA supported
- 8-bit Fractional Clock Divider with rate control

The I<sup>2</sup>S is a synchronous communication interface that can be used as a master or slave to exchange data with other audio peripherals, such as ADCs or DACs. The I<sup>2</sup>S supports a variety of data formats. In addition to the stereo I<sup>2</sup>S-justified, Left-justified and Right-justified modes, there are mono PCM modes with 8/16/24/32-bit sample size. When the I<sup>2</sup>S operates in the master mode, then when using the fractional divider, it can provide an accurate sampling frequency output and support the rate control function and fine-tuning of the output frequency to avoid system problems caused by the cumulative frequency error between different devices.

## Cyclic Redundancy Check – CRC

- Support CRC16 polynomial: 0x8005,  
 $X^{16}+X^{15}+X^2+1$
- Support CCITT CRC16 polynomial: 0x1021,  
 $X^{16}+X^{12}+X^5+1$
- Support IEEE-802.3 CRC32 polynomial: 0x04C11DB7,  
 $X^{32}+X^{26}+X^{23}+X^{22}+X^{16}+X^{12}+X^{11}+X^{10}+X^8+X^7+X^5+X^4+X^2+X+1$
- Supports 1's complement, byte reverse & bit reverse operation on data and checksum
- Supports byte, half-word & word data size
- Programmable CRC initial seed value
- CRC computation executed in 1 AHB clock cycle for 8-bit data and 4 AHB clock cycles for 32-bit data
- Supports PDMA to complete a CRC computation of a block of memory

The CRC calculation unit is an error detection technique test algorithm which is used to verify data transmission or storage data correctness. A CRC calculation takes a data stream or a block of data as input and generates a 16- or 32-bit output remainder. Ordinarily, a data stream is suffixed by a CRC code and used as a checksum when being sent or stored. Therefore, the received or restored data stream is calculated by the same generator polynomial as described above. If the new CRC code result does not match the one calculated earlier, that means data stream contains a data error.

## Peripheral Direct Memory Access – PDMA

- 8 channels with trigger source grouping
- 8-/16-/32-bit width data transfer
- Supports Address increment, decrement or fixed mode
- 4-level programmable channel priority
- Auto reload mode
- Supports trigger source: ADC, SPI, USART, UART, I<sup>2</sup>C, I<sup>2</sup>S, EBI, GPTM, MCTM, SCI and software request

The Peripheral Direct Memory Access controller, PDMA, moves data between the peripherals and the system memory on the AHB bus. Each PDMA channel has a source address, destination address, block length and transfer count. The PDMA can exclude the CPU intervention and avoid interrupt service routine execution. It improves system performance as the software does not need to join each data movement operation.

## External Bus Interface – EBI

- Programmable interface for various memory types
- Translate the AHB transactions into the appropriate external device protocol
- Memory bank regions and independent chip select control for each memory bank
- Programmable timings to support a wide range of devices
- Includes page read mode
- Automatic translation when the AHB transaction width and external memory interface width is different
- Write buffer to decrease the stalling of the AHB write burst transaction
- Multiplexed address and data line configurations
- Up to 21 address lines
- Up to 16-bit data bus width

The external bus interface is able to access external parallel interface devices such as SRAM, Flash and LCD modules. The interface is memory mapped into the internal address map of the CPU. The data and address lines are multiplexed in order to reduce the number of pins required to connect to the external devices. The read/write timing of the bus can be adjusted to meet the timing specification of the external devices. Note the interface only supports asynchronous 8 or 16-bit bus interface.

## Universal Serial Bus Device Controller – USB

- Complies with USB 2.0 full-speed (12Mbps) specification
- On-chip USB full-speed transceiver
- 1 control endpoint (EP0) for control transfer
- 3 single-buffered endpoints for bulk and interrupt transfer
- 4 double-buffered endpoints for bulk, interrupt and isochronous transfer
- 1,024 bytes EP-SRAM used as the endpoint data buffers

The USB device controller is compliant with the USB 2.0 full-speed specification. There is one control endpoint known as Endpoint 0 and seven configurable endpoints. A 1024-byte SRAM is used as the endpoint buffer. Each endpoint buffer size is programmable using corresponding registers, which provides maximum flexibility for various applications. The integrated USB full-speed transceiver helps to minimize the overall system complexity and cost. The USB functional block also contains the resume and suspend feature to meet the requirements of low-power consumption.

## Debug Support

- Serial Wire Debug Port - SW-DP
- 6 instruction comparators and 2 literal comparators for hardware breakpoint or code / literal patches
- 4 comparators for hardware watchpoints
- 1-bit asynchronous trace (TRACESWO)

## Package and Operation Temperature

- 48/64-pin LQFP package
- Operation temperature range: -40°C to +85°C

## 3 Overview

### Device Information

Table 1 HT32F1654/1653 Series Features and Peripheral List

Peripherals		HT32F1654	HT32F1653
Main Flash (KB)		63	32
Option Bytes Flash		1	1
SRAM (KB)		16	8
Timers	MCTM	2	
	GPTM	2	
	BFTM	2	
	RTC	1	
	WDT	1	
Communication	USB	1	
	SPI	2	
	USART	2	
	UART	2	
	I <sup>2</sup> C	2	
	I <sup>2</sup> S	1	
	SCI	1	
EBI		1	
CRC-16/32		1	
EXTI		16	
12-bit ADC		1	
Number of channels		12 Channels	
Comparator		2	
GPIO		Up to 51	
CPU frequency		Up to 72 MHz	
Operating voltage		2.7 V ~ 3.6 V	
Operating temperature		-40°C ~ +85°C	
Packages		48/64-pin LQFP	

## Block Diagram

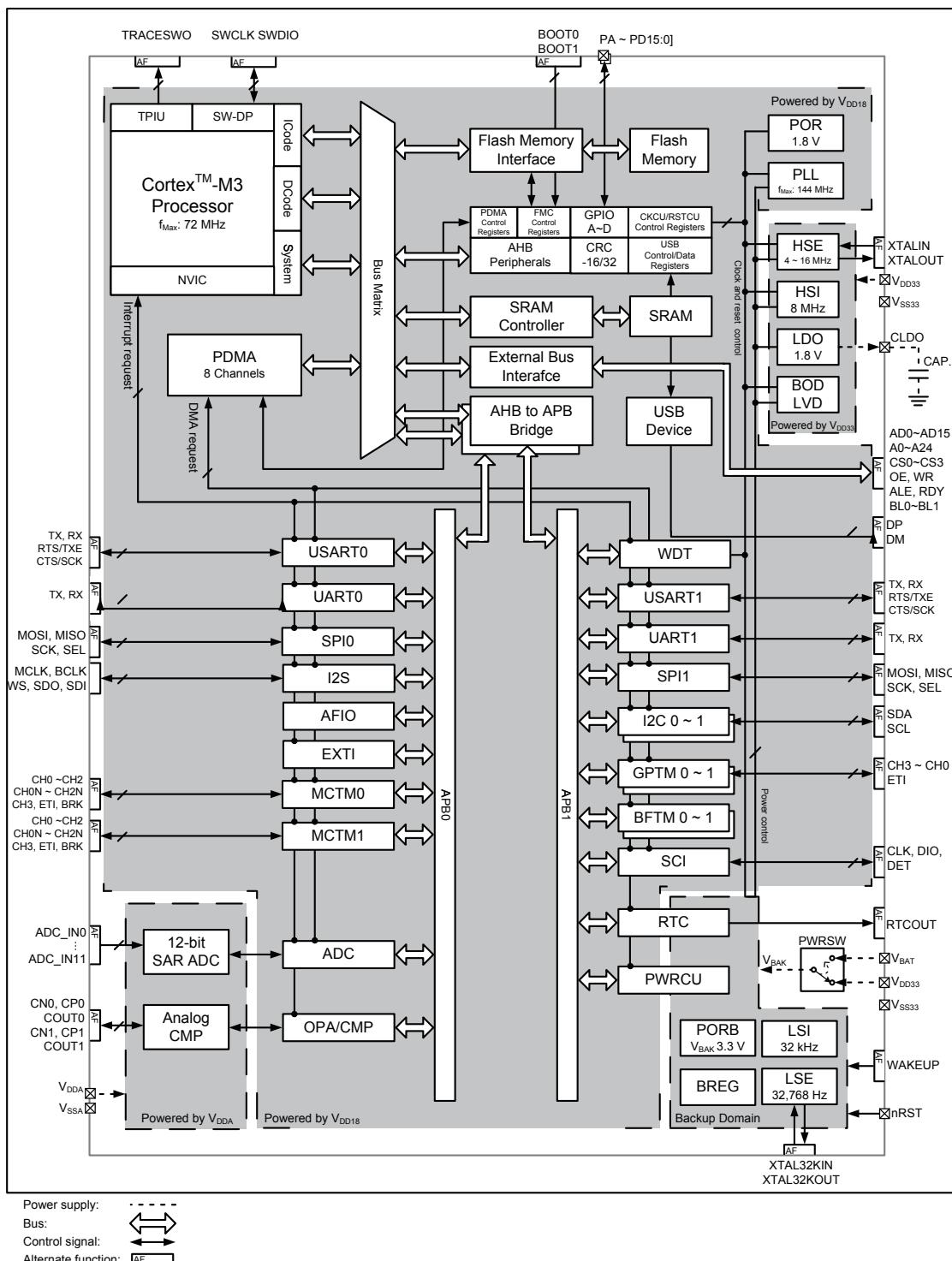
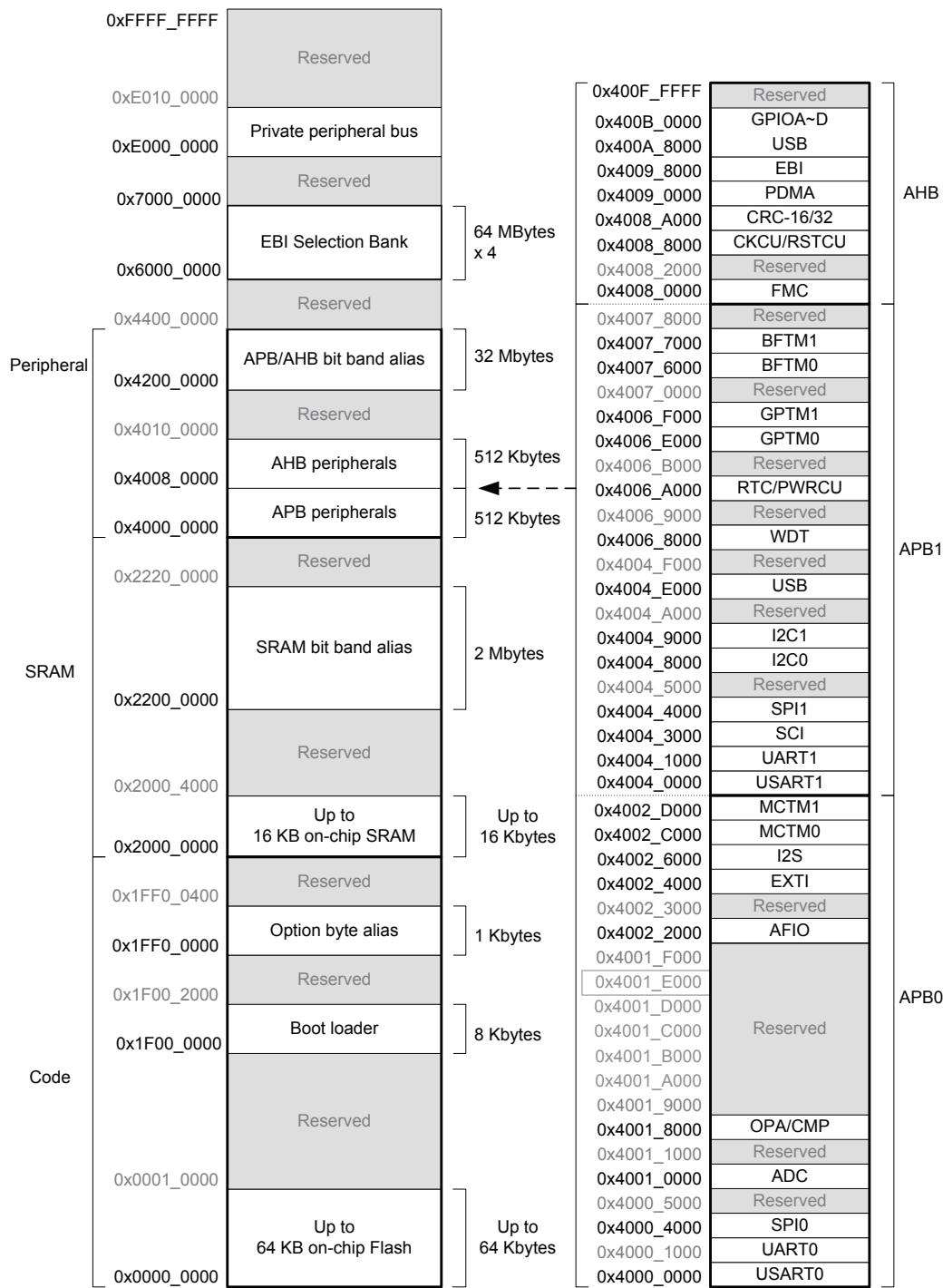


