HT32F65233
Datasheet

32-Bit Arm® Cortex®-M0+ BLDC Motor Microcontroller, 32 KB Flash and 8 KB SRAM with 2 Msps ADC, CMP, OPA, PGA, PDMA, DIV, UART, SPI, I²C, MCTM, GPTM, SCTM, BFTM, CRC, UID, LSTM and WDT

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1 General Description

The Holtek HT32F65233 device is a high performance, low power consumption 32-bit microcontroller based around an Arm® Cortex®-M0+ processor core. The Cortex®-M0+ is a next-generation processor core which is tightly coupled with Nested Vectored Interrupt Controller (NVIC), SysTick timer, and including advanced debug support.

The device operates at a frequency of up to 60 MHz with a Flash accelerator to obtain maximum efficiency. The device provides 32 KB of embedded Flash memory for code/data storage and 8 KB of embedded SRAM memory for system operation and application program usage. A variety of peripherals, such as Hardware Divider DIV, PDMA, ADC, OPA, PGA, CMP, I^2C, UART, SPI, MCTM, GPTM, SCTM, BFTM, CRC-16/32, 96-bit Unique ID, LSTM, WDT, SW-DP (Serial Wire Debug Port), etc., are also implemented in the device. Several power saving modes provide the flexibility for maximum optimization between wakeup latency and power consumption, an especially important consideration in low power applications.

The above features ensure that the device is suitable for use in BLDC applications such as hair dryers, range hoods, electric shavers, high-pressure pumps, fans and so on.

2 Features

Core

- 32-bit Arm® Cortex®-M0+ processor core
- Up to 60 MHz operating frequency
- Single-cycle multiplication
- Integrated Nested Vectored Interrupt Controller (NVIC)
- 24-bit SysTick timer

The Cortex®-M0+ processor is a very low gate count, highly energy efficient processor that is intended for microcontroller and deeply embedded applications that require an area optimized, low-power processor. The processor is based on the ARMv6-M architecture and supports Thumb® instruction sets, single-cycle I/O ports, hardware multiplier and low latency interrupt respond time.

On-Chip Memory

- 32 KB on-chip Flash memory for instruction/data and option byte storage
- 8 KB on-chip SRAM
- Supports multiple booting modes

The Arm® Cortex®-M0+ processor access and debug access share the single external interface to external AHB peripherals. The processor access takes priority over debug access. The maximum address range of the Cortex®-M0+ is 4 GB since it has a 32-bit bus address width. Additionally, a pre-defined memory map is provided by the Cortex®-M0+ processor to reduce the software complexity of repeated implementation by different device vendors. However, some regions are used by the Arm® Cortex®-M0+ system peripherals. Refer to the Arm® Cortex®-M0+ Technical Reference Manual for more information. Figure 2 in the Overview chapter shows the memory map of the device, 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 (ISP) and In Application Programming (IAP)
- Flash protection capability to prevent illegal access

The Flash Memory Controller, FMC, provides all the necessary functions, pre-fetch buffer and branch cache 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 is provided for the Flash Memory in order to reduce the CPU waiting time which will cause CPU instruction execution delays. Flash Memory word programming/page erase functions are also provided.

Reset Control Unit – RSTCU

- Supply supervisor
  - Power On Reset / Power Down Reset – POR / PDR
  - 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 external signals, internal events and the reset generators.

Clock Control Unit – CKCU

- Internal 8 MHz RC oscillator trimmed to ±2 % accuracy at 5.0 V operating voltage and 25 ºC 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 Low Speed Internal RC oscillator (LSI), a Phase Lock Loop (PLL), clock pre-scalers, clock multiplexers, APB clock divider and gating circuitry. The AHB, APB and Cortex®-M0+ clocks are derived from the system clock (CK_SYS) which can come from HSI, LSI or system PLL. The Watchdog Timer (WDT) and Low Speed Timer (LSTM) use the LSI as their clock source.

Power Management – PWRCU

- Single V_{DD} power supply: 2.5 V to 5.5 V
- Integrated 1.5 V LDO regulator for MCU core, peripherals and memories power supply
- Two power domains: V_{DD} and V_{CORE}
- Two power saving modes: Sleep and Deep-Sleep modes

Power consumption can be regarded as one of the most important issues for many embedded system applications. Accordingly the Power Control Unit, PWRCU, in the device provides two types of power saving modes such as Sleep and Deep-Sleep modes. 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 8 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 edges
- 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 8 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 A/D engines
- Up to 2 Msps conversion rate
- Up to 12 external analog input channels

A 12-bit multi-channel Analog to Digital Converter is integrated in the device. There are multiplexed channels, which include 12 external channels on which the external analog signal can be supplied and 1 internal channels. If the input voltage is required to remain within a specific threshold window, the Analog Watchdog function will monitor and detect the signals. An interrupt will then be generated to inform the device that the input voltage is higher or lower than the preset thresholds. There are three conversion modes to convert an analog signal to digital data. The A/D conversion can be operated in one shot, continuous and discontinuous conversion mode.

Programmable Gain Amplifier – PGA

- Each programmable gain amplifier has fixed dedicated I/O pins
- Internal output path to A/D converter or comparator
- 5-bit scaler can be configurable for input offset calibration

The PGA has dedicated input/output pins, which are the input pair of PGAnN and PGAnP, and an analog output pin of PGAnO. The analog output signals can also be connected internally to the ADC analog channels or the Comparator positive input.

Operational Amplifier – OPA

- Fixed dedicated I/O pins
- Internal output paths to the A/D converter or comparator
- Input offset calibration

An operational amplifier is integrated in the device.

Comparator – CMP

- Two Rail-to-rail comparators
- Each comparator has configurable negative or positive inputs used for flexible voltage selection
  - Dedicated I/O pins
  - Internal voltage reference provided by 8-bit scaler – For CMP0 only
  - Internal operational amplifier output
- Programmable hysteresis
- Programmable respond speed and power consumption
- Comparator output can be routed to I/O pin, to multiple timer or ADC trigger input
- 8-bit scaler can be configurable to dedicated I/O for voltage reference

- Configurable inverting input from CMP0N, CMP1N or CVREF
- Interrupt generation capability with wakeup from Sleep or Deep-Sleep mode through the EXTI controller

Two general purpose comparators, CMP, are implemented within the device. They can be configured either as standalone comparators or combined with the different kinds of peripheral IP. Each comparator is capable of asserting interrupts to the NVIC or waking up the CPU from the Sleep or Deep-Sleep mode through the EXTI wakeup event management unit.

I/O Ports – GPIO

- Up to 28 GPIOs
- Port A, B, C are mapped to 8-line EXTI interrupts
- Almost I/O pins are configurable output driving current

There are up to 28 General Purpose I/O pins, GPIO, named PA0 ~ PA15, PB0 ~ PB3, PB6 ~ PB8, PC1 ~ PC3 and PC10 ~ PC11 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 (AFs) 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.

Motor Control Timer – MCTM

- 16-bit up, down, up/down auto-reload counter
- Up to 4 independent channels
- 16-bit programmable prescaler that allows division of the prescaler clock source by any factor between 1 and 65536 to generate the counter clock frequency
- Compare Match Output
- PWM waveform generation with edge-aligned and center-aligned counting modes
- Single Pulse Mode Output
- Complementary Outputs with programmable dead-time insertion
- Break input to force the timer's output signals into a reset state or in a known state

The Motor Control Timer Module, MCTM, consists of a single 16-bit up/down counter, four 16-bit Compare Registers (CCRs), one 16-bit Counter-Reload Register (CRR), one 8-bit repetition counter and several control/status registers. It can be used for a variety of purposes which include output waveform generation for signals such as compare match outputs, PWM outputs or complementary PWM outputs with dead-time insertion. The MCTM is capable of offering full functional support for motor control, hall sensor interfacing and break input.

General-Purpose Timer – GPTM

- 16-bit up, down, up/down auto-reload counter
- Up to 4 independent channels
- 16-bit programmable prescaler that allows division of the prescaler clock source by any factor between 1 and 65536 to generate the counter clock frequency
- 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 quadrature decoder and Pulse/Direction Mode
- Master/Slave mode controller

The General-Purpose Timer, GPTM, 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. It can be used for a variety of purposes including general timer, input signal pulse width measurement, output waveform generation such as single pulse generation or PWM outputs. The GPTM also supports an encoder interface using a quadrature decoder with two inputs.

Single Channel Timer – SCTM

- 16-bit auto-reload up-counter
- 16-bit programmable prescaler that allows division of the prescaler clock source by any factor between 1 and 65536 to generate the counter clock frequency
- Input Capture function
- Compare Match Output
- PWM waveform generation with edge-aligned counting mode

The Single Channel Timer, SCTM, consists of one 16-bit up-counter, one 16-bit Channel 0 Capture / Compare Register (CH0CCR), one 16-bit Counter-Reload Register (CRR), one 16-bit Channel 1 Capture Register (CH1CCR) and several control/status registers. It can be used for a variety of purposes including general timer, input signal pulse width measurement or output waveform generation such as PWM outputs.

Basic Function Timer – BFTM

- 16-bit compare match up-counter – no I/O control
- One shot mode – stops counting when compare match occurs
- Repetitive mode – restarts counter when compare match occurs

The Basic Function Timer, BFTM, is a simple 16-bit up-counting counter designed to measure time intervals, generate one shot pulses or generate repetitive interrupts. The BFTM can operate in two modes which are repetitive and one shot modes. In the repetitive mode, the counter is restarted at each compare match event. The BFTM also supports a one shot mode which will force the counter to stop counting when a compare match event occurs.

Watchdog Timer – WDT

- 12-bit down-counter with a 3-bit prescaler
- Provides reset to the system
- Programmable watchdog timer window function
- Registers write protection function

The Watchdog Timer is a hardware timing circuitry that can be used to detect a system lock-up due to software trapped in a deadlock. It includes a 12-bit count-down counter, a prescaler, a WDT delta value register, WDT operation control circuitry and a WDT protection mechanism. If the software does not reload the counter value before a Watchdog Timer underflow occurs, a reset will be generated when the counter underflows. In addition, a reset is also generated if the software reloads the counter before it reaches a delta value. It means that the counter reload must occur when the Watchdog timer value has a value within a limited window using a specific method. The Watchdog Timer counter can be stopped when the processor is in the debug mode. The register write protection function can be enabled to prevent an unexpected change in the Watchdog timer configuration.

