

ARM®-based 32-bit Cortex®-M4 MCU+FPU with 256 to 1024 KB Flash, sLib, USBFS, Ethernet, 17 timers, 3 ADCs, 21 communication interfaces

Feature

- **Core: ARM® 32-bit Cortex®-M4 CPU with FPU**
 - 240 MHz maximum frequency, with a memory protection unit (MPU), single-cycle multiplication and hardware division
 - Floating point unit (FPU) and
 - DSP instructions
- **Memories**
 - 256 to 1024 KBytes of internal Flash memory
 - sLib: configurable part of main Flash set as a library area with code executable but secured, non-readable
 - SPIM interface: Extra interfacing up to 16 Mbytes of the external SPI Flash (as instruction/data memory)
 - Up to 96+128 KBytes of SRAM
 - External memory controller (XMC) with 16-bit data bus. Supports multiplexed PSRAM/NOR and NAND memories
- **XMC as LCD parallel interface, compatible with 8080/6800 modes**
- **Power control (PWC)**
 - 2.6 to 3.6 V application supply
 - Power on reset (POR), low voltage reset (LVR), and power voltage monitoring (PVM)
 - Sleep, Deepsleep, and Standby modes
 - V_{BAT} supply for LEXT, RTC, and forty-two 16-bit battery powered registers (BPR)
- **Clock and reset management (CRM)**
 - 4 to 25 MHz crystal (HEXT)
 - 48 MHz internal factory-trimmed clock (HICK), accuracy 1 % at T_A = 25 °C and 2.5 % at T_A = -40 to +105 °C, with automatic clock calibration (ACC)
 - 40 kHz internal clock (LICK)
 - 32 kHz crystal (LEXT)
- **Analog**
 - 3 x 12-bit 2 MSPS A/D converters, up to 16 input channels
 - Temperature sensor
 - 2 x 12-bit D/A converters
- **DMA: 14-channel DMA controller**
- **Debug mode**
 - Serial wire debug (SWD) and JTAG interfaces
 - Cortex®-M4 Embedded Trace Macrocell (ETM™)
- **Up to 80 fast GPIOs**
 - all mappable on 16 external interrupts (EXINT)
 - almost all 5 V-tolerant
- **Up to 17 timers (TMR)**
 - Up to 2 x 16-bit motor control PWM advanced timers with dead-time generator and emergency brake
 - Up to 8 x 16-bit + 2 x 32-bit timers, each with 4 IC/OC/PWM or puLEXT counter and quadrature encoder input
 - 2 x 16-bit basic timers to drive the DAC
 - 2 x watchdog timers (general WDT and windowed WWDT)
 - SysTick timer: a 24-bit downcounter
- **Up to 21 communication interfaces**
 - Up to 3 x I²C interfaces (SMBus/PMBus)
 - Up to 8 x USARTs (ISO7816 interface, LIN, IrDA capability, modem control)
 - Up to 4 x SPIs (50 Mbit/s), all with I²S interface multiplexed, I²S2/I²S3 support full-duplex
 - Up to 2 x CAN interface (2.0B Active)
 - USB 2.0 full speed interface supporting crystal-less
 - Up to 2 x SDIO interfaces
 - 10/100M Ethernet MAC with dedicated DMA and SRAM (4 KBytes): IEEE1588 hardware support, MII/RMII available
- **CRC calculation unit, 96-bit unique ID (UID)**
- **Operating temperatures: -40 to +105 °C**
- **Packages**
 - LQFP100 14 x 14 mm
 - LQFP64 10 x 10 mm

Table 1. Device summary

Internal Flash	Part number
1024 KBytes	AT32F407RGT7, AT32F407VGT7
512 KBytes	AT32F407RET7, AT32F407VET7
256 KBytes	AT32F407RCT7, AT32F407VCT7