Figure 1 HT32F1654/1653 Block Diagram

Overview

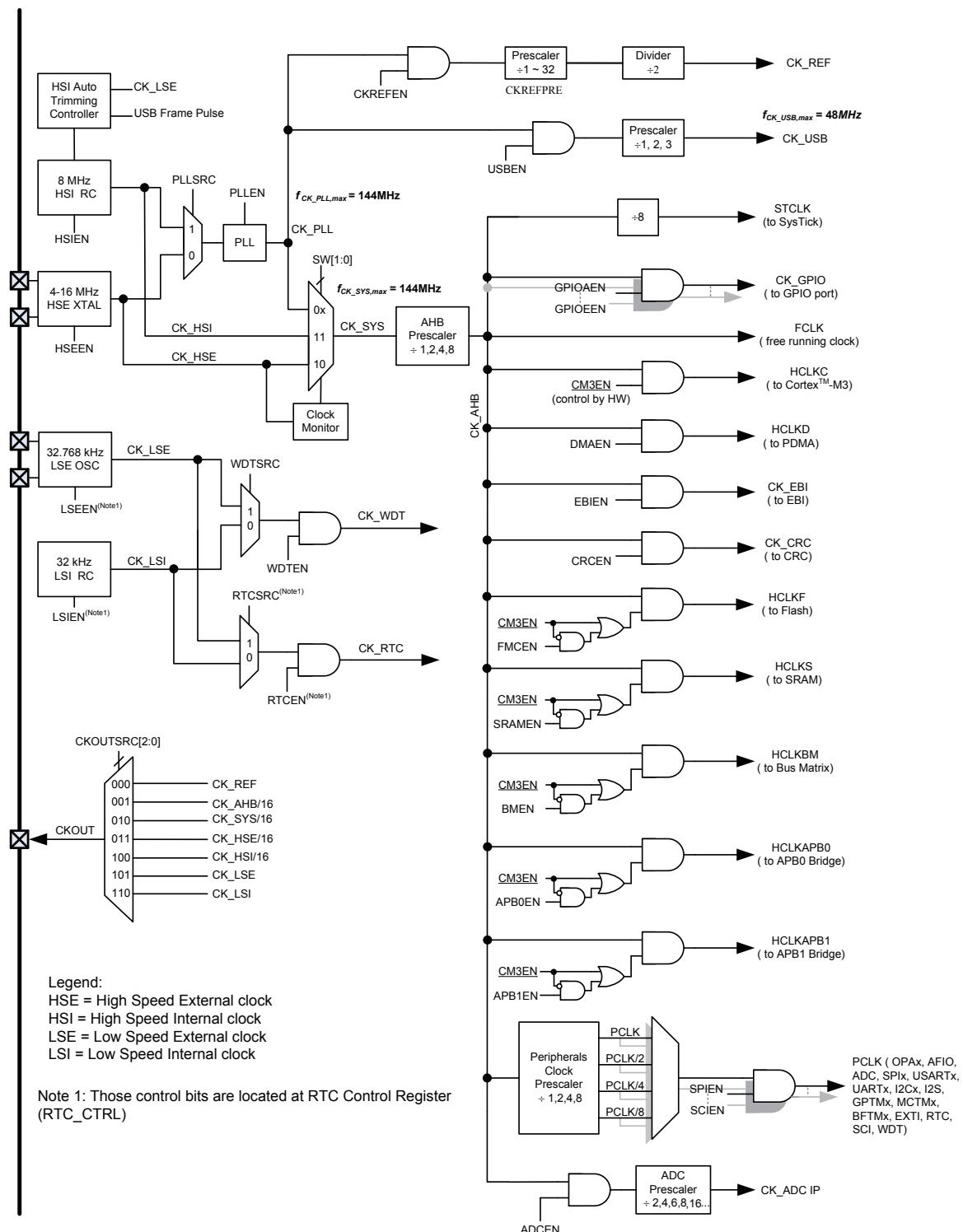
## Memory Map



Overview

Figure 2 HT32F1654/1653 Memory Map

## Clock Structure



Overview

Figure 3 HT32F1654/1653 Clock Structure

## 4 Pin Assignment

Holtek HT32F1654/1653  
48 LQFP-A

AF0 (Default)												AF1			
		AF0 (Default)										AF1			
O		48	47	46	45	44	43	42	41	40	39	38	37		
PA0	1	33V		P33	3.3 V Digital Power Pad								P33	36	VSS33_3
PA1	2	33V		AP	3.3 V Analog Power Pad								P33	35	VDD33_3
PA2	3	33V											5VT	34	PB1
PA3	4	33V											5VT	33	PB0
PA4	5	33V											5VT	32	PA15
PA5	6	33V											5VT	31	PA14
PA6	7	33V											5VT	30	SWDIO
PA7	8	33V											5VT	29	SWCLK
VDD33_1	9	P33											5VT	28	TRACESWO
VSS33_1	10	P33											5VT	27	PA10
USBDM /PB12	11	USB											5VT	26	PA9 BOOT1
USBDP /PB13	12	USB											5VT	25	PA8 BOOT0
				P18	P33	BAK 5VT	BAK P33	BAK 33V	BAK 5VT	33V	33V	5VT	5VT		
				13	14	15	16	17	18	19	20	21	22	PD2	
														PD1	
														XTAI/OUT	PB15
														XTALIN	PB14
														RTCOUT	PC15
														XITAL32K OUT	PC14
														XITAL32K N	PC13
														VBAT	CLDO
														VDD33_2	
														nRST	