Low Speed Timer – LSTM

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

The Low Speed Timer, LSTM, circuitry includes the APB interface, a 24-bit count-up counter, a control register, a prescaler, a compare register and a status register. The LSTM circuits are located in the V_{CORE} power domain. When the device enters the power-saving mode, the LSTM counter is used as a wakeup timer to let the system resume from the power saving mode.

Inter-integrated Circuit – I²C

- Supports both master and slave modes with a frequency of up to 1 MHz
- Supports 7-bit addressing mode and general call addressing
- Supports two 7-bit slave addresses

The I²C module is an internal circuit allowing communication with an external I²C interface which is an industry standard two-wire 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 I²C module provides three data transfer rates: 100 kHz in the Standard mode; 400 kHz in the Fast mode; 1 MHz in the Fast plus mode. The SCL period generation registers are used to set different kinds of duty cycle implementation for the SCL pulse.

The SDA line which is connected directly to the I²C bus is a bidirectional data line between the master and slave devices and is used for data transmission and reception.

Serial Peripheral Interface – SPI

- Supports both master and slave modes
- Frequency of up to (f_{PCLK}/2) MHz for master mode and (f_{PCLK}/3) MHz for slave mode
- FIFO Depth: 4 levels

The Serial Peripheral Interface, SPI, provides an SPI protocol data transmit and receive function in both master and slave modes. The SPI interface uses 4 pins, among which are 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 streamlined 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.

Universal Asynchronous Receiver Transmitter – UART

- Asynchronous serial communication operating baud-rate clock frequency up to (f_{PCLK}/16) MHz
- Full duplex communication capability
- Supports LIN (Local Interconnect Network) mode
- Supports single-wire mode
- 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 bits generation
  - Bit order: LSB-first or MSB-first transfer
- Error detection: Parity, overrun and frame error

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 Line Status Interrupt. The software can detect a UART error status by reading the UART Status & Interrupt Flag Register, URSIFR. 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.

Cyclic Redundancy Check – CRC

- Supports CRC16 polynomial: 0x8005,

  $X^{16} + X^{15} + X^2 + 1$
- Supports CCITT CRC16 polynomial: 0x1021,

  $X^{16} + X^{12} + X^5 + 1$
- Supports 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 and is used to verify data transmission or storage data correctness. A CRC calculation takes a data stream or a block of data as its input and generates a 16-bit 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 the data stream contains a data error.

Peripheral Direct Memory Access – PDMA

- 6 channels with trigger source grouping
- 8-bit, 16-bit and 32-bit width data transfer
- Supports linear address, circular address and fixed address modes
- 4-level programmable channel priority
- Auto reload mode
- Supports trigger sources:

  ADC, UART, GPTM, SCTM and software request

The Peripheral Direct Memory Access circuitry, 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 connect each data movement operation.

Hardware Divider – DIV

- Signed/unsigned 32-bit divider
- Calculate in 8 clock cycles, load in 1 clock cycle
- Division by zero error flag

The divider is the truncated division and requires a software triggered start signal by controlling the "START" bit in the control register. The divider calculation complete flag will be set to 1 after 8 clock cycles, however, if the divisor register data is zero during the calculation, the division by zero error flag will be set to 1.

Unique Identifier – UID

- Total 96-bit UID is unique and not duplicate with other HT32 MCU devices
- It is unchangeable and determined by MCU manufacturer

Debug Support

- Serial Wire Debug Port – SW-DP
- 4 comparators for hardware breakpoint or code / literal patch
- 2 comparators for hardware watch points

Package and Operation Temperature

- 24-pin SSOP and 32-pin QFN packages
- Operation temperature: -40 °C to 105 °C

3 Overview

Device Information

Table 1. Features and Peripheral List

Peripherals		HT32F65233
Main Flash (KB)		31
Option Bytes Flash (KB)		1
SRAM (KB)		8
Timers	MCTM	1
	GPTM	1
	SCTM	2
	BFTM	2
	WDT	1
	LSTM	1
Communication	UART	1
	SPI	1
	I^2C	1
PDMA		6 channels
Hardware Divider		1
CRC-16/32		1
EXTI		8
12-bit 2 Msps ADC		1
Number of channels		12 external channels
CMP		2
Programmable Gain Amplifier		2
Operational Amplifier		1
GPIO		Up to 28
CPU frequency		Up to 60 MHz
Operating voltage		2.5 V ~ 5.5 V
Operating temperature		-40 °C ~ 105 °C
Package		24-pin SSOP and 32-pin QFN

