

MAX32520

ChipDNA Secure Arm Cortex M4 Microcontroller

General Description

DeepCover® embedded security solutions cloak sensitive data under multiple layers of advanced physical security to provide the most secure key storage possible.

The DeepCover secure microcontroller MAX32520 provides an interoperable, secure, and cost-effective solution to build new generations of trusted embedded systems and communication devices such as IoT, IoT gateways, and wireless access points.

The MAX32520 incorporates Maxim's patented ChipDNA™ PUF technology. ChipDNA technology involves a physically unclonable function (PUF) that enables cost-effective protection against invasive physical attacks. Using the random variation of semiconductor device characteristics that naturally occur during wafer fabrication, the ChipDNA circuit generates a unique output value that is repeatable over time, temperature, and operating voltage. Attempts to probe or observe ChipDNA operation modifies the underlying circuit characteristics, preventing discovery of the unique value used by the chip cryptographic functions. The MAX32520 utilizes the ChipDNA output as key content to cryptographically secure all device stored data including user firmware. User firmware encryption provides ultimate software IP protection. The ChipDNA can also generate a private key for the ECDSA signing operation.

The MAX32520 integrates an Arm® Cortex® -M4 processor, 2MB of Flash, 136KB of system RAM + 34KB ECC, 8KB of one-time-programmable (OTP) memory and 128KB of boot ROM.

The MAX32520 provides a FIPS/NIST compliant TRNG, environmental and tamper detection circuitry to facilitate system-level security.

Multiple high-speed interfaces are supported including SPI, UART, and an I²C. The four on-chip timers also support PWM output generation for direct control of external devices. One of the SPI ports has a serial flash emulation mode allowing direct code fetching enabling secure boot for a host microcontroller.

Applications

- Embedded Connected Systems
- Secure Industrial Appliances, Sensors, and Controllers
- IoT Nodes and Gateways
- Embedded Communication Equipment (Routers, Gateways, etc.)
- Set-Top Boxes

Benefits and Features

- High-Efficiency Microcontroller for Secure Element IoT
 - Arm Cortex-M4F with FPU Up to 120MHz
 - 16KB Unified Code Cache
 - 2MB PUF Encrypted Flash Memory with Cache Provides Ultimate Firmware IP Protection
 - Low Latency On-the-Fly Decryption of Flash Execution
 - 136KB SRAM + 34KB ECC
 - 8KB User-Programmable OTP
- Secure Element
 - PUF-Based Keys
 - For Internal Flash Encryption
 - For Strong Device Authentication
 - Secure Boot Loader with Public Key Authentication and Serial Flash Emulation
 - AES, SHA, and ECDSA Accelerators
 - Hardware True Random Number Generator
 - SP800-90B Compliant Entropy Source
 - SP800-90A Compliant DRBG
 - Die Shield
 - Temperature and Voltage Tamper Monitor
 - External Tamper Sensor with Random Dynamic Pattern
- Power Management Maximizes Operating Time for Battery Applications
 - Single 3.3V/2.5V/1.8V Supply
 - Down to 3.2µA Backup Mode
 - 15µs Wake-Up Time from Standby Mode
 - Clock Gating, Power Gating, Registers, and Memory Retention Modes
- Multiple Peripherals for System Control
 - One UART
 - One I²C Interface
 - QSPI
 - Four Timers with PWM Capability
 - Up to 27 General-Purpose I/O Pins with Selectable Output Driver Strength
 - 4-Channel DMA Controller
 - 4-Pin JTAG

[Ordering Information](#) appears at end of data sheet.