Contents

1	Descriptions	9
2	Functionality overview	11
2.1	ARM®Cortex®-M4 with FPU	11
2.2	Memory	12
2.2.1	Internal Flash memory	12
2.2.2	Memory protection unit (MPU)	12
2.2.3	Embedded SRAM.....	12
2.2.4	External memory controller (XMC).....	12
2.3	Interrupts	13
2.3.1	Nested vectored interrupt controller (NVIC).....	13
2.3.2	External interrupts (EXINT).....	13
2.4	Power control (PWC).....	13
2.4.1	Power supply schemes	13
2.4.2	Reset and power voltage monitoring (POR / LVR / PVM)	13
2.4.3	Voltage regulator (LDO)	13
2.4.4	Low-power modes	14
2.5	Boot modes	14
2.6	Clocks	15
2.7	General-purpose inputs / outputs (GPIO)	15
2.8	Remap capability	15
2.9	Direct Memory Access Controller (DMA)	16
2.10	Timers (TMR)	16
2.10.1	Advanced timers (TMR1 and TMR8)	17
2.10.2	General-purpose timers (TMRx)	17
2.10.3	Basic timers (TMR6 and TMR7).....	18
2.10.4	SysTick timer	18
2.11	Watchdog (WDT)	18
2.12	Window watchdog (WWDT)	18
2.13	Real-time clock (RTC) and battery powered registers (BPR).....	19

2.14	Communication interfaces	19
2.14.1	Serial peripheral interface (SPI) / Inter-integrated sound interface (I ² S)	19
2.14.2	Universal synchronous / asynchronous receiver transmitters (USART)	19
2.14.3	Inter-integrated-circuit interface (I ² C)	20
2.14.4	Secure digital input / output interface (SDIO)	20
2.14.5	Controller area network (CAN)	20
2.14.6	Universal serial bus full-speed (USBFS)	20
2.14.7	Ethernet MAC interface (EMAC)	21
2.15	Cyclic redundancy check (CRC) calculation unit	21
2.16	Analog-to-digital converter (ADC)	22
2.16.1	Temperature sensor (V_{TS})	22
2.16.2	Internal reference voltage (V_{NTRV})	22
2.17	Digital-to-analog converter (DAC)	23
2.18	Debug	23
2.18.1	Serial wire (SWD) / JTAG port	23
2.18.2	Embedded Trace Macrocell (ETM TM)	23
3	Pin functional definitions	24
4	Memory mapping	33
5	Electrical characteristics	34
5.1	Parameter conditions	34
5.1.1	Minimum and maximum values	34
5.1.2	Typical values	34
5.1.3	Typical curves	34
5.1.4	Power supply scheme	34
5.2	Absolute maximum	35
5.2.1	Ratings	35
5.2.2	Electrical sensitivity	36
5.3	Specification	37
5.3.1	General operating conditions	37
5.3.2	Operating conditions at power-up / power-down	37
5.3.3	Embedded reset and power control block characteristics	38
5.3.4	Memory characteristics	39

5.3.5	Supply current characteristics	39
5.3.6	External clock source characteristics	48
5.3.7	Internal clock source characteristics	52
5.3.8	PLL characteristics	53
5.3.9	Wakeup time from low-power mode	53
5.3.10	EMC characteristics	54
5.3.11	GPIO port characteristics	55
5.3.12	NRST pin characteristics	57
5.3.13	XMC characteristics	58
5.3.14	TMR timer characteristics	66
5.3.15	I ² C interface characteristics	66
5.3.16	SPI / I ² S characteristics	67
5.3.17	SDIO characteristics	71
5.3.18	USBFS characteristics	72
5.3.19	EMAC characteristics	73
5.3.20	12-bit ADC characteristics	75
5.3.21	Internal reference voltage (V_{NTRV}) characteristics	79
5.3.22	Temperature sensor (V_{TS}) characteristics	79
5.3.23	12-bit DAC specifications	80
6	Package information	81
6.1	LQFP100 package information	81
6.2	LQFP64 package information	83
6.3	Thermal characteristics	84
7	Part numbering	85
8	Document revision history	86

List of Tables

Table 1. Device summary	1
Table 2. AT32F407 features and peripheral counts	10
Table 3. The Bootloader supporting part numbers and pin configurations	15
Table 4. Timer feature comparison	16
Table 5. USART / UART feature comparison	20
Table 6. AT32F407 series pin definitions	26
Table 7. XMC pin definition	31
Table 8. Voltage characteristics	35
Table 9. Current characteristics	35
Table 10. Thermal characteristics	35
Table 11. ESD values	36
Table 12. Latch-up values	36
Table 13. General operating conditions	37
Table 14. Operating conditions at power-up / power-down	37
Table 15. Embedded reset and power management block characteristics	38
Table 16. Internal Flash memory characteristics	39
Table 17. Internal Flash memory endurance and data retention	39
Table 18. Typical current consumption in Run mode	40
Table 19. Typical current consumption in Sleep mode	41
Table 20. Maximum current consumption in Run mode	42
Table 21. Maximum current consumption in Sleep mode	43
Table 22. Typical and maximum current consumptions in DeepSleep and Standby modes	43
Table 23. Typical and maximum current consumptions on V _{BAT}	45
Table 24. Peripheral current consumption	46
Table 25. HEXT 4-25 MHz crystal characteristics	48
Table 26. HEXT external source characteristics	49
Table 27. LEXT 32.768 kHz crystal characteristics	50
Table 28. LEXT external source characteristics	51
Table 29. HICK clock characteristics	52
Table 30. LICK clock characteristics	52
Table 31. PLL characteristics	53
Table 32. Low-power mode wakeup time	53
Table 33. EMS characteristics	54
Table 34. GPIO static characteristics	55