Block Diagram

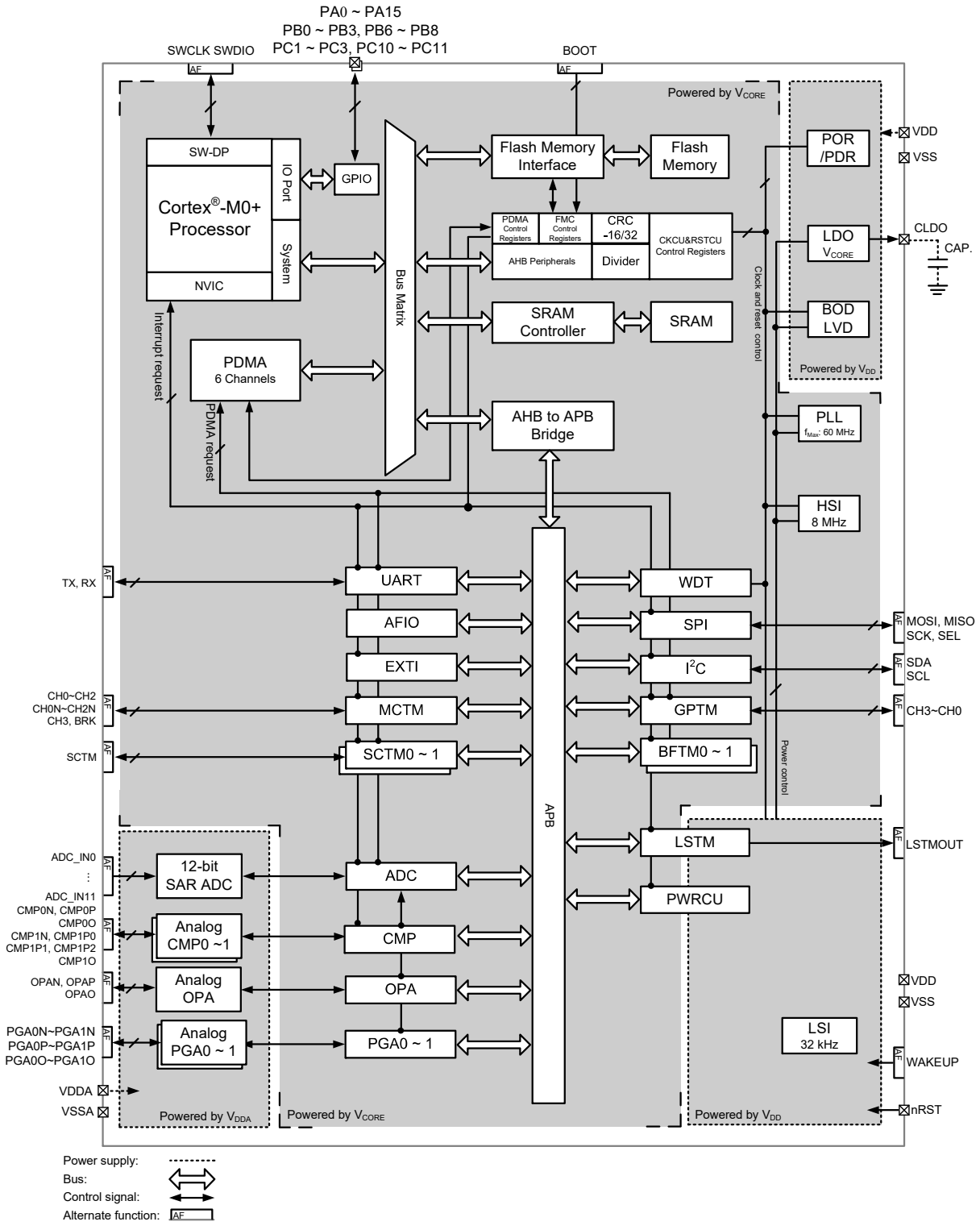


Figure 1. Block Diagram

Memory Map

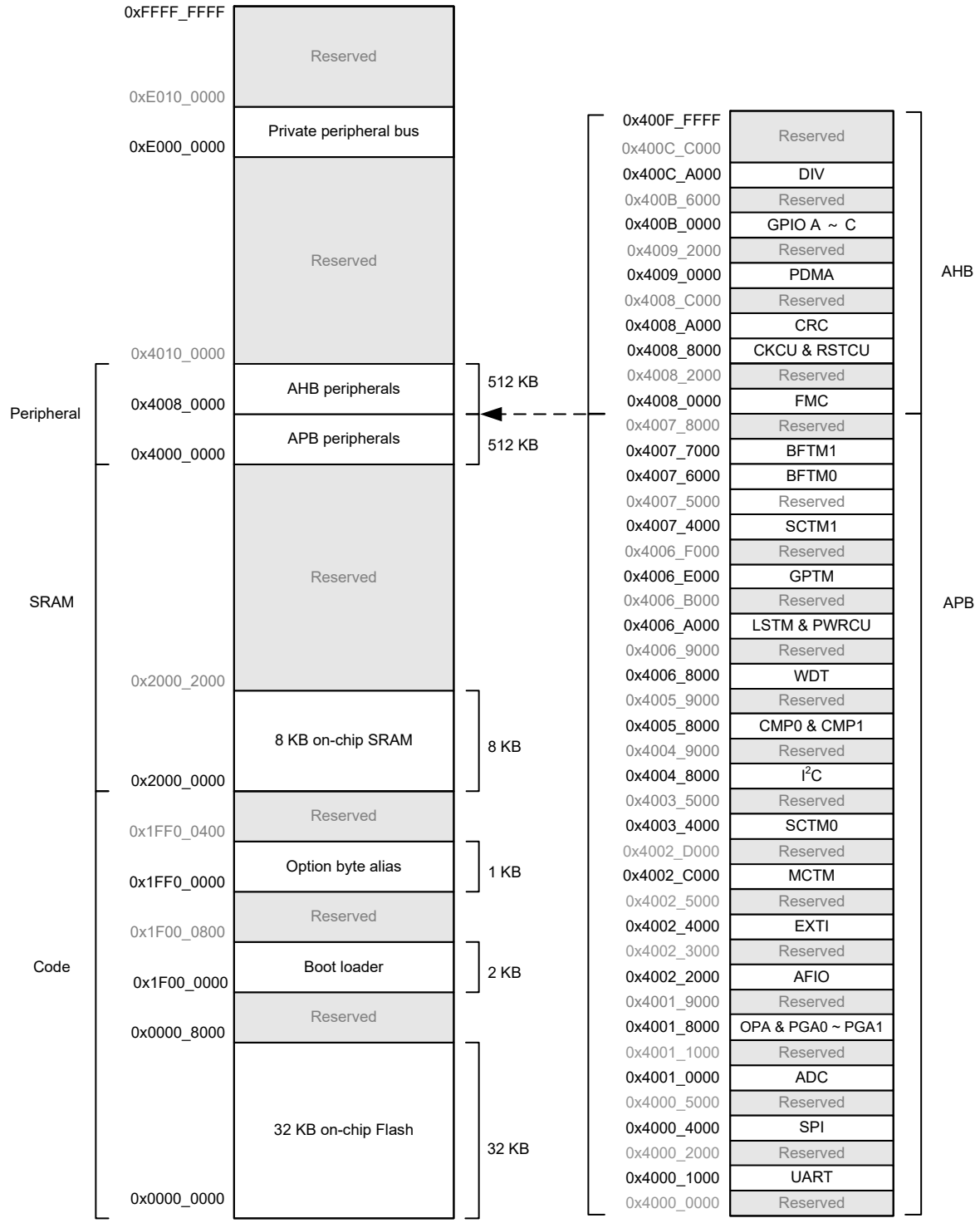


Figure 2. Memory Map

Table 2. Register Map

Start Address	End Address	Peripheral	Bus
0x4000_0000	0x4000_0FFF	Reserved	APB
0x4000_1000	0x4000_1FFF	UART	
0x4000_2000	0x4000_3FFF	Reserved	
0x4000_4000	0x4000_4FFF	SPI	
0x4000_5000	0x4000_FFFF	Reserved	
0x4001_0000	0x4001_0FFF	ADC	
0x4001_1000	0x4001_7FFF	Reserved	
0x4001_8000	0x4001_8FFF	OPA & PGA0 ~ PGA1	
0x4001_9000	0x4002_1FFF	Reserved	
0x4002_2000	0x4002_2FFF	AFIO	
0x4002_3000	0x4002_3FFF	Reserved	
0x4002_4000	0x4002_4FFF	EXTI	
0x4002_5000	0x4002_BFFF	Reserved	
0x4002_C000	0x4002_CFFF	MCTM	
0x4002_D000	0x4003_3FFF	Reserved	
0x4003_4000	0x4003_4FFF	SCTM0	
0x4003_5000	0x4004_7FFF	Reserved	
0x4004_8000	0x4004_8FFF	I^2C	
0x4004_9000	0x4005_7FFF	Reserved	
0x4005_8000	0x4005_8FFF	CMP0 & CMP1	
0x4005_9000	0x4006_7FFF	Reserved	
0x4006_8000	0x4006_8FFF	WDT	
0x4006_9000	0x4006_9FFF	Reserved	
0x4006_A000	0x4006_AFFF	LSTM & PWRCU	
0x4006_B000	0x4006_DFFF	Reserved	
0x4006_E000	0x4006_EFFF	GPTM	
0x4006_F000	0x4007_3FFF	Reserved	
0x4007_4000	0x4007_4FFF	SCTM1	
0x4007_5000	0x4007_5FFF	Reserved	
0x4007_6000	0x4007_6FFF	BFTM0	
0x4007_7000	0x4007_7FFF	BFTM1	
0x4007_8000	0x4007_FFFF	Reserved	

Start Address	End Address	Peripheral	Bus
0x4008_0000	0x4008_1FFF	FMC	AHB
0x4008_2000	0x4008_7FFF	Reserved	
0x4008_8000	0x4008_9FFF	CKCU & RSTCU	
0x4008_A000	0x4008_BFFF	CRC	
0x4008_C000	0x4008_FFFF	Reserved	
0x4009_0000	0x4009_1FFF	PDMA	
0x4009_2000	0x400A_FFFF	Reserved	
0x400B_0000	0x400B_1FFF	GPIO A	
0x400B_2000	0x400B_3FFF	GPIO B	
0x400B_4000	0x400B_5FFF	GPIO C	
0x400B_6000	0x400C_9FFF	Reserved	
0x400C_A000	0x400C_BFFF	DIV	
0x400C_C000	0x400F_FFFF	Reserved	