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Simplified Block Diagram

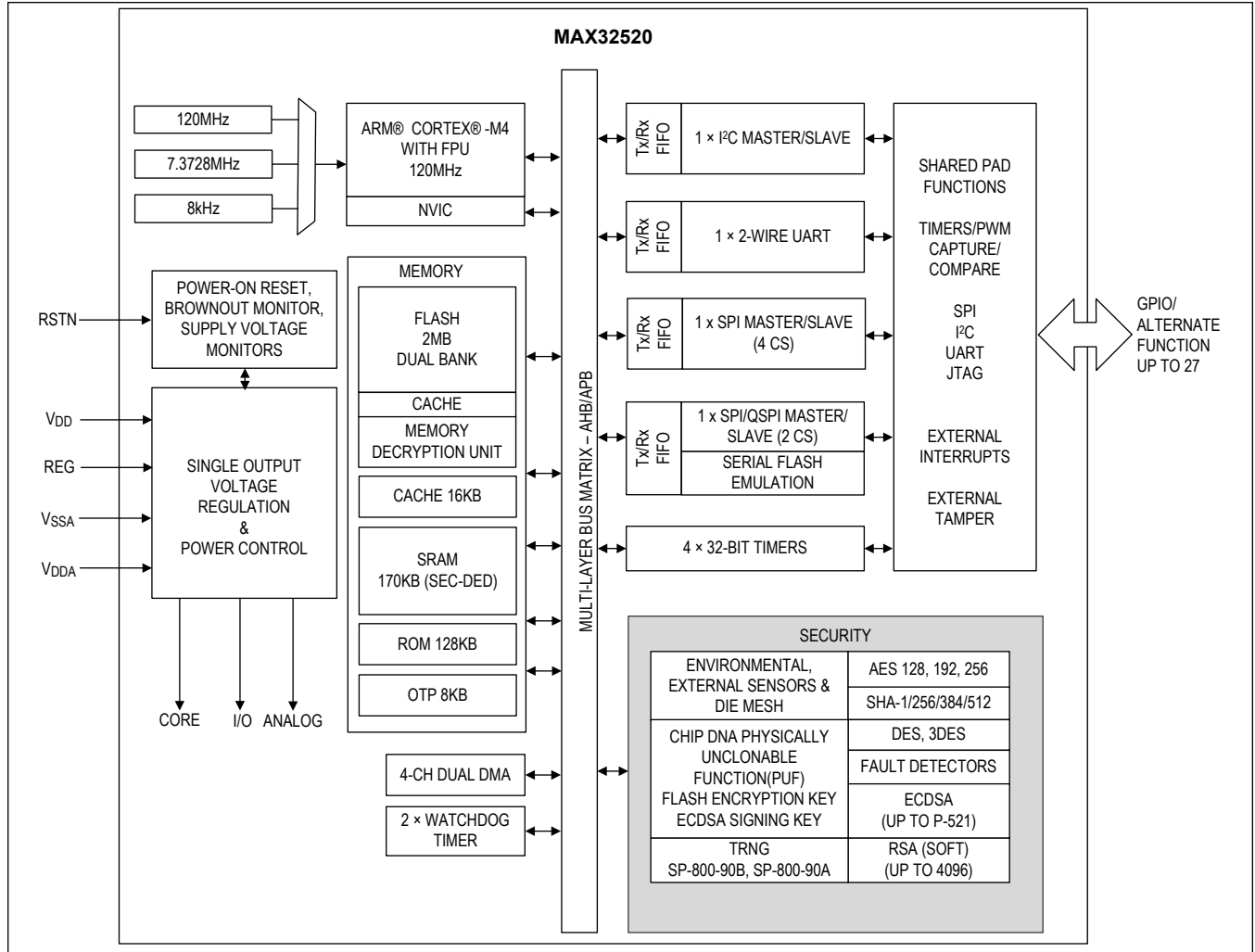


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Absolute Maximum Ratings

Continuous Power Dissipation ($T_A = +70^\circ\text{C}$) (Single-layer board, derate 21.3mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$)..... 1702.1mW
 Continuous Power Dissipation TQFN (Multilayer Board) ($T_A = +70^\circ\text{C}$, derate 34.5mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$.)..... 2758.6 mW
 Operating Temperature Range -40°C to $+105^\circ\text{C}$
 Storage Temperature Range..... -65°C to $+150^\circ\text{C}$
 V_{DD} -0.3V to 3.6V

V_{DDA} -0.3V to 3.6V
 RSTN, GPIO -0.3V to $V_{DD} + 0.5\text{V}$
 V_{SSA} 1mA
 V_{SS} 100mA
 Output Current (sink) by Any GPIO Pin 25mA
 Output Current (source) by Any GPIO Pin..... -25mA

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Package Information

32 TQFN

| | |
|--|-------------------------|
| Package Code | T3255+8C |
| Outline Number | 21-0140 |
| Land Pattern Number | 90-0013 |
| Thermal Resistance, Single-Layer Board: | |
| Junction to Ambient (θ_{JA}) | 47°C/W |
| Junction to Case (θ_{JC}) | 1.70°C/W |
| Thermal Resistance, Four-Layer Board: | |
| Junction to Ambient (θ_{JA}) | 29°C/W |
| Junction to Case (θ_{JC}) | 1.70°C/W |

30 WLP

| | |
|--|--------------------------------|
| Package Code | W302N2+1 |
| Outline Number | 21-100380 |
| Land Pattern Number | Refer to Application Note 1891 |
| Thermal Resistance, Four-Layer Board: | |
| Junction to Ambient (θ_{JA}) | 49.38°C/W |
| Junction to Case (θ_{JC}) | N/A |

For the latest package outline information and land patterns (footprints), go to www.maximintegrated.com/packages. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to www.maximintegrated.com/thermal-tutorial.