Table 35. Output voltage characteristics.....	56
Table 36. Input AC characteristics	56
Table 37. NRST pin characteristics.....	57
Table 38. Asynchronous multiplexed PSRAM / NOR read timings	59
Table 39. Asynchronous multiplexed PSRAM / NOR write timings.....	60
Table 40. Synchronous multiplexed PSRAM / NOR read timings.....	62
Table 41. Synchronous multiplexed PSRAM write timings.....	63
Table 42. NAND Flash read and write timings.....	64
Table 43. TMR characteristics	66
Table 44. SPI characteristics	67
Table 45. I ² S characteristics	69
Table 46. SD / MMC characteristics	71
Table 47. USBFS startup time	72
Table 48. USBFS DC electrical characteristics	72
Table 49. USBFS electrical characteristics.....	72
Table 50. EMAC DC electrical characteristics	73
Table 51. Dynamic characteristics: EMAC signals for SMI	73
Table 52. Dynamic characteristics: EMAC signals for RMII.....	73
Table 53. Dynamic characteristics: EMAC signals for MII.....	74
Table 54. ADC characteristics.....	75
Table 55. R _{AIN} max for f _{ADC} = 14 MHz.....	76
Table 56. R _{AIN} max for f _{ADC} = 28 MHz.....	76
Table 57. ADC accuracy	77
Table 58. Internal reference voltage characteristics.....	79
Table 59. Temperature sensor characteristics	79
Table 60. DAC characteristics.....	80
Table 61. LQFP100 – 14 x 14 mm 100 pin low-profile quad flat package mechanical data.....	82
Table 62. LQFP64 – 10 x 10 mm 64 pin low-profile quad flat package mechanical data	84
Table 63. Package thermal characteristics.....	84
Table 64. AT32F407 series part numbering.....	85
Table 65. Document revision history.....	86

List of figures

Figure 1. AT32F407 block diagram.....	11
Figure 2. AT32F407 LQFP100 pinout	24
Figure 3. AT32F407 LQFP64 pinout	25
Figure 4. Memory map.....	33
Figure 5. Power supply scheme	34
Figure 6. Power on reset and low voltage reset waveform.....	38
Figure 7. Typical current consumption in DeepSleep mode vs. temperature at different V_{DD}	44
Figure 8. Typical current consumption in Standby mode vs. temperature at different V_{DD}	44
Figure 9. Typical current consumption on V_{BAT} with LEXT and RTC ON vs. temperature at different V_{BAT}	45
Figure 10. HEXT typical application with an 8 MHz crystal.....	48
Figure 11. HEXT external source AC timing diagram.....	49
Figure 12. LEXT typical application with a 32.768 kHz crystal	50
Figure 13. LEXT external source AC timing diagram	51
Figure 14. HICK clock frequency accuracy vs. temperature.....	52
Figure 15. Recommended NRST pin protection	57
Figure 16. Asynchronous multiplexed PSRAM / NOR read waveforms	59
Figure 17. Asynchronous multiplexed PSRAM / NOR write waveforms.....	60
Figure 18. Synchronous multiplexed PSRAM / NOR read timings	62
Figure 19. Synchronous multiplexed PSRAM write timings.....	63
Figure 20. NAND controller read waveforms.....	65
Figure 21. NAND controller write waveforms	65
Figure 22. NAND controller common memory read waveforms	65
Figure 23. NAND controller for common memory write waveforms.....	66
Figure 24. SPI timing diagram - slave mode and CPHA = 0	68
Figure 25. SPI timing diagram - slave mode and CPHA = 1	68
Figure 26. SPI timing diagram - master mode.....	68
Figure 27. I ² S slave timing diagram (Philips protocol)	69
Figure 28. I ² S master timing diagram (Philips protocol).....	70
Figure 29. SDIO high-speed mode.....	71
Figure 30. SD default mode.....	71
Figure 31. USBFS timings: definition of data signal rise and fall time	72
Figure 32. EMAC SMI timing diagram.....	73