Clock Structure

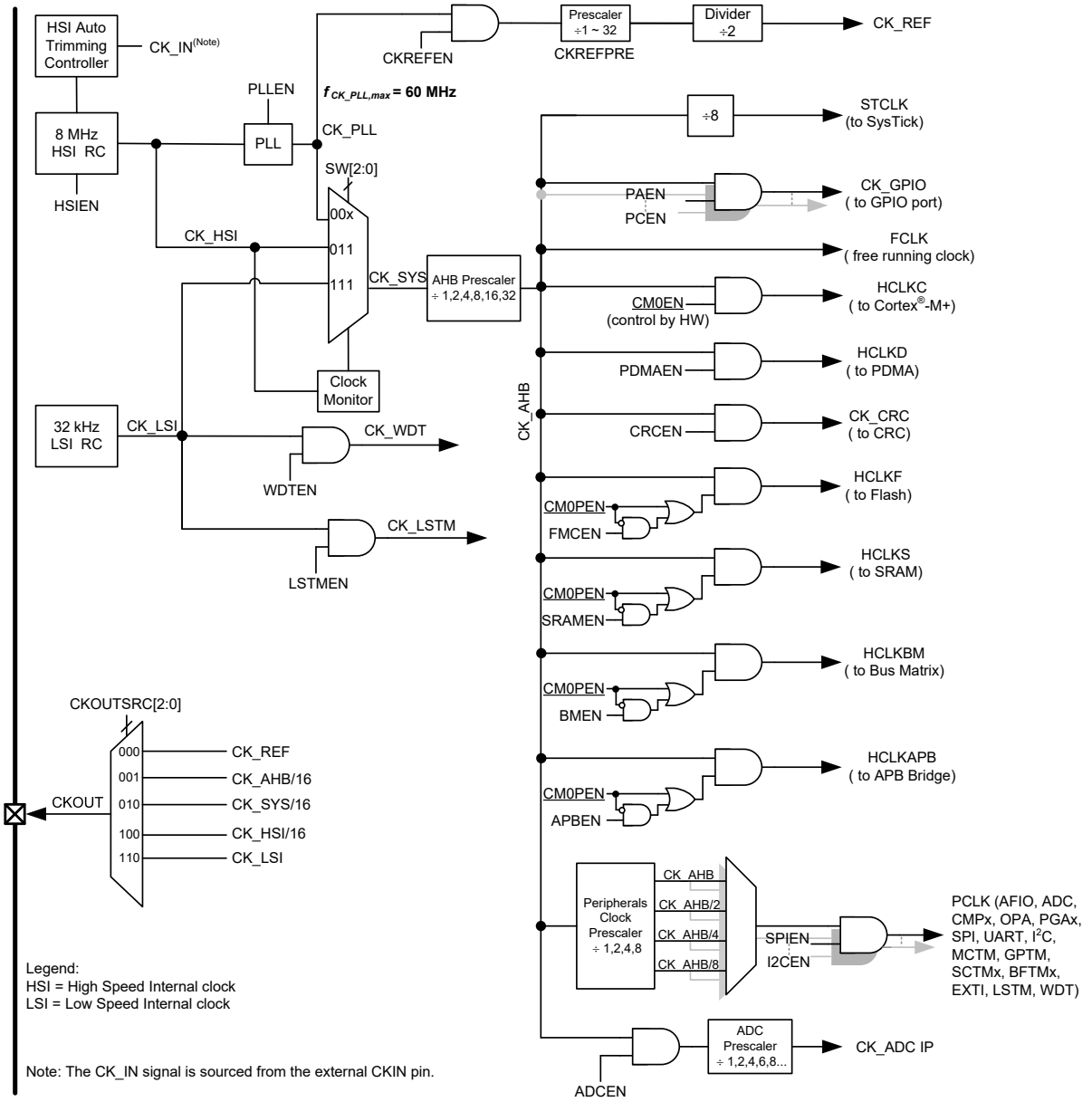


Figure 3. Clock Structure

4 Pin Assignment

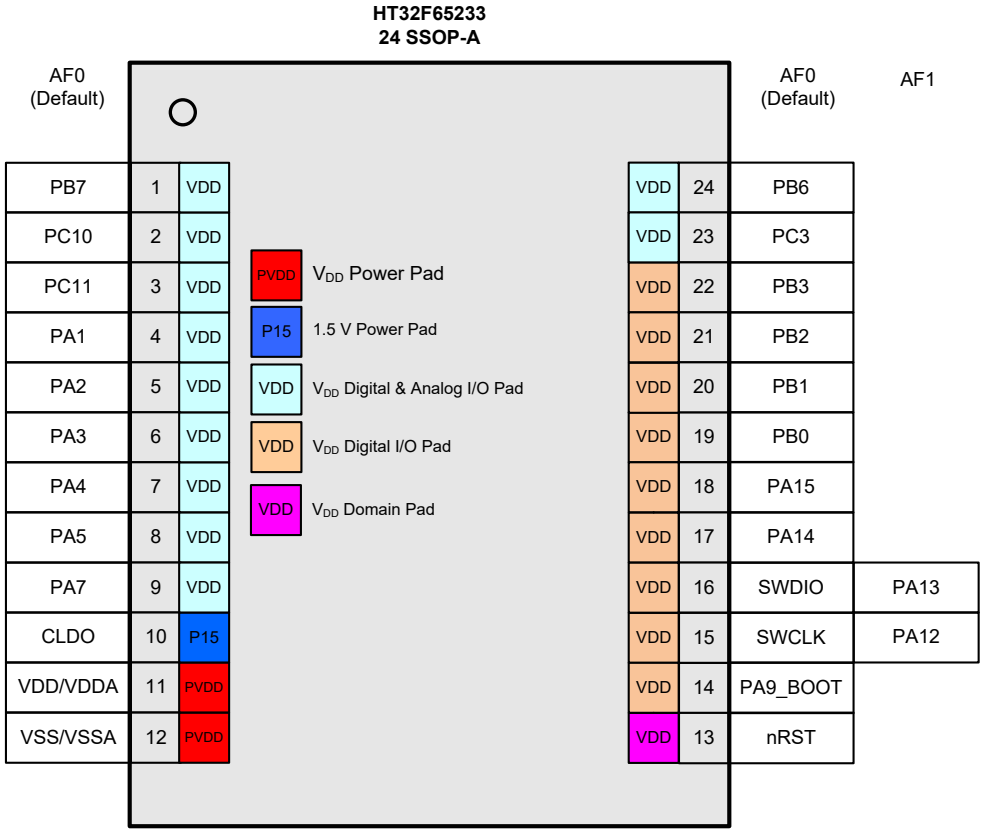


Figure 4. 24-pin SSOP Pin Assignment

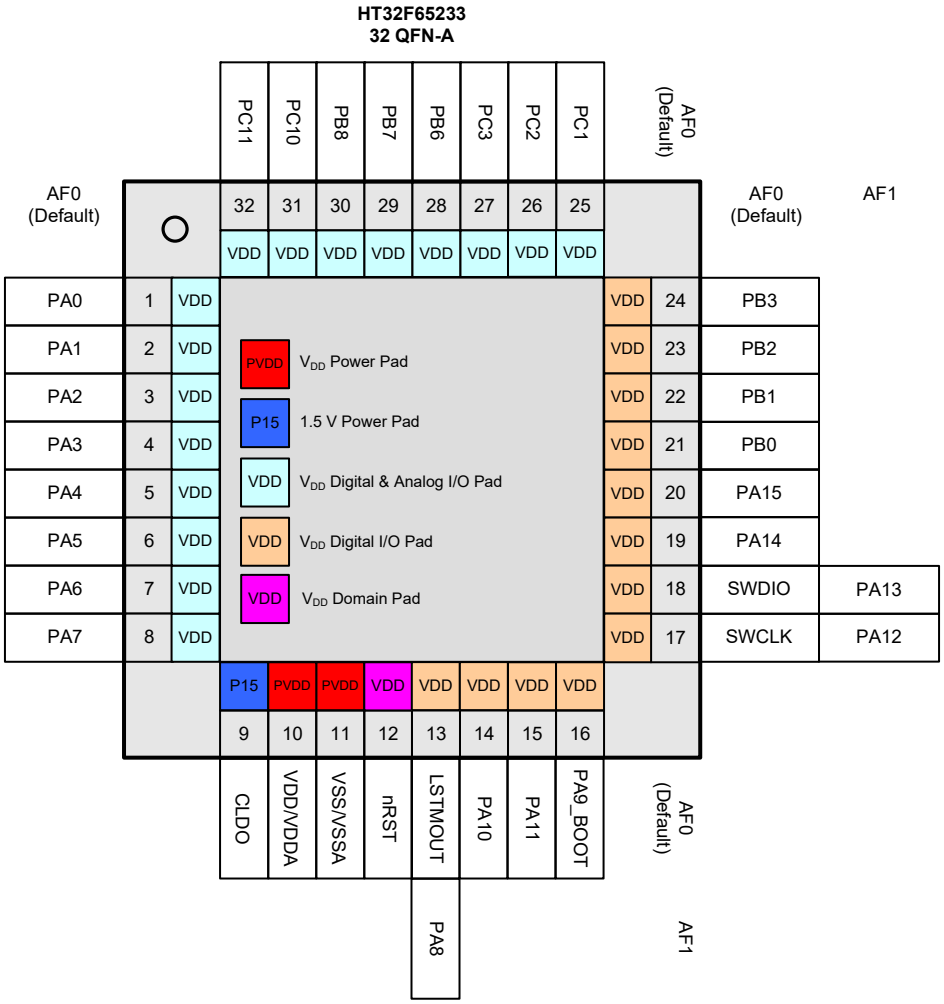


Figure 5. 32-pin QFN Pin Assignment

Table 3. Pin Assignment

Package		Alternate Function Mapping															
		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
32 QFN	24 SSOP	System Default	GPIO	ADC	CMP	GPTM /MCTM	SPI	UART	I²C	PGA /OPA	SCTM	N/A	N/A	N/A	MCTM	MCTM	MCTM / System Other
1		PA0		ADC_IN7		GT_CH2	SPI_MISO		I2C_SDA	PGA0O	SCTM1						
2	4	PA1		ADC_IN6		GT_CH0	SPI_MOSI		I2C_SCL	PGA0N							
3	5	PA2		ADC_IN5		GT_CH1	SPI_SCK	UR_RX	I2C_SDA	PGA0P	SCTM0						
4	6	PA3		ADC_IN4	CMP1P0	GT_CH0	SPI_SEL	UR_TX	I2C_SCL		SCTM1						
5	7	PA4		ADC_IN3	CMP1P1	GT_CH1	SPI_MISO	UR_RX	I2C_SCL		SCTM0						
6	8	PA5		ADC_IN2	CMP1P2	GT_CH2	SPI_MOSI	UR_TX	I2C_SDA		SCTM1						
7		PA6		ADC_IN1	CMP1N	GT_CH3	SPI_SCK				SCTM1						
8	9	PA7		ADC_IN0	CMP1O	MT_BRK	SPI_SEL				SCTM0						VBG
9	10	CLDO															
10	11	VDD/VDDA															
11	12	VSS/VSSA															
12	13	nRST															
13		LSTMOUT	PA8			GT_CH2	SPI_SEL	UR_TX			SCTM0						WAKEUP
14		PA10				GT_CH3	SPI_MOSI	UR_RX			SCTM1						
15		PA11				GT_CH0	SPI_MISO	UR_TX									
16	14	PA9_BOOT				MT_BRK	SPI_SCK	UR_RX							MT_CH2	MT_CH0	CKOUT
17	15	SWCLK	PA12			MT_BRK	SPI_MISO	UR_TX	I2C_SCL		SCTM1						
18	16	SWDIO	PA13			MT_CH3	SPI_MOSI	UR_RX	I2C_SDA		SCTM0						
19	17	PA14				MT_CH2N									MT_CH2		MT_CH2N
20	18	PA15				MT_CH2									MT_CH2N	MT_CH1	MT_CH1N
21	19	PB0				MT_CH1N									MT_CH1	MT_CH0	MT_CH0N
22	20	PB1				MT_CH1									MT_CH1N	MT_CH2	MT_CH2N
23	21	PB2				MT_CH0N									MT_CH0	MT_CH1	MT_CH2N
24	22	PB3				MT_CH0									MT_CH0N	MT_CH2N	MT_CH2
25		PC1		ADC_IN11	CMP0N	MT_BRK	SPI_SCK	UR_RX	I2C_SDA								
26		PC2		ADC_IN10	CMP0P	MT_CH3	SPI_SEL										
27	23	PC3		ADC_IN9	CMP0O	GT_CH0	SPI_MOSI	UR_TX	I2C_SCL	OPAO							
28	24	PB6				GT_CH1	SPI_MISO	UR_RX	I2C_SDA	OPAN	SCTM1						
29	1	PB7				GT_CH2	SPI_MOSI	UR_TX	I2C_SCL	OPAP	SCTM1						
30		PB8		ADC_IN8	CMP0O	MT_CH3		UR_TX	I2C_SDA	PGA1O	SCTM0						
31	2	PC10				GT_CH0		UR_RX		PGA1N							
32	3	PC11				GT_CH1	SPI_MISO		I2C_SCL	PGA1P	SCTM0						CKIN

Table 4. Pin Description

Pin Number		Pin Name	Type(1)	I/O Structure(2)	Output Driving	Description
32QFN	24SSOP					Default Function (AF0)
1		PA0	AI/O	5V	4/8/12/16 mA	PA0
2	4	PA1	AI/O	5V	4/8/12/16 mA	PA1
3	5	PA2	AI/O	5V	4/8/12/16 mA	PA2
4	6	PA3	AI/O	5V	4/8/12/16 mA	PA3
5	7	PA4	AI/O	5V	4/8/12/16 mA	PA4, this pin provides a UART_RX function in the Boot loader mode.
6	8	PA5	AI/O	5V	4/8/12/16 mA	PA5, this pin provides a UART_TX function in the Boot loader mode.
7		PA6	AI/O	5V	4/8/12/16 mA	PA6
8	9	PA7	AI/O	5V	4/8/12/16 mA	PA7
9	10	CLDO	P	—	—	Core power LDO V_{CORE} output It is recommended to connect a 2.2 μF capacitor as close as possible between this pin and VSS
10	11	VDD/VDDA	P	—	—	Digital and analog voltage input
11	12	VSS/VSSA	P	—	—	Ground reference
12	13	nRST(3)	I	5V_PU	—	External reset pin
13		PA8	I/O	5V	4/8/12/16 mA	PA8
14		PA10	I/O	5V	4/8/12/16 mA	PA10
15		PA11	I/O	5V	4/8/12/16 mA	PA11
16	14	PA9	I/O	5V_PU	4/8/12/16 mA	PA9_BOOT
17	15	PA12	I/O	5V_PU	4/8/12/16 mA	SWCLK
18	16	PA13	I/O	5V_PU	4/8/12/16 mA	SWDIO
19	17	PA14	I/O	5V	4/8/12/16 mA	PA14
20	18	PA15	I/O	5V	4/8/12/16 mA	PA15
21	19	PB0	I/O	5V	4/8/12/16 mA	PB0
22	20	PB1	I/O	5V	4/8/12/16 mA	PB1
23	21	PB2	I/O	5V	4/8/12/16 mA	PB2
24	22	PB3	I/O	5V	4/8/12/16 mA	PB3
25		PC1	AI/O	5V	4/8/12/16 mA	PC1
26		PC2	AI/O	5V	4/8/12/16 mA	PC2
27	23	PC3	AI/O	5V	4/8/12/16 mA	PC3
28	24	PB6	AI/O	5V	4/8/12/16 mA	PB6
29	1	PB7	AI/O	5V	4/8/12/16 mA	PB7
30		PB8	AI/O	5V	4/8/12/16 mA	PB8
31	2	PC10	I/O	5V	4/8/12/16 mA	PC10
32	3	PC11	I/O	5V	4/8/12/16 mA	PC11

Note: 1. I = input, O = output, A = Analog port, P = Power Supply, V_{DD} = V_{DD} Power.