Figure 4 HT32F1654/1653 LQFP-48 Pin Assignment

Holtek HT32F1653/1654 64 LQFP-A																	
AF0 (Default)	AF0 (Default)															AF1	
	O								AF0 (Default)								
	64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	
PA0	1	33V	P33 3.3 V Digital Power Pad														
PA1	2	33V	AP 3.3 V Analog Power Pad														
PA2	3	33V	P18 1.8 V Power Pad														
PA3	4	33V	33V 3.3 V I/O Pad														
PA4	5	33V	5VT 5 V Tolerance I/O Pad														
PA5	6	33V	5VT High Current Output 5 V Tolerance I/O Pad														
PA6	7	33V	USB USB PHY Pad														
PA7	8	33V	BAK Backup Domain Pad														
VDD33_1	9	P33															
VSS33_1	10	P33															
PC9	11	33V															
PC10	12	33V															
PC11	13	33V															
PC12	14	33V															
USBDM /PB12	15	USB															
USBDP /PB13	16	USB															
		P18 P33 P33 BAK 5VT BAK P33 BAK 33V BAK 33V BAK 5VT 5VT 33V 33V 5VT 5VT 5VT 5VT 5VT															
		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
		nRST VBAT XTAL32KOUT PC14 PC13															
		CLDO VDD33_2 VSS33_2															

Figure 5 HT32F1654/1653 LQFP-64 Pin Assignment

**Table 2 HT32F1654/1653 Series Pin Assignment for LQFP 64 / 48 Package**

Package		Alternate function number																
		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15	
LQFP-64	LQFP-48	System Default	GPIO	ADC	CMP	MCTM/GPTM	SPI	USART/JUART	I <sup>2</sup> C	SCI	EBI	I <sup>2</sup> S	N/A	N/A	N/A	N/A	System Other	
1	1	PA0		ADC_IN0		GT1_CH0		USR0_RTS	I2C1_SCL	SCI_CLK		I2S_WS						
2	2	PA1		ADC_IN1		GT1_CH1		USR0_CTS	I2C1_SDA	SCI_DIO		I2S_BCLK						
3	3	PA2		ADC_IN2		GT1_CH2		USR0_TX				I2S_SDO						
4	4	PA3		ADC_IN3		GT1_CH3		USR0_RX				I2S_SD1						
5	5	PA4		ADC_IN4		GT0_CH0	SPI0_SCK	USR1_TX	I2C0_SCL									
6	6	PA5		ADC_IN5		GT0_CH1	SPI0_MOSI	USR1_RX	I2C0_SDA									
7	7	PA6		ADC_IN6		GT0_CH2	SPI0_MISO	USR1_RTS										
8	8	PA7		ADC_IN7		GT0_CH3	SPI0_SEL	USR1_CTS				I2S_MCLK						
9	9	VDD33_1																
10	10	VSS33_1																
11		PC9		ADC_IN8		GT0_CH0	SPI1_SEL	UR0_TX	I2C1_SCL		EBI_A19							
12		PC10		ADC_IN9		GT0_CH1	SPI1_SCK	UR0_RX	I2C1_SDA		EBI_A20							
13		PC11		ADC_IN10		GT0_CH2	SPI1_MOSI				EBI_A0							
14		PC12		ADC_IN11		GT0_CH3	SPI1_MISO				EBI_A1							
15	11	PB12				MT1_CH2			I2C0_SCL									
16	12	USBDM																
16	12	USBDP																
16	12	PB13				MT1_CH2N			I2C0_SDA									
17	13	CLDO																
18	14	VDD33_2																
19	15	VSS33_2																
20	16	nRST																
21	17	VBAT																
22	18	XTAL32KIN	PC13															
23	19	XTAL32KOUT	PC14															
24	20	RTCOUT	PC15_WAKE-UP															
25		PD0				MT1_ET1			I2C0_SDA		EBI_A18	I2S_SD1						
26	21	XTALIN	PB14															
27	22	XTALOUT	PB15															
28	23	PD1				MT1_CH0	SPI0_SEL		I2C1_SCL		EBI_A16	I2S_MCLK						
29	24	PD2				MT1_CH0N	SPI0_SCK		I2C1_SDA		EBI_A17							
30		PC0				GT1_CH0	SPI1_SEL				EBI_AD13	I2S_WS						
31		PC1				GT1_CH1	SPI1_SCK				EBI_AD14	I2S_BCLK						
32		PC2				GT1_CH2	SPI1_MOSI	UR1_TX	I2C0_SCL		EBI_AD15	I2S_SDO						
33		PC3				GT1_CH3	SPI1_MISO	UR1_RX	I2C0_SDA		EBI_CS3	I2S_SD1						

Package		Alternate function number															
		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
34	25	PA8_BOOT0				GT0_ETI		USR0_TX				I2S_MCLK					CKOUT
35	26	PA9_BOOT1				SPI0_MOSI					EBI_A1	I2S_WS					
36	27	PA10			MT1_CH1		USR0_RX		SCI_DET								
37	28	TRACESWO	PA11		MT1_CH1N	SPI0_MISO					EBI_A0	I2S_MCLK					TRACESWO
38	29	SWCLK	PA12														
39	30	SWDIO	PA13														
40	31	PA14			MT0_CH0	SPI1_SEL	USR1_TX		SCI_CLK	EBI_AD0							
41	32	PA15			MT0_CH0N	SPI1_SCK	USR1_RX		SCI_DIO	EBI_AD1							
42		VDD33_3															
43		VSS33_3															
44	33	PB0			MT0_CH1	SPI1_MOSI	USR0_TX	I2C0_SCL		EBI_AD2							
45	34	PB1			MT0_CH1N	SPI1_MISO	USR0_RX	I2C0_SDA		EBI_AD3							
46		PC4			MT1_CH2		USR1_RTS		SCI_CLK	EBI_AD10							
47		PC5			MT1_CH2N		USR1_CTS		SCI_DIO	EBI_AD11							
48		PC6			MT1_CH3				SCI_DET	EBI_AD12							
	35	VDD33_3															
	36	VSS33_3															
49	37	PB2			MT0_CH2	SPI0_SEL	UR0_TX			EBI_AD4							
50	38	PB3			MT0_CH2N	SPI0_SCK	UR0_RX			EBI_AD5							
51	39	PB4			MT0_BRK	SPI0_MOSI	UR1_TX			EBI_AD6							
52	40	PB5			MT1_BRK	SPI0_MISO	UR1_RX			EBI_AD7							
53		PC7			MT0_CH3			I2C0_SCL		EBI_AD8							
54		PC8			MT0_ETI			I2C0_SDA		EBI_AD9							
55		VDD33_4															
56		VSS33_4															
57	41	PB6		CN0	MT1_CH0	SPI1_SEL	UR1_TX			EBI_OE	I2S_MCLK						
58	42	PB7		CP0	MT1_CH0N	SPI1_SCK				EBI_CS0							
59	43	PB8		COUT0	GT1_ETI	SPI1_MOSI	UR1_RX			EBI_WE							
60	44	PB9		CN1	MT1_CH2	SPI1_MISO	UR0_TX			EBI_ALE	I2S_BCLK						
61	45	PB10		CP1	MT1_CH2N			I2C1_SCL		EBI_CS1	I2S_SD0						
62	46	PB11		COUT1	MT1_CH3		UR0_RX	I2C1_SDA		EBI_CS2	I2S_SD1						
63	47	VDDA															
64	48	VSSA															

**Table 3 HT32F1654/1653 Pin Description**

Pin number		Pin Name	Type (Note1)	IO Structure (Note2)	Output Driving	Description	
LQFP 64	LQFP 48					Default function (AF0)	
1	1	PA0	AI/O	33V	4/8mA	PA0	
2	2	PA1	AI/O	33V	4/8mA	PA1	
3	3	PA2	AI/O	33V	4/8mA	PA2	
4	4	PA3	AI/O	33V	4/8mA	PA3	
5	5	PA4	AI/O	33V	4/8mA	PA4	
6	6	PA5	AI/O	33V	4/8mA	PA5	
7	7	PA6	AI/O	33V	4/8mA	PA6	
8	8	PA7	AI/O	33V	4/8mA	PA7	
9	9	VDD33_1	P	—	—	3.3 V voltage for digital I/O	
10	10	VSS33_1	P	—	—	Ground reference for digital I/O	
11		PC9	AI/O	33V	4/8mA	PC9	
12		PC10	AI/O	33V	4/8mA	PC10	
13		PC11	AI/O	33V	4/8mA	PC11	
14		PC12	AI/O	33V	4/8mA	PC12	
15	11	PB12	I/O	5VT	8mA	PB12	
15	11	USBDM	AI/O	—	—	USB Differential data bus conforming to the Universal Serial Bus standard.	
16	12	USBDP	AI/O	—	—	USB Differential data bus conforming to the Universal Serial Bus standard.	
16	12	PB13	I/O	5VT	8mA	PB13	
17	13	CLDO	P	—	—	Core power LDO 1.8 V output It is recommended to connect a 4.7uF capacitor as close as possible between this pin and VSS33_2.	
18	14	VDD33_2	P	—	—	3.3 V voltage for digital I/O	
19	15	VSS33_2	P	—	—	Ground reference for digital I/O	
20	16	nRST	I (BK)	5VT_PU	—	External reset pin and external wakeup pin in the Power-Down mode	
21	17	VBAT	P	—	—	Battery power input for the backup domain	
22	18	PC13 <sup>Note 4</sup>	AI/O (BK)	33V	1mA	XTAL32KIN	
23	19	PC14 <sup>Note 4</sup>	AI/O (BK)	33V	1mA	XTAL32KOUT	
24	20	PC15 <sup>Note 4</sup>	I/O (BK)	5VT	1mA	RTCOUT	
25		PD0	I/O	5VT	8mA	PD0	
26	21	PB14	AI/O	33V	4/8mA	XTALIN	
27	22	PB15	AI/O	33V	4/8mA	XTALOUT	
28	23	PD1	I/O	5VT	8mA	PD1	
29	24	PD2	I/O	5VT	8mA	PD2	
30		PC0	I/O	5VT	12mA	PC0	
31		PC1	I/O	5VT	12mA	PC1	
32		PC2	I/O	5VT	12mA	PC2	
33		PC3	I/O	5VT	12mA	PC3	