Figure 33. EMAC RMII timing diagram.....	74
Figure 34. EMAC MII timing diagram	74
Figure 35. ADC accuracy characteristics	77
Figure 36. Typical connection diagram using the ADC	78
Figure 37. Power supply and reference decoupling (V_{REF+} not connected to V_{DDA})	78
Figure 38. Power supply and reference decoupling (V_{REF+} connected to V_{DDA})	78
Figure 39. V_{TS} vs. temperature	79
Figure 40. LQFP100 – 14 x 14 mm 100 pin low-profile quad flat package outline	81
Figure 41. LQFP64 – 10 x 10 mm 64 pin low-profile quad flat package outline	83

1 Descriptions

The AT32F407 incorporates the high-performance ARM® Cortex®-M4 32-bit RISC core operating at 240 MHz. The Cortex®-M4 core features a Floating point unit (FPU) single precision which supports all ARM single-precision data processing instructions and data type. It also implements a full set of DSP instructions and a memory protection unit (MPU) which enhances application security.

The AT32F407 incorporates high-speed embedded memories (up to 1024 KBytes of internal Flash memory, 96+128 KBytes of SRAM), the extensive external SPI Flash (up to 16 MBytes addressing capability), and enhanced GPIOs and peripherals connected to two APB buses. Any block of the embedded Flash memory can be protected by the "sLib", functioning as a security area with code-executable only.

The AT32F407 offers three 12-bit ADC, two 12-bit DAC, eight general-purpose 16-bit timers plus two general-purpose 32-bit timers, and up to two PWM timers for motor control. It supports standard and advanced communication interfaces: up to three I²Cs, four SPIs (all multiplexed as I²Ss), two SDIOs, eight USARTs/UARTs, an USBFS, two CANs, and an Ethernet MAC.

The AT32F407 operates in the -40 to +105 °C temperature range, from a 2.6 to 3.6 V power supply. A comprehensive set of power-saving mode allows the design of low-power application.

The AT32F407 offers devices in different package types. Depending on the different packages, the pin-to-pin is completely compatible among devices, and also the software and functionality. Only different sets of peripherals are included.

Table 2. AT32F407 features and peripheral counts

Part Number		AT32F407xxT7					
		RC	RE	RG	VC	VE	VG
CPU frequency (MHz)		240					
Int. Flash ⁽¹⁾⁽²⁾	ZW (KBytes)	256	256	256	256	256	256
	NZW (KBytes)	0	256	768	0	256	768
	Total (KBytes)	256	512	1024	256	512	1024
SRAM ⁽²⁾ (KBytes)		96 + 128					
Timers	Advanced	2			2		
	32-bit general-purpose	2			2		
	16-bit general-purpose	8			8		
	Basic	2			2		
	Sys Tick	1			1		
	WDT	1			1		
	VWDT	1			1		
	RTC	1			1		
Communication	I ² C	3			3		
	SPi/Ps	4/4 (2 full-duplex)			4/4 (2 full-duplex)		
	USART + UART	4 + 4			4 + 4		
	SDIO	2			2		
	USBFS device	1			1		
	CAN	2			2		
	Ethernet MAC	1			1		
Analog	12-bit ADC numbers/channels	3					
		16			16		
	12-bit DAC numbers	2					
XMC		1 ⁽³⁾			1		
SPiM ⁽⁴⁾		1 ch / up to 16 MB					
GPIO		51			80		
Operating temperatures		-40 to +105 °C					
Packages		LQFP64 10 x 10 mm			LQFP100 14 x 14 mm		

(1) ZW = zero wait-state, up to SYSCLK 240 MHz

NZW = non-zero wait-state

(2) The internal Flash and SRAM sizes are configurable with user's Option bytes. Take the AT32F407VGT7 as an example, on which the Flash/SRAM can be configured into two options below:

- ZW: 256 KBytes, NZW: 768 KBytes, SRAM: 96 KBytes;
- ZW: 128 KBytes, NZW: 896 KBytes, SRAM: 224 KBytes.

(3) For LQFP64 package, XMC only supports the LCD panel with 8-bit mode.

(4) SPiM = External SPi Flash memory extension, for both program execution and data storage with encryption capability.