2. 5V = 5 V operation I/O type, PU = Pull-up.

3. These pins are located at the V_{DD} power domain.

4. In the Boot loader mode, the UART interface can be used for communication.

5 Electrical Characteristics

Power Supply Scheme

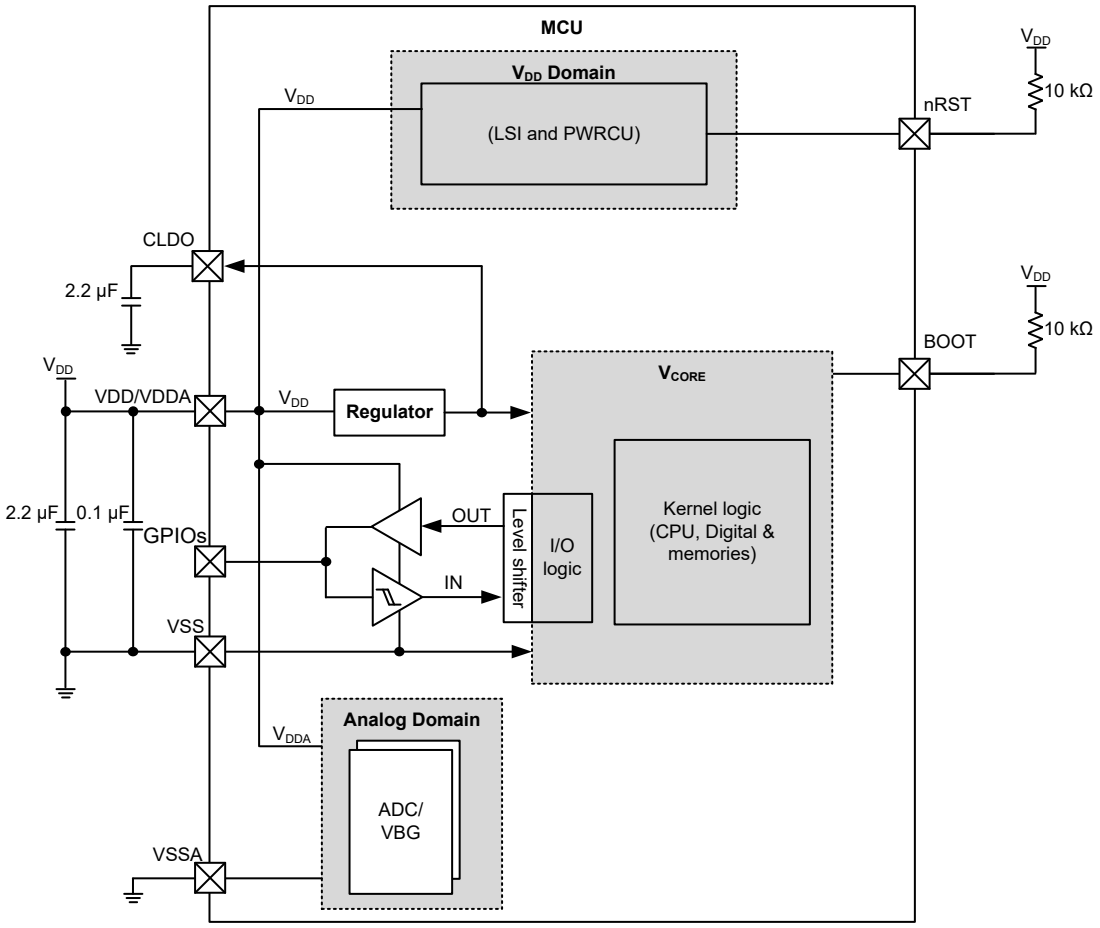


Figure 6. Power Supply Scheme

Note: 1. All regulator capacitors must be placed as close to the MCU as possible.
2. It is recommended that the pull-up resistor of the BOOT pin is 10 kΩ.
3. It is recommended that the pull-up resistor of the nRST pin is 10 kΩ.

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 5. Absolute Maximum Ratings

Symbol	Parameter	Min.	Max.	Unit
V_{DD}	External Main Supply Voltage	V_{SS} - 0.3	V_{SS} + 5.5	V
V_{DDA}	External Analog Supply Voltage	V_{SSA} - 0.3	V_{SSA} + 5.5	V
V_{IN}	Input Voltage on I/O	V_{SS} - 0.3	V_{DD} + 0.3	V
T_A	Ambient Operating Temperature Range	-40	105	°C
T_{STG}	Storage Temperature Range	-60	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 6. Recommended DC Operating Conditions

T_A = 25 °C, unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{DD}	Operating Voltage	—	2.5	5.0	5.5	V
V_{DDA}	Analog Operating Voltage	—	2.5	5.0	5.5	V

On-Chip LDO Voltage Regulator Characteristics

Table 7. LDO Characteristics

T_A = 25 °C, unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{LDO}	Internal Regulator Output Voltage	V_{DD} ≥ 2.5 V Regulator input @ I_{LDO} = 20 mA and voltage variation = ±5 %, After trimming	1.38	1.5	1.62	V
I_{LDO}	Output Current	V_{DD} = 2.5 V Regulator input @ V_{LDO} = 1.5 V	—	30	35	mA
C_{LDO}	External Filter Capacitor Value for Internal Core Power Supply	The capacitor value is dependent on the core power current consumption	1	2.2	—	μF

Power Consumption

The current consumption is influenced by several parameters and factors, including the operating voltage, ambient temperature, I/O pin loading, device software configuration, operating frequencies, I/O pin switching rate, program location in memory and executed binary code.

The MCU is configured under the following conditions for current consumption measured:

- All I/O pins are set to a high-impedance (floating) state.
- All peripherals are disabled unless specifically stated otherwise.
- The Flash memory access time is optimized using the minimum wait states number, depending on the f_{HCLK} frequency.
- When the peripherals are enabled, $f_{PCLK} = f_{HCLK}$.

Table 8. Power Consumption Characteristics

T_A = 25 °C, unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
I_{DD}	Supply Current (Run Mode)	V_{DD} = 5.0 V, HSI = 8 MHz, PLL = 60 MHz, f_{HCLK} = 60 MHz, f_{PCLK} = 60 MHz, all peripherals enabled	—	10.9	—	mA
		V_{DD} = 5.0 V, HSI = 8 MHz, PLL = 60 MHz, f_{HCLK} = 60 MHz, f_{PCLK} = 60 MHz, all peripherals disabled	—	6.7	—	mA
		V_{DD} = 5.0 V, HSI = 8 MHz, PLL = 40 MHz, f_{HCLK} = 40 MHz, f_{PCLK} = 40 MHz, all peripherals enabled	—	9.6	—	mA
		V_{DD} = 5.0 V, HSI = 8 MHz, PLL = 40 MHz, f_{HCLK} = 40 MHz, f_{PCLK} = 40 MHz, all peripherals disabled	—	9.6	—	mA
		V_{DD} = 5.0 V, HSI = 8 MHz, PLL = 20 MHz, f_{HCLK} = 20 MHz, f_{PCLK} = 20 MHz, all peripherals enabled	—	6.7	—	mA
		V_{DD} = 5.0 V, HSI = 8 MHz, PLL = 20 MHz, f_{HCLK} = 20 MHz, f_{PCLK} = 20 MHz, all peripherals disabled	—	3.1	—	mA
		V_{DD} = 5.0 V, HSI = 8 MHz, PLL off, f_{HCLK} = 8 MHz, f_{PCLK} = 8 MHz, all peripherals enabled	—	1.9	—	mA
		V_{DD} = 5.0 V, HSI = 8 MHz, PLL off, f_{HCLK} = 8 MHz, f_{PCLK} = 8 MHz, all peripherals disabled	—	1.3	—	mA
		V_{DD} = 5.0 V, HSI off, PLL off, LSI on, f_{HCLK} = 32 kHz, f_{PCLK} = 32 kHz, all peripherals enabled	—	34	—	μA
		V_{DD} = 5.0 V, HSI off, PLL off, LSI on, f_{HCLK} = 32 kHz, f_{PCLK} = 32 kHz, all peripherals disabled	—	31.6	—	μA
	Supply Current (Sleep Mode)	V_{DD} = 5.0 V, HSI = 8 MHz, PLL = 60 MHz, f_{HCLK} = 0 MHz, f_{PCLK} = 60 MHz, all peripherals enabled	—	6	—	mA
		V_{DD} = 5.0 V, HSI = 8 MHz, PLL = 60 MHz, f_{HCLK} = 0 MHz, f_{PCLK} = 60 MHz, all peripherals disabled	—	1	—	mA
		V_{DD} = 5.0 V, HSI = 8 MHz, PLL = 40 MHz, f_{HCLK} = 0 MHz, f_{PCLK} = 40 MHz, all peripherals enabled	—	4.1	—	mA
		V_{DD} = 5.0 V, HSI = 8 MHz, PLL = 40 MHz, f_{HCLK} = 0 MHz, f_{PCLK} = 40 MHz, all peripherals disabled	—	0.8	—	mA
		V_{DD} = 5.0 V, HSI = 8 MHz, PLL = 20 MHz, f_{HCLK} = 0 MHz, f_{PCLK} = 20 MHz, all peripherals enabled	—	2.4	—	mA
		V_{DD} = 5.0 V, HSI = 8 MHz, PLL = 20 MHz, f_{HCLK} = 0 MHz, f_{PCLK} = 20 MHz, all peripherals disabled	—	0.6	—	mA
		V_{DD} = 5.0 V, HSI = 8 MHz, PLL off, f_{HCLK} = 0 MHz, f_{PCLK} = 8 MHz, all peripherals enabled	—	1	—	mA
		V_{DD} = 5.0 V, HSI = 8 MHz, PLL off, f_{HCLK} = 0 MHz, f_{PCLK} = 8 MHz, all peripherals disabled	—	0.26	—	mA
	Supply Current (Deep-Sleep Mode)	V_{DD} = 5.0 V, all clock off (HSI), LDO in low power mode, LSI on, LSTM on	—	27.3	—	μA

Note: 1. HSI means 8 MHz high speed internal oscillator.
2. LSI means 32 kHz low speed internal oscillator.
3. Code = while (1) {208 NOP} executed in Flash.