Pin number		Pin Name	Type (Note1)	IO Structure (Note2)	Output Driving	Description	
LQFP 64	LQFP 48					Default function (AF0)	
34	25	PA8	I/O	5VT_PU	12mA	PA8_BOOT0	
35	26	PA9	I/O	5VT_PU	12mA	PA9_BOOT1	
36	27	PA10	I/O	5VT	8mA	PA10	
37	28	PA11	I/O	5VT	8mA	TRACESWO	
38	29	PA12	I/O	5VT_PU	8mA	SWCLK	
39	30	PA13	I/O	5VT_PU	8mA	SWDIO	
40	31	PA14	I/O	5VT	12mA	PA14	
41	32	PA15	I/O	5VT	12mA	PA15	
42		VDD33_3	P	—	—	3.3 V voltage for digital I/O	
43		VSS33_3	P	—	—	Ground reference for digital I/O	
44	33	PB0	I/O	5VT	12mA	PB0	
45	34	PB1	I/O	5VT	12mA	PB1	
46		PC4	I/O	5VT	8mA	PC4	
47		PC5	I/O	5VT	8mA	PC5	
48		PC6	I/O	5VT	8mA	PC6	
	35	VDD33_3	P	—	—	3.3 V voltage for digital I/O	
	36	VSS33_3	P	—	—	Ground reference for digital I/O	
49	37	PB2	I/O	5VT	12mA	PB2	
50	38	PB3	I/O	5VT	12mA	PB3	
51	39	PB4	I/O	5VT	12mA	PB4	
52	40	PB5	I/O	5VT	12mA	PB5	
53		PC7	I/O	5VT	8mA	PC7	
54		PC8	I/O	5VT	8mA	PC8	
55		VDD33_4	P	—	—	3.3 V voltage for digital I/O	
56		VSS33_4	P	—	—	Ground reference for digital I/O	
57	41	PB6	AI/O	33V	4/8mA	PB6	
58	42	PB7	AI/O	33V	4/8mA	PB7	
59	43	PB8	AI/O	33V	4/8mA	PB8	
60	44	PB9	AI/O	33V	4/8mA	PB9	
61	45	PB10	AI/O	33V	4/8mA	PB10	
62	46	PB11	AI/O	33V	4/8mA	PB11	
63	47	VDDA	P	—	—	3.3 V analog voltage for ADC and Comparator	
64	48	VSSA	P	—	—	Ground reference for the ADC and Comparator	

Note: 1. I = input, O = output, A = Analog port, P = power supply, PU = pull-up, BK = Back-up domain

2. 5VT = 5 V tolerant; 33V = 3.3 V tolerant.

3. The GPIOs are in an AF0 state after a  $V_{DD18}$  power on reset (POR) except for the RTCOUT pin in the Backup Domain I/O. The RTCOUT pin is reset by the Backup Domain power-on-reset (PORB) or by the Backup Domain software reset (BAK\_RST bit in BAK\_CR register).

4. The backup domain of the I/O pins have a source current capability limitation of <1 mA @  $V_{BAT} = 3.3V$  and sink current typical is 4 mA @  $V_{BAT} = 3.3V$ .

## 5 Electrical Characteristics

### Absolute Maximum Ratings

The following table shows the absolute maximum ratings of the device. These are stress ratings only. Stresses beyond absolute maximum ratings may cause permanent damage to the device. Note that the device is not guaranteed to operate properly at the maximum ratings. Exposure to the absolute maximum rating conditions for extended periods may affect device reliability.

**Table 4 Absolute Maximum Ratings**

Symbol	Parameter	Min	Max	Unit
$V_{DD33}$	External main supply voltage	$V_{SS} - 0.3$	$V_{SS} + 3.6$	V
$V_{DDA}$	External analog supply voltage	$V_{SSA} - 0.3$	$V_{SSA} + 3.6$	V
$V_{BAT}$	External battery supply voltage	$V_{SS} - 0.3$	$V_{SS} + 3.6$	V
$V_{LDOIN}$	External LDO supply voltage	$V_{SS} - 0.3$	$V_{SS} + 3.6$	V
$V_{IN}$	Input voltage on 5 V-tolerant I/O	$V_{SS} - 0.3$	$V_{SS} + 5.5$	V
	Input voltage on other I/O	$V_{SS} - 0.3$	$V_{DD33} + 0.3$	V
$T_A$	Ambient operating temperature range	-40	+85	°C
$T_{STG}$	Storage temperature range	-55	+150	°C
$T_J$	Maximum junction temperature	—	125	°C
$P_D$	Total power dissipation	—	500	mW
$V_{ESD}$	Electrostatic discharge voltage - human body mode	-4000	+4000	V

### Recommended DC Operating Conditions

**Table 5 Recommended DC Operating Conditions**

$T_A = 25^\circ\text{C}$ , unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{DD33}$	I/O operating voltage		2.7	3.3	3.6	V
$V_{DDA}$	Analog operating voltage		2.7	3.3	3.6	V
$V_{BAT}$	Battery supply operating voltage		2.7	3.3	3.6	V
$V_{LDOIN}$	LDO operating voltage		2.7	3.3	3.6	V

### On-Chip LDO Voltage Regulator Characteristics

**Table 6 LDO Characteristics**

$T_A = 25^\circ\text{C}$ , unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{LDOOUT}$	Internal regulator output voltage	$V_{DD33} = 3.3 \text{ V}$ Regulator input	1.71	1.8	1.89	V
$I_{LDOOUT}$	Output current	$V_{DD33} = 2.7 \text{ V}$ Regulator input	—	—	200	mA
$C_{LDO}$	External filter capacitor value for internal core power supply	The capacitor value is dependent on the core power current consumption	2.2	—	10	$\mu\text{F}$

## Power Consumption

**Table 7 Power Consumption Characteristics**

T<sub>A</sub> = 25°C, unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I <sub>DD</sub>	Supply current (Run mode)	V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V, HSE = 8MHz, PLL = 144 MHz, f <sub>HCLK</sub> = 72 MHz, f <sub>PCLK</sub> = 72 MHz, All peripherals enabled	—	76	—	mA
		V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V, HSE = 8MHz, PLL = 144 MHz, f <sub>HCLK</sub> = 72 MHz, f <sub>PCLK</sub> = 72 MHz, All peripherals disabled	—	33	—	mA
	Supply current (Sleep mode)	V <sub>DD</sub> = V <sub>BAT</sub> = 3.3 V, HSE = 8MHz, PLL = 144 MHz, f <sub>HCLK</sub> = 0 MHz, f <sub>PCLK</sub> = 72 MHz, All peripherals enabled	—	55	—	mA
		V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V, HSE = 8MHz, PLL = 144 MHz, f <sub>HCLK</sub> = 0 MHz, f <sub>PCLK</sub> = 72 MHz, All peripherals disabled	—	10	—	mA
	Supply current (Deep-Sleep1 mode)	V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V, All clock off (HSE/PLL/f <sub>HCLK</sub> ), LDO in low power mode, LSI on, RTC on	—	63	—	μA
	Supply current (Deep-Sleep2 mode)	V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V, All clock off (HSE/PLL/f <sub>HCLK</sub> ), LDO off (DMOS on), LSI on, RTC on	—	22	—	μA
	Supply current (Power-Down mode)	V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V, LDO off, LSE on, LSI off, RTC on	—	-	—	μA
		V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V, LDO off, LSE on, LSI off, RTC off	—	-	—	μA
		V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V, LDO off, LSE off, LSI on, RTC on	—	-	—	μA
		V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V, LDO off, LSE off, LSI on, RTC off	—	5	—	μA
I <sub>BAT</sub>	Battery supply current (Power-Down mode)	V <sub>DD33</sub> not present, V <sub>BAT</sub> = 3.3 V, LDO off, LSE off, LSI on, RTC on	—	4	—	μA
		V <sub>DD33</sub> not present, V <sub>BAT</sub> = 3.3 V, LDO off, LSE off, LSI on, RTC off	—	3.9	—	μA

- Note:
1. HSE means high speed external oscillator. HSI means 8MHz high speed internal oscillator.
  2. LSE means low speed external oscillator. LSI means 32.768KHz low speed internal oscillator.
  3. RTC means real time clock.
  4. Code = while (1) { 208 NOP } executed in Flash.