Electrical Characteristics

(Limits are 100% tested at $T_A = +25^\circ\text{C}$ and $T_A = +105^\circ\text{C}$. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|-------------------------------|-----------|------------|------|-----|-----|-------|
| POWER SUPPLIES | | | | | | |
| Input Supply Voltage, Digital | V_{DD} | | 1.71 | 1.8 | 3.6 | V |
| Input Supply Voltage, Analog | V_{DDA} | | 1.71 | 1.8 | 3.6 | V |

Electrical Characteristics (continued)

(Limits are 100% tested at $T_A = +25^\circ\text{C}$ and $T_A = +105^\circ\text{C}$. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|----------------|---|---|------|---------|---------------|
| V_{DD} Current, Active Mode | I_{DD_ACT} | Total current into V_{DD} pins, $f_{SYS_CLK} = 120\text{MHz}$, CPU in Active mode, executing While(1) from cache, inputs tied to V_{SS} , outputs source/sink 0mA | $V_{DD} = 1.8\text{V}$ | 10.6 | | mA |
| | | | $V_{DD} = 3.3\text{V}$ | 10.7 | | |
| V_{DD} Current, Sleep Mode | I_{DD_SLP} | Total current into V_{DD} pins, $f_{SYS_CLK} = 120\text{MHz}$, CPU in Sleep mode, inputs tied to V_{SS} , outputs source/sink 0mA | $V_{DD} = 1.8\text{V}$ | 2.16 | | mA |
| | | | $V_{DD} = 3.3\text{V}$ | 2.35 | | |
| V_{DD} Fixed Current, DeepSleep Mode | I_{DD_FDL} | Standby state with full retention | $V_{DD} = 1.8\text{V}$ | 65 | | μA |
| | | | $V_{DD} = 3.3\text{V}$ | 69 | | |
| V_{DD} Current, Backup Mode | I_{DD_BK} | Total current into V_{DD} pins, inputs tied to V_{SS} , AES keys retained, outputs source/sink 0mA | 72KB ECC memory retention, $V_{DD} = 1.8\text{V}$ | 4.72 | | μA |
| | | | 72KB ECC memory retention, $V_{DD} = 3.3\text{V}$ | 6.74 | | |
| | | | No memory retention, $V_{DD} = 1.8\text{V}$ | 3.22 | | |
| | | | No memory retention, $V_{DD} = 3.3\text{V}$ | 5.25 | | |
| | | | 32KB ECC memory retention, $V_{DD} = 1.8\text{V}$ | 3.84 | | |
| | | | 32KB ECC memory retention, $V_{DD} = 3.3\text{V}$ | 5.87 | | |
| | | | 64KB ECC memory retention, $V_{DD} = 1.8\text{V}$ | 4.4 | | |
| | | | 64KB ECC memory retention, $V_{DD} = 3.3\text{V}$ | 6.5 | | |
| CLOCKS | | | | | | |
| System Clock Frequency | f_{SYS_CLK} | | 0.0625 | | 120,000 | kHz |

Electrical Characteristics (continued)