Reset and Supply Monitor Characteristics

Table 9. V_{DD} Power Reset Characteristics

T_A = 25 °C, unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{POR}	Power On Reset Threshold (Rising Voltage on V_{DD})	T_A = -40 °C ~ 105 °C	2.22	2.35	2.48	V
V_{PDR}	Power Down Reset Threshold (Falling Voltage on V_{DD})		2.12	2.20	2.33	V
$V_{PORHYST}$	POR Hysteresis	—	—	150	—	mV
t_{POR}	Reset Delay Time	V_{DD} = 5.0 V	—	0.1	0.2	ms

Note: 1. Data based on characterization results only, not tested in production.

2. If the LDO is turned on, the V_{DD} POR has to be in the de-assertion condition. When the V_{DD} POR is in the assertion state then the LDO will be turned off.

Table 10. LVD / BOD Characteristics

T_A = 25 °C, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_{BOD}	Voltage of Brown-Out Detection	T_A = -40 °C ~ 105 °C, After factory-trimmed V_{DD} Falling edge		2.37	2.45	2.53	V
V_{LVD}	Voltage of Low Voltage Detection	V_{DD} Falling edge	LVDS = 000	2.57	2.65	2.73	V
			LVDS = 001	2.77	2.85	2.93	V
			LVDS = 010	2.97	3.05	3.13	V
			LVDS = 011	3.17	3.25	3.33	V
			LVDS = 100	3.37	3.45	3.53	V
			LVDS = 101	4.15	4.25	4.35	V
			LVDS = 110	4.35	4.45	4.55	V
			LVDS = 111	4.55	4.65	4.75	V
$V_{LVDHTST}$	LVD Hysteresis	V_{DD} = 5.0 V	—	—	100	—	mV
t_{suLVD}	LVD Setup Time	V_{DD} = 5.0 V	—	—	—	5	μs
t_{atLVD}	LVD Active Delay Time	V_{DD} = 5.0 V	—	—	200	—	μs
I_{DDLVD}	Operation Current (2)	V_{DD} = 5.0 V	—	—	10	20	μA

Note: 1. Data based on characterization results only, not tested in production.

2. Bandgap current is not included.

3. LVDS field is in the PWRCU LVDCSR register.

Internal Clock Characteristics

Table 11. High Speed Internal Clock (HSI) Characteristics

T_A = 25 °C, unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{DD}	Operation Voltage Range	T_A = -40 °C ~ 105 °C	2.5	—	5.5	V
f_{HSI}	HSI Frequency	V_{DD} = 5.0 V @ 25 °C	—	8	—	MHz

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
ACC_{HSI}	Factory Calibrated HSI Oscillator Frequency Accuracy	V_{DD} = 5.0 V, T_A = 25 °C	-2	—	+2	%
		V_{DD} = 2.5 V ~ 5.5 V T_A = -20 °C ~ 105 °C	-3	—	+3	%
		V_{DD} = 2.5 V ~ 5.5 V T_A = -40 °C ~ -20 °C or T_A = 85 °C ~ 105 °C	-3.5	—	+3.5	%
Duty	HSI Oscillator Duty Cycle	f_{HSI} = 8 MHz	35	—	65	%
I_{DDHSI}	HSI Oscillator Oscillator Supply Current	f_{HSI} = 8 MHz	—	300	500	μA
	HSI Oscillator Power Down Current		—	—	0.05	μA
t_{SUHSI}	HSI Oscillator Startup Time	f_{HSI} = 8 MHz	—	—	10	μs

Table 12. Low Speed Internal Clock (LSI) Characteristics

T_A = 25 °C, unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{DD}	Operation Voltage Range	—	2.5	—	5.5	V
f_{LSI}	LSI Frequency	V_{DD} = 5.0 V, T_A = -40 °C ~ 105 °C	21	32	43	kHz
ACC_{LSI}	LSI Frequency Accuracy	After factory-trimmed, V_{DD} = 5.0 V	-10	—	10	%
I_{DDLSI}	LSI Oscillator Operating Current	V_{DD} = 5.0 V	—	0.4	0.8	μA
t_{SULSI}	LSI Oscillator Startup Time	V_{DD} = 5.0 V	—	—	100	μs

System PLL Characteristics

Table 13. System PLL Characteristics

T_A = 25 °C, unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
f_{PLLIN}	System PLL Input Clock	—	4	—	16	MHz
f_{CK_PLL}	System PLL Output Clock	—	16	—	60	MHz
t_{LOCK}	System PLL Lock Time	—	—	200	—	μs

Memory Characteristics

Table 14. Flash Memory Characteristics

T_A = 25 °C, unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
N_{ENDU}	Number of Guaranteed Program/Erase Cycles before failure (Endurance)	T_A = -40 °C ~ 105 °C	20	—	—	K cycles
t_{RET}	Data Retention Time	T_A = -40 °C ~ 105 °C	10	—	—	Years
t_{PROG}	Word Programming Time	T_A = -40 °C ~ 105 °C	20	—	—	μs
t_{ERASE}	Page Erase Time	T_A = -40 °C ~ 105 °C	2	—	—	ms
t_{MERASE}	Mass Erase Time	T_A = -40 °C ~ 105 °C	10	—	—	ms

I/O Port Characteristics

Table 15. I/O Port Characteristics

T_A = 25 °C, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
I_{IL}	Low Level Input Current	5.0 V I/O	$V_I = V_{SS}$, On-chip pull-up resister disabled	—	—	3	μA
		Reset pin		—	—	3	
I_{IH}	High Level Input Current	5.0 V I/O	$V_I = V_{DD}$, On-chip pull-down resister disabled	—	—	3	μA
		Reset pin		—	—	3	
V_{IL}	Low Level Input Voltage	5.0 V I/O		- 0.5	—	V_{DD} × 0.35	V
		Reset pin		0.5	—	V_{DD} × 0.35	
V_{IH}	High Level Input Voltage	5.0 V I/O		V_{DD} × 0.65	—	V_{DD} + 0.5	V
		Reset pin		V_{DD} × 0.65	—	V_{DD} + 0.5	
V_{HYS}	Schmitt Trigger Input Voltage Hysteresis	5.0 V I/O		—	0.12 × V_{DD}	—	mV
		Reset pin		—	0.12 × V_{DD}	—	
I_{OL}	Low Level Output Current (GPIO Sink Current)	5.0 V I/O 4 mA drive, V_{OL} = 0.6 V		4	—	—	mA
		5.0 V I/O 8 mA drive, V_{OL} = 0.6 V		8	—	—	mA
		5.0 V I/O 12 mA drive, V_{OL} = 0.6 V		12	—	—	mA
		5.0 V I/O 16 mA drive, V_{OL} = 0.6 V		16	—	—	mA
I_{OH}	High Level Output Current (GPIO Source Current)	5.0 V I/O 4 mA drive, $V_{OH} = V_{DD}$ - 0.6 V		4	—	—	mA
		5.0 V I/O 8 mA drive, $V_{OH} = V_{DD}$ - 0.6 V		8	—	—	mA
		5.0 V I/O 12 mA drive, $V_{OH} = V_{DD}$ - 0.6 V		12	—	—	mA
		5.0 V I/O 16 mA drive, $V_{OH} = V_{DD}$ - 0.6 V		16	—	—	mA
V_{OL}	Low Level Output Voltage	5.0 V 4 mA drive I/O, I_{OL} = 4 mA		—	—	0.6	V
		5.0 V 8 mA drive I/O, I_{OL} = 8 mA		—	—	0.6	
		5.0 V 12 mA drive I/O, I_{OL} = 12 mA		—	—	0.6	
		5.0 V 16 mA drive I/O, I_{OL} = 16 mA		—	—	0.6	
V_{OH}	High Level Output Voltage	5.0 V 4 mA drive I/O, I_{OH} = 4 mA		V_{DD} - 0.6	—	—	V
		5.0 V 8 mA drive I/O, I_{OH} = 8 mA		V_{DD} - 0.6	—	—	
		5.0 V 12 mA drive I/O, I_{OH} = 12 mA		V_{DD} - 0.6	—	—	
		5.0 V 16 mA drive I/O, I_{OH} = 16 mA		V_{DD} - 0.6	—	—	
R_{PU}	Internal Pull-up Resistor	5.0 V I/O, V_{DD} = 5.0 V		—	60	—	kΩ
R_{PD}	Internal Pull-down Resistor	5.0 V I/O, V_{DD} = 5.0 V		—	60	—	kΩ

Bandgap Voltage Characteristics

Table 16. Bandgap Voltage Characteristics

T_A = 25 °C, unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{DDA}	Operating Voltage	—	2.2	5.0	5.5	V
V_{BG}	Bandgap Reference Voltage	V_{DDA} = 2.2 V ~ 5.5 V @T_A = -40 °C ~ 105 °C	1.208	1.22	1.232	V
t_{SBG}	ADC Sampling Time when Reading Bandgap Voltage	—	5	—	—	μs

ADC Characteristics

Table 17. ADC Characteristics

T_A = 25 °C, unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{DDA}	A/D Converter Operating Voltage	—	2.5	5.0	5.5	V
V_{ADCIN}	A/D Converter Input Voltage Range	—	0	—	V_{REF+}	V
V_{REF+}	A/D Converter Reference Voltage	—	—	V_{DDA}	V_{DDA}	V
I_{ADC}	A/D Converter Operating Current	V_{DDA} = 5.0 V	—	0.85	1	mA
I_{ADC_DN}	Power Down Current Consumption	V_{DDA} = 5.0 V	—	—	0.1	μA
f_{ADC}	A/D Converter Clock Frequency	—	0.7	—	32	MHz
f_S	Sampling Rate	—	0.05	—	2	Msps
t_{DL}	Data Latency	—	—	12.5	—	$1/f_{ADC}$ Cycles
$t_{S\&H}$	Sampling & Hold Time	—	—	3.5	—	$1/f_{ADC}$ Cycles
$t_{ADCCONV}$	A/D Converter Conversion Time	ADST[7:0]=2	—	16	—	$1/f_{ADC}$ Cycles
R_I	Input Sampling Switch Resistance	—	—	—	1	kΩ
C_I	Input Sampling Capacitance	No pin/pad capacitance included	—	16	—	pF
t_{SU}	Startup Time	—	—	—	1	μs
N	Resolution	—	—	12	—	bits
INL	Integral Non-linearity Error	f_S = 750 ksps, V_{DDA} = 5.0 V	—	—	±2	LSB
DNL	Differential Non-linearity Error	f_S = 750 ksps, V_{DDA} = 5.0 V	—	—	±1	LSB
E_O	Offset Error	—	—	—	±10	LSB
E_G	Gain Error	—	—	—	±10	LSB

Note: 1. Data based on characterization results only, not tested in production.