## Reset and Supply Monitor Characteristics

Table 8 LVD/BOD Characteristics

T<sub>A</sub> = 25°C, unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit	
V <sub>BOD</sub>	Brown Out Detector Voltage	—	—	2.6	—	V	
V <sub>LVD</sub>		LVDS <sup>(Note1)</sup> = '000'	—	2.7	—	V	
		LVDS <sup>(Note1)</sup> = '001'	—	2.8	—	V	
		LVDS <sup>(Note1)</sup> = '010'	—	2.9	—	V	
		LVDS <sup>(Note1)</sup> = '011'	—	3.0	—	V	
		LVDS <sup>(Note1)</sup> = '100'	—	3.1	—	V	
		LVDS <sup>(Note1)</sup> = '101'	—	3.2	—	V	
		LVDS <sup>(Note1)</sup> = '110'	—	3.4	—	V	
		LVDS <sup>(Note1)</sup> = '111'	—	3.5	—	V	
V <sub>POR</sub>	Power On Reset Voltage	—	—	1.36	—	V	

Note: LVDS field is in PWRCU LVDCSR register

## External Clock Characteristics

Table 9 High Speed External Clock (HSE) Characteristics

T<sub>A</sub> = 25°C, unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f <sub>HSE</sub>	High Speed External oscillator frequency (HSE)	V <sub>DD33</sub> = 3.3 V	4	—	16	MHz
C <sub>HSE</sub>	Recommended load capacitance on XTALIN and XTALOUT pins	—	—	TBD	—	pF
R <sub>FHSE</sub>	Recommended external feedback resistor between XTALIN and XTALOUT pins	—	—	1.0	—	MΩ
D <sub>HSE</sub>	HSE oscillator Duty cycle	—	40	—	60	%
I <sub>DDHSE</sub>	HSE oscillator current consumption	V <sub>DD33</sub> = 3.3 V, T <sub>A</sub> = 25°C	—	0.96	—	mA
I <sub>STBHSE</sub>	HSE oscillator standby current	V <sub>DD33</sub> = 3.3 V, T <sub>A</sub> = 25°C	—	—	0.1	μA
t <sub>SUHSE</sub>	HSE oscillator startup time	V <sub>DD33</sub> = 3.3 V, T <sub>A</sub> = 25°C	—	—	4	ms

**Table 10 Low Speed External Clock (LSE) Characteristics**

T<sub>A</sub> = 25°C, unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f <sub>LSE</sub>	Low Speed External oscillator frequency (LSE)	V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V	—	32.768	—	kHz
C <sub>LSE</sub>	Recommended load capacitance on XTAL32KIN and XTAL32KOUT pins	—	—	TBD	—	pF
R <sub>FLSE</sub>	Recommended external feedback resistor between XTAL32KIN and XTAL32KOUT pins	—	—	10	—	MΩ
D <sub>LSE</sub>	LSE oscillator Duty cycle		40	—	60	%
I <sub>DDLSE</sub>	LSE Oscillator Operating current	V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V, LSESIM = 0 (Normal startup mode)	—	1.7	—	μA
I <sub>STBLSE</sub>	LSE Oscillator Standby current	V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V, LSESIM = 1 (Fast startup mode)	—	3	8	μA
t <sub>SULSE</sub>	LSE Oscillator Startup time	V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V, LSESIM = 1 (Fast startup mode)	—	200	—	ms

Note: The following PCB layout guidelines are recommended to increase the stability of the crystal circuit for the HSE/LSE clock:

- The crystal oscillator should be located as close as possible to the MCU to minimise trace length thus reducing parasitic capacitance.
- Use a ground plane as a shield under the crystal circuit to reduce the effects of noise interference..
- Route high frequency signals away from crystal oscillator area to prevent crosstalk.

## Internal Clock Characteristics

**Table 11 High Speed Internal Clock (HSI) Characteristics**

T<sub>A</sub> = 25°C, unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f <sub>HSI</sub>	High Speed Internal Oscillator Frequency (HSI)	V <sub>DD33</sub> = 3.3 V, T <sub>A</sub> = -40°C ~ +85°C	—	8	—	MHz
ACC <sub>HSI</sub>	HSI Oscillator Frequency accuracy	Factory-trimmed, V <sub>DD33</sub> = 3.3 V, T <sub>A</sub> = -40°C ~ +85°C	-5	—	+5	%
D <sub>HSI</sub>	HSI Oscillator Duty cycle	V <sub>DD33</sub> = 3.3 V, f <sub>HSI</sub> = 8 MHz	35	—	65	%
I <sub>DDHSI</sub>	HSI Oscillator current	V <sub>DD33</sub> = 3.3 V, f <sub>HSI</sub> = 8 MHz	—	0.92	—	mA
t <sub>SUHSI</sub>	HSI Oscillator Startup time	V <sub>DD33</sub> = 3.3 V, f <sub>HSI</sub> = 8 MHz, HSIRCBL = 0 (HSI Ready Counter Bits Length 7 Bits )	—	17	—	μs

Note: HSIRCBL field is in PWRCU HSIRCRL register

**Table 12 Low Speed Internal Clock (LSI) Characteristics**

T<sub>A</sub> = 25°C, unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f <sub>LSI</sub>	Low Speed Internal Oscillator Frequency (LSI)	V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V, T <sub>A</sub> = -40°C ~ +85°C	25	32	43	kHz
I <sub>DDLSI</sub>	LSI Oscillator Operating current	V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V, T <sub>A</sub> = 25°C	—	1.0	2	μA
t <sub>SULSI</sub>	LSI Oscillator startup time	V <sub>DD33</sub> = V <sub>BAT</sub> = 3.3 V, T <sub>A</sub> = 25°C	—	35	—	ms

## PLL Characteristics

**Table 13 PLL Characteristics**

T<sub>A</sub> = 25°C, unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f <sub>PLLIN</sub>	PLL input clock	—	4	—	16	MHz
f <sub>CK_PLL</sub>	PLL output clock	—	8	—	144	MHz
t <sub>LOCK</sub>	PLL lock time	—	—	TBD	—	ms

## Memory Characteristics

**Table 14 Flash Memory Characteristics**

T<sub>A</sub> = 25°C, unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
N <sub>ENDU</sub>	Number of guaranteed program/erase cycles before failure. (Endurance)	T <sub>A</sub> = -40°C ~ +85°C	20	—	—	K cycles
T <sub>RET</sub>	Data retention time	T <sub>A</sub> = 25°C	100	—	—	Years
t <sub>PROG</sub>	Word programming time	T <sub>A</sub> = -40°C ~ +85°C	20	—	40	μs
t <sub>ERASE</sub>	Page erase time	T <sub>A</sub> = -40°C ~ +85°C	20	—	40	ms
t <sub>MERASE</sub>	Mass erase time	T <sub>A</sub> = -40°C ~ +85°C	20	—	40	ms

## I/O Port Characteristics

Table 15 I/O Port Characteristics

T<sub>A</sub> = 25°C, unless otherwise specified.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
I <sub>IL</sub>	Low level input current	3.3 V IO	V <sub>I</sub> = 0 V, On-chip pull-up resister disabled.	—	—	3	μA
		5 V-tolerant IO	On-chip pull-down resister disabled.	—	—	3	μA
		Reset pin	—	—	3	μA	
I <sub>IH</sub>	High level input current	3.3 V IO	V <sub>I</sub> = V <sub>DD33</sub> ,	—	—	3	μA
		5 V-tolerant IO	On-chip pull-down resister disabled.	—	—	3	μA
		Reset pin	—	—	3	μA	
V <sub>IL</sub>	Low level input voltage	3.3 V IO	—	-0.3	—	0.8	V
		5 V-tolerant IO	—	-0.3	—	0.8	V
		Reset pin	—	-0.3	—	0.8	V
V <sub>IH</sub>	High level input voltage	3.3 V IO	—	2	—	3.6	V
		5 V-tolerant IO	—	2	—	5.5	V
		Reset pin	—	2	—	5.5	V
V <sub>HYS</sub>	Schmitt trigger input voltage hysteresis	3.3 V IO	—	400	—	—	mV
		5 V-tolerant IO	—	400	—	—	mV
		Reset pin	—	400	—	—	mV
I <sub>OL</sub>	Low level output current (GPIO Sink current)	3.3 V IO 4 mA drive, V <sub>OL</sub> = 0.4 V	—	4	—	—	mA
		3.3 V IO 8 mA drive, V <sub>OL</sub> = 0.4 V	—	8	—	—	mA
		5 V-tolerant IO 8 mA drive, V <sub>OL</sub> = 0.4 V	—	8	—	—	mA
		5 V-tolerant IO 12 mA drive, V <sub>OL</sub> = 0.4 V	—	12	—	—	mA
		Backup Domain IO drive @ V <sub>BAT</sub> = 3.3 V, V <sub>OL</sub> = 0.4 V, PC13, PC14, PC15.	—	—	4	—	mA
		3.3 V I/O 4 mA drive, V <sub>OH</sub> = V <sub>DD33</sub> - 0.4 V	—	—	4	—	mA
I <sub>OH</sub>	High level output current (GPIO Source current)	3.3 V I/O 8 mA drive, V <sub>OH</sub> = V <sub>DD33</sub> - 0.4 V	—	—	8	—	mA
		5 V-tolerant I/O 8 mA drive, V <sub>OH</sub> = V <sub>DD33</sub> - 0.4 V	—	—	8	—	mA
		5 V-tolerant I/O 12 mA drive, V <sub>OH</sub> = V <sub>DD33</sub> - 0.4 V	—	—	12	—	mA
		Backup Domain IO drive @ V <sub>BAT</sub> = 3.3 V, V <sub>OL</sub> = V <sub>DD33</sub> - 0.4V, PC13, PC14, PC15.	—	—	—	1	mA
		3.3 V 4 mA drive IO, I <sub>OL</sub> = 4 mA	—	—	—	0.4	V
		3.3 V 8 mA drive IO, I <sub>OL</sub> = 8 mA	—	—	—	0.4	V
V <sub>OL</sub>	Low level output voltage	5 V-tolerant 8 mA drive IO, I <sub>OL</sub> = 8 mA	—	—	—	0.4	V
		5 V-tolerant 12 mA drive IO, I <sub>OL</sub> = 12 mA	—	—	—	0.4	V

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V <sub>OH</sub>	High level output voltage	3.3 V 4 mA drive IO, I <sub>OH</sub> = 4 mA	V <sub>DD33</sub> - 0.4 V	—	—	V
		3.3 V 8 mA drive IO, I <sub>OH</sub> = 8 mA	V <sub>DD33</sub> - 0.4 V	—	—	V
		5 V-tolerant 8 mA drive IO, I <sub>OH</sub> = 8 mA	V <sub>DD33</sub> - 0.4 V	—	—	V
		5 V-tolerant 12 mA drive IO, I <sub>OH</sub> = 12 mA	V <sub>DD33</sub> - 0.4 V	—	—	V
R <sub>PU</sub>	Internal pull-up resistor	3.3 V I/O 5 V-tolerant I/O	34 38	— —	74 89	kΩ
R <sub>PD</sub>	Internal pull-down resistor	3.3 V I/O 5 V-tolerant I/O	29 35	— —	86 107	kΩ

## ADC Characteristics

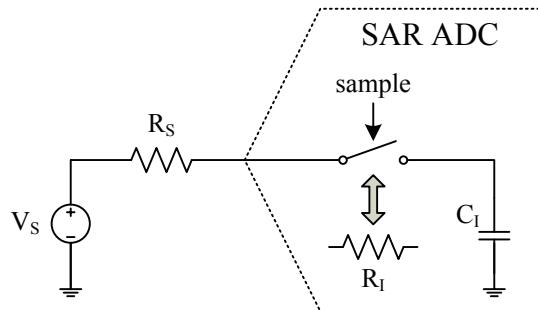
Table 16 ADC Characteristics

T<sub>A</sub> = 25°C, unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V <sub>DDA</sub>	Operating voltage	—	2.7	3.3	3.6	V
V <sub>ADCIN</sub>	A/D Converter input voltage range	—	0	—	V <sub>REF+</sub>	V
V <sub>REF+</sub>	A/D Converter Reference voltage	—	—	V <sub>DDA</sub>	V <sub>DDA</sub>	V
I <sub>ADC</sub>	Current consumption	V <sub>DDA</sub> = 3.3 V	—	1	TBD	mA
I <sub>ADC_DN</sub>	Power down current consumption	V <sub>DDA</sub> = 3.3 V	—	1	10	μA
f <sub>ADC</sub>	A/D Converter clock	—	0.7	—	14	MHz
f <sub>s</sub>	Sampling rate	—	0.05	—	1	MHz
f <sub>ADCCONV</sub>	A/D Converter conversion time	—	—	14	—	1/f <sub>ADC</sub> Cycles
R <sub>I</sub>	Input sampling switch resistance	—	—	—	1	kΩ
C <sub>I</sub>	Input sampling capacitance	No pin/pad capacitance included	—	—	5	pF
t <sub>su</sub>	Startup up time	—	—	—	1	μs
N	Resolution	—	—	12	—	bits
INL	Integral Non-linearity error	f <sub>s</sub> = 1 MHz, V <sub>DDA</sub> = 3.3 V	—	±2	±5	LSB
DNL	Differential Non-linearity error	f <sub>s</sub> = 1 MHz, V <sub>DDA</sub> = 3.3 V	—	—	±1	LSB
E <sub>O</sub>	Offset error	—	—	—	±10	LSB
E <sub>G</sub>	Gain error	—	—	—	±10	LSB

Note: 1. Guaranteed by design, not tested in production.

2. The figure below shows the equivalent circuit of the A/D Converter Sample-and-Hold input stage where C<sub>I</sub> is the storage capacitor, R<sub>I</sub> is the resistance of the sampling switch and R<sub>S</sub> is the output impedance of the signal source V<sub>S</sub>. Normally the sampling phase duration is approximately, 1.5/f<sub>ADC</sub>. The capacitance, C<sub>I</sub>, must be charged within this time frame and it must be ensured that the voltage at its terminals becomes sufficiently close to V<sub>S</sub> for accuracy. To guarantee this, R<sub>S</sub> may not have an arbitrarily large value.



**Figure 6 ADC Sampling Network Model**

The worst case occurs when the extremities of the input range (0V and VREF) are sampled consecutively. In this situation a sampling error below  $\frac{1}{4}$  LSB is ensured by using the following equation:

$$R_s < \frac{1.5}{f_{ADC} C_I \ln(2^{N+2})} - R_I$$

where  $f_{ADC}$  is the ADC clock frequency and N is the ADC resolution (N = 12 in this case). A safe margin should be considered due to the pin/pad parasitic capacitances, which are not accounted for in this simple model.

If, in a system where the A/D Converter is used, there are no rail-to-rail input voltage variations between consecutive sampling phases,  $R_s$  may be larger than the value indicated by the equation above.

## Comparator Characteristics

**Table 17 Comparator Characteristics**

$T_A = -40^\circ\text{C} \sim 85^\circ\text{C}$ , unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{DDA}$	Operating voltage	Comparator mode	2.7	3.3	3.6	V
$V_{IN}$	Input Common Mode Voltage Range	CP or CN	$V_{SSA}$	—	$V_{DDA}$	V
$V_{IOS}$	Input offset voltage <sup>(Note)</sup>	$T_A = 25^\circ\text{C}$	-5	—	5	mV
$V_{hys}$	Input Hysteresis	No hysteresis (CMPnHM [1:0] = 00)	—	0	—	mV
		Low hysteresis (CMPnHM [1:0] = 01)	—	30	—	mV
		Middle hysteresis (CMPnHM [1:0] = 10)	—	70	—	mV
		High hysteresis (CMPnHM [1:0] = 11)	—	100	—	mV
$t_{RT}$	Response time Input Overdrive = $\pm 100\text{mV}$	High Speed mode	—	50	100	ns
		Low Speed mode	—	2	5	us
$I_{CMP}$	Current Consumption $V_{DDA} = 3.3\text{ V}$	High Speed mode	—	100	—	uA
		Low Speed mode	—	10	—	uA
$t_{CMPST}$	Comparator Startup Time	Comparator enabled to output valid.	—	—	50	us
$I_{CMP\_DN}$	Power Down Supply Current	$\text{CMPEN} = 0$ $\text{CVREFEN} = 0$ $\text{CVREFOE}=0$	—	—	0.1	uA

### Comparator Voltage Reference (CVR)

$V_{CVR}$	Output Range	—	$V_{SSA}$	—	$V_{DDA}$	V
$N_{\text{Bits}}$	CVR Scaler Resolution	—	—	6	—	bits
$t_{CVRST}$	Setting Time	CVR scaler setting time from $\text{CVREF} = "000000"$ to $"111111"$	—	—	100	us
$I_{CVR}$	Current Consumption $V_{DDA} = 3.3\text{ V}$	CVREFEN=1, CMPREFOE=0	—	10	—	uA
		CVREFEN=1, CVREFOE=1	—	20	40	uA

Note: Guaranteed by design, not tested in production.

## GPTM/MCTM Characteristics

**Table 18 GPTM/MCTM Characteristics**

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$f_{TM}$	Timer clock source for GPTM and MCTM	—	—	—	72	MHz
$t_{RES}$	Timer resolution time	—	1	—	—	$f_{TM}$
$f_{EXT}$	External single frequency on channel 1 ~ 4	—	—	—	1/2	$f_{TM}$
RES	Timer resolution	—	—	—	16	bits

## I<sup>2</sup>C Characteristics

Table 19 I<sup>2</sup>C Characteristics

Symbol	Parameter	Standard mode		Fast mode		Fast mode plus		Unit
		Min	Max	Min	Max	Min	Max	
$f_{SCL}$	SCL clock frequency	—	100	—	400	—	1000	kHz
$t_{SCL(H)}$	SCL clock high time	4.5	—	1.125	—	0.45	—	μs
$t_{SCL(L)}$	SCL clock low time	4.5	—	1.125	—	0.45	—	μs
$t_{FALL}$	SCL and SDA fall time	—	1.3	—	0.34	—	0.135	μs
$t_{RISE}$	SCL and SDA rise time	—	1.3	—	0.34	—	0.135	μs
$t_{SU(SDA)}$	SDA data setup time	500	—	125	—	50	—	ns
$t_{H(SDA)}$	SDA data hold time	0	—	0	—	0	—	ns
$t_{SU(STA)}$	START condition setup time	500	—	125	—	50	—	ns
$t_{H(STA)}$	START condition hold time	0	—	0	—	0	—	ns
$t_{SU(STO)}$	STOP condition setup time	500	—	125	—	50	—	ns

Note: 1. Guaranteed by design, not tested in production.

2. To achieve 100kHz standard mode, the peripheral clock frequency must be higher than 2MHz.
3. To achieve 400kHz fast mode, the peripheral clock frequency must be higher than 8MHz.
4. To achieve 1MHz fast mode plus, the peripheral clock frequency must be higher than 20MHz.
5. The above characteristic parameters of the I<sup>2</sup>C bus timing are based on: SEQ\_FILTER = 01 and COMB\_FILTER\_En is disabled.