2. The figure below shows the equivalent circuit of the A/D Converter Sample-and-Hold input stage where C_I is the storage capacitor, R_I is the resistance of the sampling switch and R_S is the output impedance of the signal source V_S. Normally the sampling phase duration is approximately, $3.5/f_{ADC}$. The capacitance, C_I, must be charged within this time frame and it must be ensured that the voltage at its terminals becomes sufficiently close to V_S for accuracy. To guarantee this, R_S is not allowed to have an arbitrarily large value.

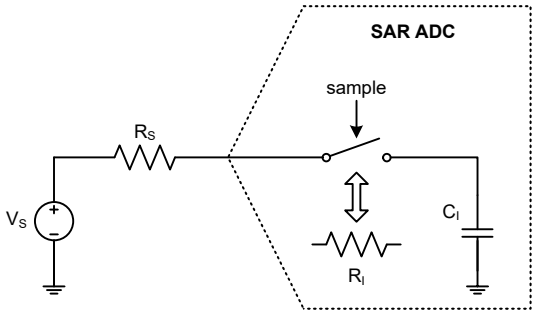


Figure 7. ADC Sampling Network Model

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

$$R_S < \frac{3.5}{f_{ADC} C_I \ln(2^{N+2})} - R_I$$

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 18. Comparator Characteristics

T_A = 25 °C, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_{DDA}	Operating Voltage	Comparator mode		2.5	5.0	5.5	V
V_{IN}	Input Common Mode Voltage Range	CP or CN		V_{SSA}	—	V_{DDA}	V
V_{IOS}	Input Offset Voltage(Note)	—		-15	—	15	mV
V_{HYS}	Input Hysteresis V_{DDA} = 5.0 V	No hysteresis, CMPHM [1:0] = 00		—	0	—	mV
		Low hysteresis, CMPHM [1:0] = 01		—	30	—	mV
		Middle hysteresis, CMPHM [1:0] = 10		—	60	—	mV
		High hysteresis, CMPHM [1:0] = 11		—	100	—	mV
t_{RT}	Response Time Input Overdrive = ±100 mV	High Speed Mode	$V_{DDA} \geq$ 2.7 V	—	50	100	ns
			V_{DDA} < 2.7 V	—	100	250	
		Low Speed Mode		—	2	5	μs
I_{CMP}	Current Consumption V_{DDA} = 5.0 V	High Speed Mode		—	180	—	μA
		Low Speed Mode		—	30	—	μA
t_{CMPST}	Comparator Startup Time	Comparator enabled to output valid		—	—	50	μs
I_{CMP_DN}	Power Down Supply Current	CMPEN = 0 CVREN = 0 CVROE = 0		—	—	0.1	μA

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Comparator Voltage Reference (CVR)						
V_{CVR}	Output Range	—	V_{SSA}	—	V_{DDA}	V
N_{Bits}	CVR Scaler Resolution	—	—	8	—	bits
t_{CVRST}	Settling Time	CVR Scaler Settling Time from CVRVAL = “00000000” to “11111111”	—	—	100	μs
I_{CVR}	Current Consumption V_{DDA} = 5.0 V	CVREN=1, CVROE=0	—	65	—	μA
		CVREN=1, CVROE=1	—	80	110	μA

Note: Data based on characterization results only, not tested in production.

Programmable Gain Amplifier

Table 19. Programmable Gain Amplifier Characteristics

T_A = 25 °C, unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{DDA}	Operating Voltage	—	3.0	5.0	5.5	V
I_{OPA_DN}	Power Down Current	—	—	—	0.1	μA
I_{OPA}	Operating Current	V_{DD} = 3.3 V	—	800	—	μA
V_{OS}	Input Offset Voltage	Without calibration (PGAOnOF[4:0] = 10000B), V_{IN} = 0 ~ V_{CM_max}/2	-15	—	+15	mV
		With calibration, V_{IN} = 0 ~ V_{CM_max}/2	-2	—	+2	
G_E	DC Gain Error	Gain = 6/8/12/16/24/32 (PGAnPGA = 1, PGAnHVDDAEN[1:0] = 0b0X, PGAnNUG = 0 and PGAnREF[1:0] = b00), V_{OUT} = 0.2 ~ (V_{DD} - 0.2 V)	—	—	2	%
		Gain = 5/7/11/15/23/31 (PGAnPGA = 1, PGAnHVDDAEN[1:0] = 0b10, PGAnNUG = 0 and PGAnREF[1:0] = b00) V_{OUT} = 0.2 ~ (V_{DD} - 0.2 V)				
V_{OR}	Maximum Output Voltage Range	—	V_{SS} + 0.2	—	V_{DD} - 0.2	V
I_{OS}	Input Offset Current	V_{IN} = 1/2 V_{CM}	—	1	10	nA
PSRR	Power Supply Rejection Ratio	—	—	60	—	dB
CMRR	Common Mode Rejection Ratio	V_{CM} = 0 ~ (V_{DD} - 1.4)	—	60	—	dB
SR	Slew Rate+, Slew Rate-	R_L = 100 kΩ, C_L = 50 pF	—	6	—	V/μs
GBW	Gain Band Width	R_L = 100 kΩ, C_L = 50 pF	—	6	—	MHz
A_{OL}	Open Loop Gain	R_L = 100 kΩ, C_L = 50 pF	60	80	—	dB
PM	Phase Margin	RL = 100 kΩ, C_L = 50 pF	50	60	—	Deg
V_{CM}	Common Mode Voltage Range	—	V_{SS}	—	V_{DD} - 1.4	V

Operational Amplifier

Table 20. Operational Amplifier Characteristics

T_A = 25 °C, unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{DDA}	Operating Voltage	OPA mode	3.0	5.0	5.5	V
I_{OPA_DN}	Power Down Current	—	—	—	0.1	μA
I_{OPA}	Operating Current	V_{DD} = 5V	—	800	—	μA
V_{OS}	Input Offset Voltage	Without calibration (OPAOOF[4:0] = 10000B) V_{IN} = 0 ~ V_{CM_max}/2	-15	—	+15	mV
		With calibration, V_{IN} = 0 ~ V_{CM_max}/2	-2	—	+2	
V_{OR}	Maximum Output Voltage Range	—	V_{SS} + 0.2	—	V_{DD} - 0.2	V
I_{OS}	Input Offset Current	V_{IN} = 1/2 V_{CM}	—	1	10	nA
PSRR	Power Supply Rejection Ratio	—	—	60	—	dB
CMRR	Common Mode Rejection Ratio	V_{CM} =0 ~ (V_{DD} - 1.4)	—	60	—	dB
SR	Slew Rate+, Slew Rate-	R_L = 100 kΩ, C_L = 50 pF	—	6	—	V/μs
GBW	Gain Band Width	R_L = 100 kΩ, C_L = 50 pF	—	6	—	MHz
A_{OL}	Open Loop Gain	R_L = 100 kΩ, C_L = 50 pF	60	80	—	dB
PM	Phase Margin	R_L = 100 kΩ, C_L = 50 pF	50	60	—	Deg
V_{CM}	Common Mode Voltage Range	—	V_{SS}	—	V_{DD} - 1.4	V

GPTM / MCTM / SCTM Characteristics

Table 21. GPTM/ MCTM / SCTM Characteristics

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
f_{TM}	Timer Clock Source for GPTM, MCTM, SCTM	—	—	—	f_{PCLK}	MHz
t_{RES}	Timer Resolution Time	—	1	—	—	1/f_{TM}
f_{EXT}	External Signal Frequency on Channel 0 ~ 3	—	—	—	1/2	f_{TM}
RES	Timer Resolution	—	—	—	16	bits

I²C Characteristics

Table 22. I²C Characteristics

Symbol	Parameter	Standard Mode		Fast Mode		Fast Plus Mode		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 (5)	0	—	0	—	0	—	ns
	SDA Data Hold Time (6)	—	1.6	—	0.475	—	0.25	μs
$t_{VD(SDA)}$	SDA Data Valid Time	—	1.6	—	0.475	—	0.25	μs
$t_{SU(STA)}$	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. Data based on characterization results only, not tested in production.

2. To achieve 100 kHz standard mode, the peripheral clock frequency must be higher than 2 MHz.
3. To achieve 400 kHz fast mode, the peripheral clock frequency must be higher than 8 MHz.
4. To achieve 1 MHz fast plus mode, the peripheral clock frequency must be higher than 20 MHz.
5. The above characteristic parameters of the I²C bus timing are based on: COMBFILTEREN = 0 and SEQFILTER = 00.
6. The above characteristic parameters of the I²C bus timing are based on: COMBFILTEREN = 1 and SEQFILTER = 00.