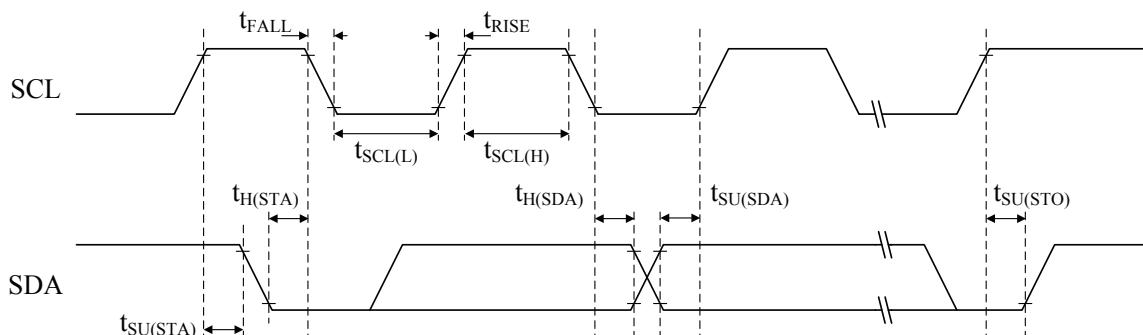


Figure 7 I<sup>2</sup>C Timing Diagrams

## SPI Characteristics

Table 20 SPI Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$f_{SCK}$	SCK clock frequency	—	—	—	$f_{PCLK}/2$	MHz
$t_{SCK(H)}$	SCK clock high time	—	$f_{PCLK}/8$	—	—	ns
$t_{SCK(L)}$	SCK clock low time	—	$f_{PCLK}/8$	—	—	ns
<b>SPI Master mode</b>						
$t_{V(MO)}$	Data output valid time	—	—	—	5	ns
$t_{H(MO)}$	Data output hold time	—	2	—	—	ns
$t_{SU(MI)}$	Data input setup time	—	5	—	—	ns
$t_{H(MI)}$	Data input hold time	—	5	—	—	ns
<b>SPI Slave mode</b>						
$t_{SU(SEL)}$	SEL enable setup time	—	$4 t_{PCLK}$	—	—	ns
$t_{H(SEL)}$	SEL enable hold time	—	$2 t_{PCLK}$	—	—	ns
$t_{A(SO)}$	Data output access time	—	—	—	$3 t_{PCLK}$	ns
$t_{DIS(SO)}$	Data output disable time	—	—	—	10	ns
$t_{V(SO)}$	Data output valid time	—	—	—	25	ns
$t_{H(SO)}$	Data output hold time	—	15	—	—	ns
$t_{SU(SI)}$	Data input setup time	—	5	—	—	ns
$t_{H(SI)}$	Data input hold time	—	4	—	—	ns

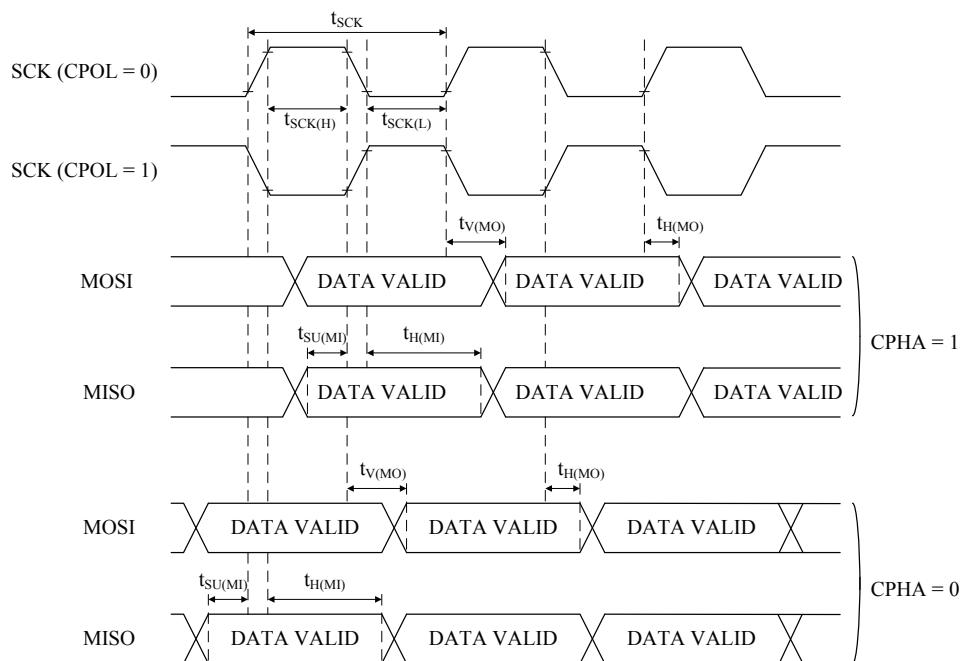


Figure 8 SPI Timing Diagrams - SPI Master Mode

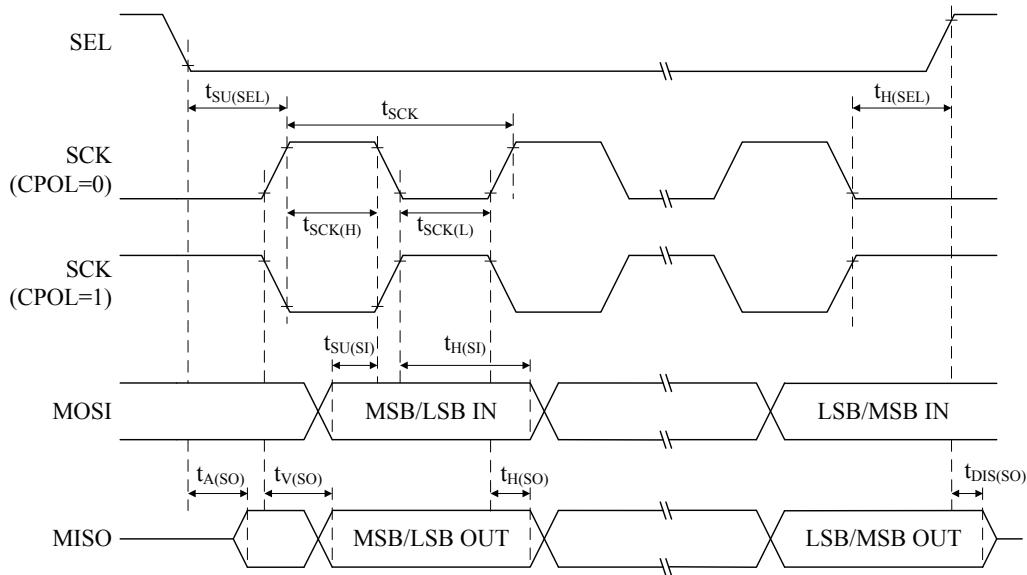
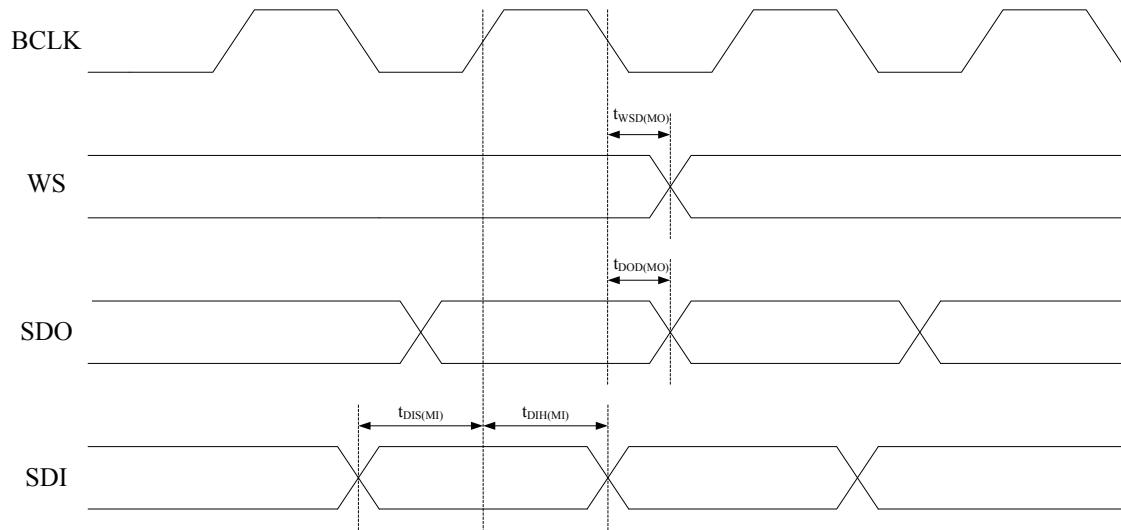