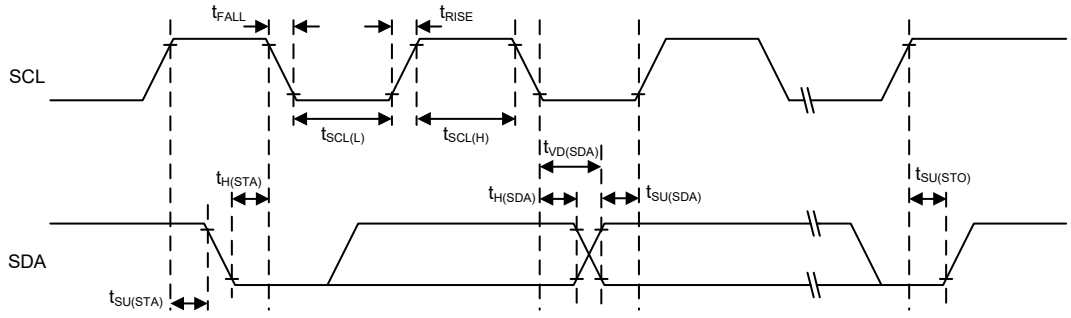


Figure 8. I²C Timing Diagram

SPI Characteristics

Table 23. SPI Characteristics

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
SPI Master Mode						
f_{SCK}	SPI Master Output SCK Clock Frequency	Master mode SPI peripheral clock frequency f_{PCLK}	—	—	$f_{PCLK}/2$	MHz
$t_{SCK(H)}$ $t_{SCK(L)}$	SCK Clock High and Low Time	—	$t_{SCK}/2$ - 2	—	$t_{SCK}/2$ + 1	ns
$t_{V(MO)}$	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
SPI Slave Mode						
f_{SCK}	SPI Slave Input SCK Clock Frequency	Slave mode SPI peripheral clock frequency f_{PCLK}	—	—	$f_{PCLK}/3$	MHz
$Duty_{SCK}$	SPI Slave Input SCK Clock Duty Cycle	—	30	—	70	%
$t_{SU(SEL)}$	SEL Enable Setup Time	—	3 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

Note: 1. f_{SCK} is SPI output/input clock frequency and $t_{SCK} = 1/f_{SCK}$.
2. f_{PCLK} is SPI peripheral clock frequency and $t_{PCLK} = 1/f_{PCLK}$.

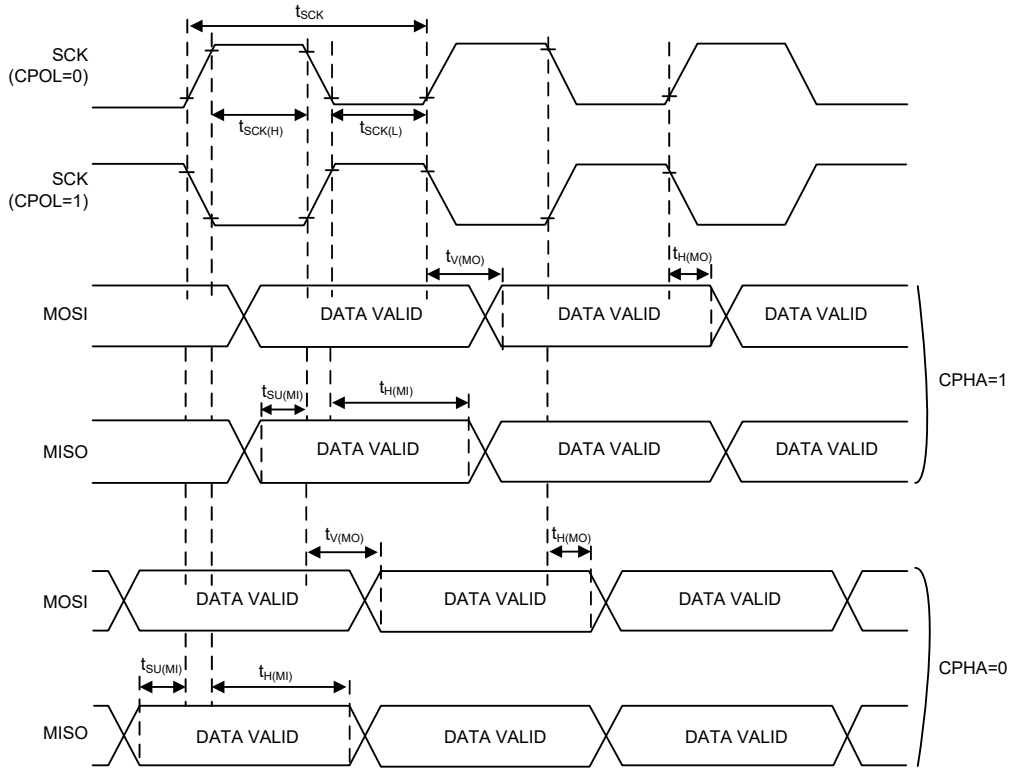


Figure 9. SPI Timing Diagram – SPI Master Mode

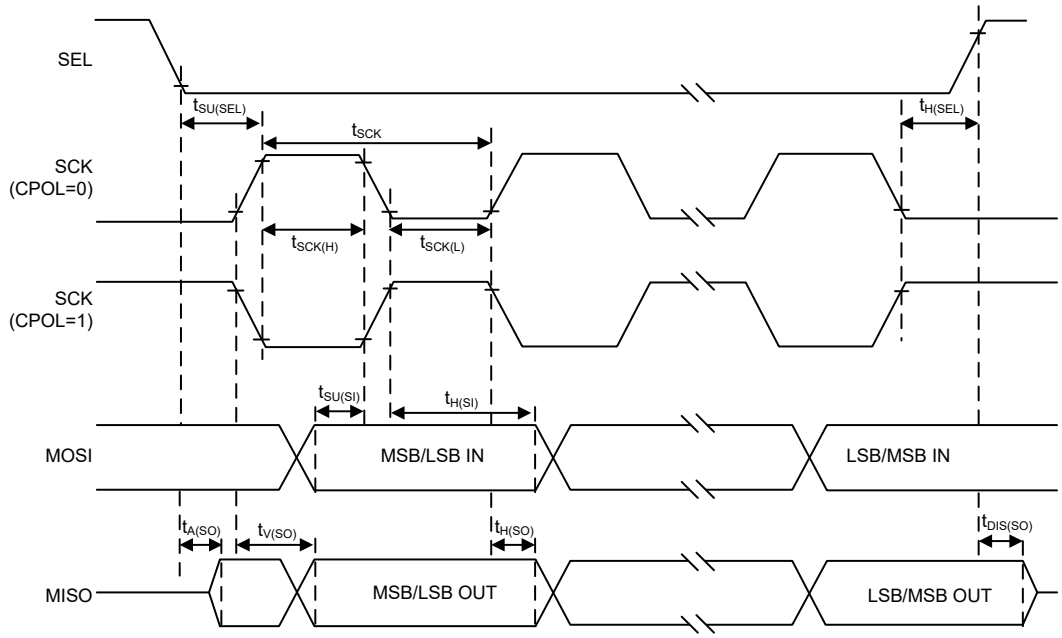


Figure 10. SPI Timing Diagram – SPI Slave Mode with CPHA = 1

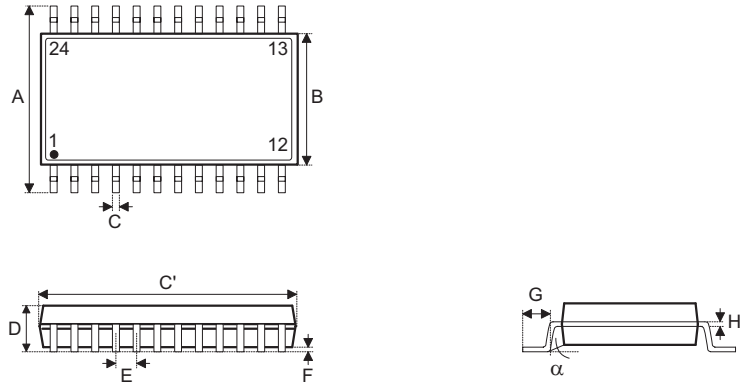
6 Package Information

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/Carton Information.

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

- Package Information (include Outline Dimensions, Product Tape and Reel Specifications)
- The Operation Instruction of Packing Materials
- Carton information

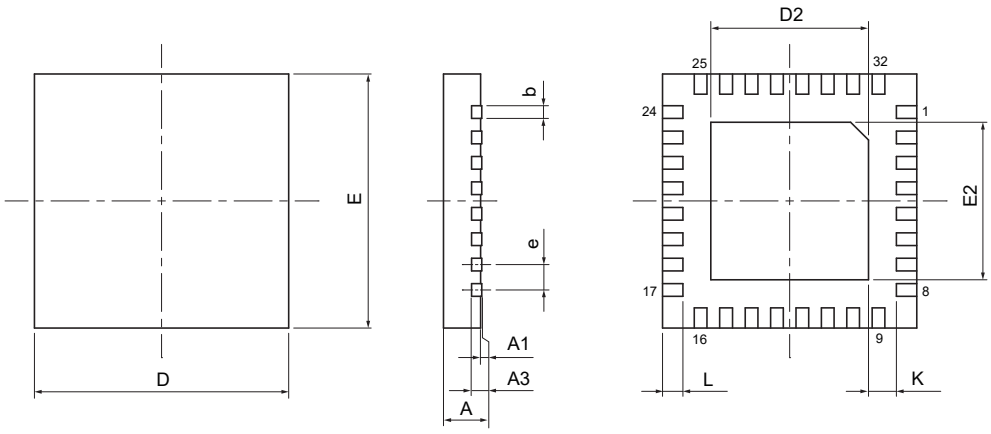
24-pin SSOP (150mil) Outline Dimensions



Symbol	Dimensions in inch		
	Min.	Nom.	Max.
A		0.236 BSC	
B		0.154 BSC	
C	0.008	—	0.012
C’		0.341 BSC	
D	—	—	0.069
E		0.025 BSC	
F	0.004	—	0.010
G	0.016	—	0.050
H	0.004	—	0.010
α	0°	—	8°

Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A		6.00 BSC	
B		3.90 BSC	
C	0.20	—	0.30
C’		8.66 BSC	
D	—	—	1.75
E		0.635 BSC	
F	0.10	—	0.25
G	0.41	—	1.27
H	0.10	—	0.25
α	0°	—	8°

SAW Type 32-pin QFN (4mm × 4mm × 0.75mm) Outline Dimensions



Symbol	Dimensions in inch		
	Min.	Nom.	Max.
A	0.028	0.030	0.031
A1	0.000	0.001	0.002
A3		0.008 REF	
b	0.006	0.008	0.010
D		0.157 BSC	
E		0.157 BSC	
e		0.016 BSC	
D2	0.100	—	0.108
E2	0.100	—	0.108
L	0.010	—	0.018
K	0.008	—	—

Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	0.70	0.75	0.80
A1	0.00	0.02	0.05
A3		0.203 REF	
b	0.15	0.20	0.25
D		4.00 BSC	
E		4.00 BSC	
e		0.40 BSC	
D2	2.55	—	2.75
E2	2.55	—	2.75
L	0.25	—	0.45
K	0.20	—	—