Figure 9 SPI Timing Diagrams - SPI Slave Mode with CPHA=1

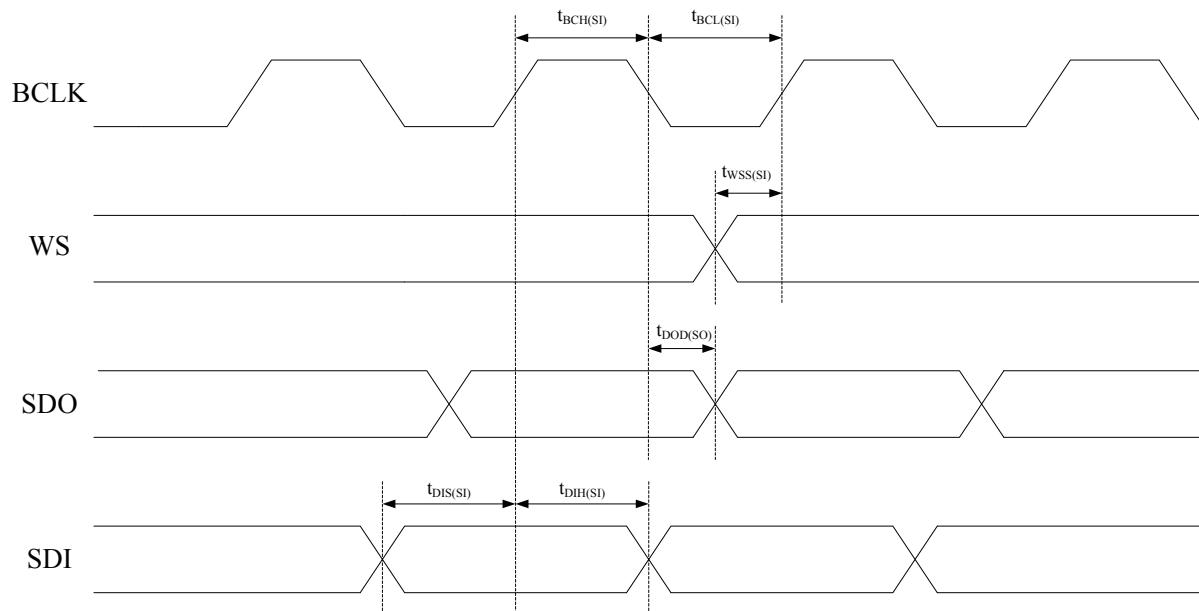
## I<sup>2</sup>S Characteristics

Table 21 I<sup>2</sup>S Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I <sup>2</sup> S Master mode						
t <sub>WSD(MO)</sub>	WS output to BCLK delay	—	—	TBD	—	ns
t <sub>DOD(MO)</sub>	Data output to BCLK delay	—	—	TBD	—	ns
t <sub>DIS(MI)</sub>	Data input setup time	—	—	TBD	—	ns
t <sub>DIH(MI)</sub>	Data input hold time	—	—	TBD	—	ns
I <sup>2</sup> S Slave mode						
t <sub>BCH(SI)</sub>	BCLK high pulse width	—	—	TBD	—	ns
t <sub>BCL(SI)</sub>	BCLK low pulse width	—	—	TBD	—	ns
t <sub>WSS(SI)</sub>	WS input setup time	—	—	TBD	—	ns
t <sub>DOD(SO)</sub>	Data output to BCLK delay	—	—	TBD	—	ns
t <sub>DIS(SI)</sub>	Data input setup time	—	—	TBD	—	ns
t <sub>DIH(SI)</sub>	Data input hold time	—	—	TBD	—	ns



**Figure 10 Timing of I<sup>2</sup>S Master Mode**



**Figure 11 Timing of I<sup>2</sup>S Slave Mode**

## USB Characteristics

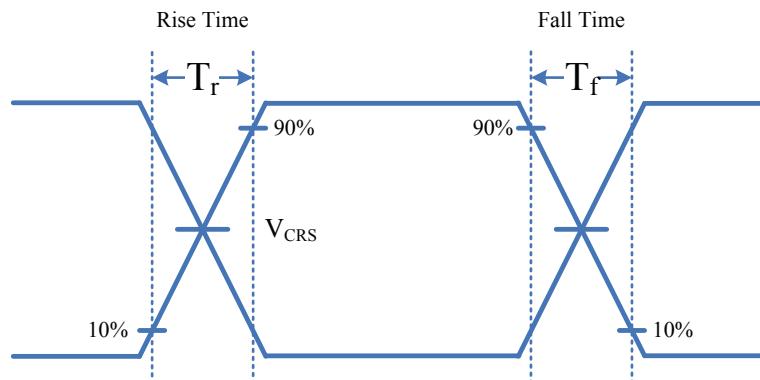
The USB interface is USB-IF certified - Full Speed.

**Table 22 USB DC Electrical Characteristics**

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{DD33}$	USB operating voltage	—	3.0	—	3.6	V
$V_{DI}$	Differential input sensitivity	USBDP-USBDM	0.2	—	—	V
$V_{CM}$	Common mode voltage range	—	0.8	—	2.5	V
$V_{SE}$	Single-ended receiver threshold	—	0.8	—	2.0	V
$V_{OL}$	Pad output low voltage	—	0	—	0.3	V
$V_{OH}$	Pad output high voltage	RL of 1.5 kΩ to $V_{DD33}$	2.8	—	3.6	V
$V_{CRS}$	Differential output signal cross-point voltage	—	1.3	—	2.0	V
$Z_{DRV}$	Driver output resistance	—	—	10	—	Ω
$C_{IN}$	Transceiver pad capacitance	—	—	—	20	pF

Note: 1. Guaranteed by design, not tested in production.

2. To be compliant with the USB 2.0 full-speed electrical specification, the USBDP pin should be pulled up with a 1.5 kΩ external resistor to a 3.0-to-3.6 V voltage supply.
3. The USB functionality is ensured down to 2.7 V but not the full USB electrical characteristics which will experience degradation in the 2.7-to-3.0 V  $V_{DD33}$  voltage range.
4. RL is the load connected to the USB driver USBDP.



**Figure 12 USB Signal Rise Time and Fall Time and Cross-Point Voltage (VCRS) Definition**

**Table 23 USB AC Electrical Characteristics**

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$T_r$	Rise time	$C_L = 50 \text{ pF}$	4	-	20	ns
$T_f$	Fall time	$C_L = 50 \text{ pF}$	4	-	20	ns
$T_{rf}$	Rise time / fall time matching	$T_{rf} = T_r / T_f$	90	-	110	%

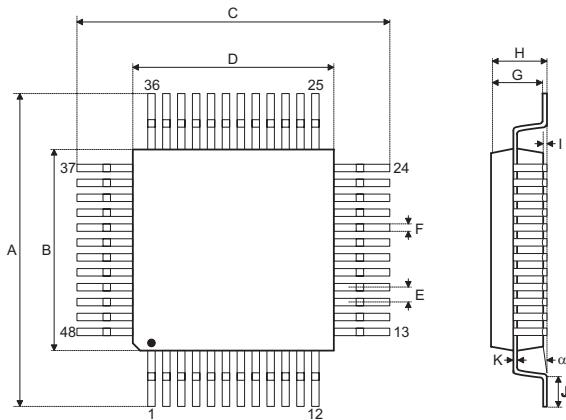
## 6 Package Information

Note that the package information provided here is for consultation purposes only. As this information may be updated at regular intervals users are reminded to consult the [Holtek website](#) for the latest version of the package information.

Additional supplementary information with regard to packaging is listed below. Click on the relevant section to be transferred to the relevant website page.

- [Further Package Information](#) (include Outline Dimensions, Product Tape and Reel Specifications)
- [Packing Meterials Information](#)
- [Carton information](#)

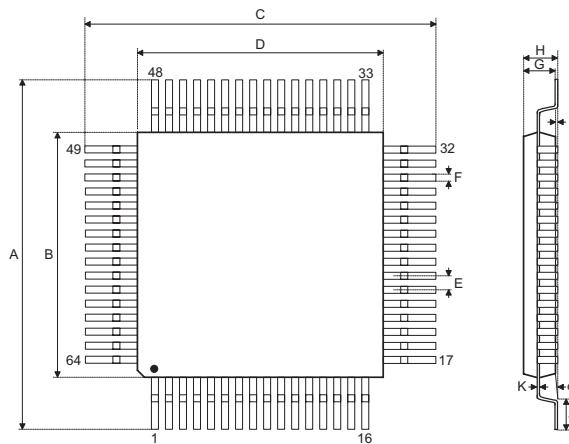
## 48-pin LQFP (7mm×7mm) Outline Dimensions



Symbol	Dimensions in inch		
	Min.	Nom.	Max.
A	—	0.354 BSC	—
B	—	0.276 BSC	—
C	—	0.354 BSC	—
D	—	0.276 BSC	—
E	—	0.0197 BSC	—
F	0.007	0.009	0.011
G	0.053	0.055	0.057
H	—	—	0.063
I	0.002	—	0.006
J	0.018	0.024	0.030
K	0.004	—	0.008
$\alpha$	0°	—	7°

Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	—	9.0 BSC	—
B	—	7.0 BSC	—
C	—	9.0 BSC	—
D	—	7.0 BSC	—
E	—	0.5 BSC	—
F	0.17	0.22	0.27
G	1.35	1.4	1.45
H	—	—	1.60
I	0.05	—	0.15
J	0.45	0.60	0.75
K	0.09	—	0.20
$\alpha$	0°	—	7°

## 64-pin LQFP (7mm×7mm) Outline Dimensions



Symbol	Dimensions in inch		
	Min.	Nom.	Max.
A	—	0.354 BSC	—
B	—	0.276 BSC	—
C	—	0.354 BSC	—
D	—	0.276 BSC	—
E	—	0.016 BSC	—
F	0.005	0.007	0.009
G	0.053	0.055	0.057
H	—	—	0.063
I	0.002	—	0.006
J	0.018	0.024	0.030
K	0.004	—	0.008
α	0°	—	7°

Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	—	9.0 BSC	—
B	—	7.0 BSC	—
C	—	9.0 BSC	—
D	—	7.0 BSC	—
E	—	0.4 BSC	—
F	0.13	0.18	0.23
G	1.35	1.4	1.45
H	—	—	1.60
I	0.05	—	0.15
J	0.45	0.60	0.75
K	0.09	—	0.20
α	0°	—	7°

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