(Limits are 100% tested at $T_A = +25^\circ\text{C}$ and $T_A = +105^\circ\text{C}$. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested.)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|-------------------------------------|------------------------|--|--|----------------------------|-------------------------|----------------------------|---------------|
| System Clock Period | $t_{\text{SYS_CLK}}$ | | | | $1/f_{\text{SYS_CLK}}$ | | ns |
| Nano-ring Oscillator Frequency | f_{NANO} | | | | 8 | | kHz |
| High-Speed Oscillator Frequency | f_{HSCLK} | | | 115.5 | 120 | 124.5 | MHz |
| 7MHz Oscillator Frequency | f_{7MCLK} | | | | 7.3728 | | MHz |
| GENERAL-PURPOSE I/O | | | | | | | |
| Input Low Voltage for All GPIO | V_{IL} | | | | | $0.3 \times V_{\text{DD}}$ | V |
| Input Low Voltage for RSTN | $V_{\text{IL_RSTN}}$ | | | | | $0.3 \times V_{\text{DD}}$ | V |
| Input High Voltage for All GPIO | V_{IH} | | | $0.7 \times V_{\text{DD}}$ | | | V |
| Input High Voltage for RSTN | $V_{\text{IH_RSTN}}$ | | | $0.7 \times V_{\text{DD}}$ | | | V |
| Output Low Voltage for All GPIO | V_{OL} | $V_{\text{DD}} = 1.71\text{V}$ | GPIO _n _DS_SEL[1:0] = 00, $I_{\text{OL}} = 1\text{mA}$ | 0.2 | 0.4 | | V |
| | | | GPIO _n _DS_SEL[1:0] = 01, $I_{\text{OL}} = 2\text{mA}$ | 0.2 | 0.4 | | |
| | | | GPIO _n _DS_SEL[1:0] = 10, $I_{\text{OL}} = 4\text{mA}$ | 0.2 | 0.4 | | |
| | | | GPIO _n _DS_SEL[1:0] = 11, $I_{\text{OL}} = 8\text{mA}$ | 0.2 | 0.4 | | |
| Combined I_{OL} , All GPIO | $I_{\text{OL_TOTAL}}$ | GBD | | | | 48 | mA |
| Output High Voltage for All GPIO | V_{OH} | $V_{\text{DD}} = 1.71\text{V}$ | GPIO _n _DS_SEL[1:0] = 00, $I_{\text{OL}} = -1\text{mA}$ | $V_{\text{DD}} - 0.4$ | | | V |
| | | | GPIO _n _DS_SEL[1:0] = 01, $I_{\text{OL}} = -2\text{mA}$ | $V_{\text{DD}} - 0.4$ | | | |
| | | | GPIO _n _DS_SEL[1:0] = 10, $I_{\text{OL}} = -4\text{mA}$ | $V_{\text{DD}} - 0.4$ | | | |
| | | | GPIO _n _DS_SEL[1:0] = 11, $I_{\text{OL}} = -8\text{mA}$ | $V_{\text{DD}} - 0.4$ | | | |
| Combined I_{OH} , All GPIO | $I_{\text{OH_TOTAL}}$ | GBD | | | | -48 | mA |
| Input Hysteresis (Schmitt) | V_{IHYS} | | | | 300 | | mV |
| Input Leakage Current Low | I_{IL} | $V_{\text{DD}} = 3.6\text{V}$, $V_{\text{IN}} = 0\text{V}$, internal pullup disabled | | -1 | | +1 | μA |
| Input Leakage Current High | I_{IH} | $V_{\text{DD}} = 3.6\text{V}$, $V_{\text{IN}} = 3.6\text{V}$, internal pulldown disabled | | -1 | | +1 | μA |

Electrical Characteristics (continued)

(Limits are 100% tested at $T_A = +25^\circ\text{C}$ and $T_A = +105^\circ\text{C}$. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|--------------------|--------------------------------|------|------|------|------------------|
| Input Pullup Resistor RSTN | R _{PU_R} | | | 25 | | k Ω |
| Input Pullup/Pulldown Resistor for All GPIO | R _{PU1} | Normal resistance | | 25 | | k Ω |
| | R _{PU2} | Highest resistance | | 1 | | M Ω |
| ENVIRONMENTAL SENSORS | | | | | | |
| V _{DD} Overvoltage Threshold | V _{DD_OV} | | 3.6 | | 3.8 | V |
| V _{DD} Undervoltage Threshold | V _{DD_UV} | V _{TM_LOTHSEL} = [00] | 1.56 | 1.66 | 1.76 | V |
| | | V _{TM_LOTHSEL} = [01] | 2.1 | 2.2 | 2.3 | |
| | | V _{TM_LOTHSEL} = [1x] | 2.7 | 2.8 | 2.9 | |
| High-Temperature Threshold | T _{HTR} | GBD | 115 | 125 | 135 | $^\circ\text{C}$ |
| Low-Temperature Threshold | T _{LTR1} | GBD | -70 | -60 | -50 | $^\circ\text{C}$ |
| | T _{LTR2} | GBD | -50 | -40 | -30 | |

Electrical Characteristics—SPI

(Timing specifications are guaranteed by design and not production tested.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|-------------------------------------|--|---------------------|---------------------|-----|-------|
| MASTER MODE | | | | | | |
| SPI Master Operating Frequency | f _{MCK} | f _{SYS_CLK} = 120MHz, f _{MCK(MAX)} = f _{SYS_CLK} /2 | | | 60 | MHz |
| SPI Master SCK Period | t _{MCK} | | | 1/f _{MCK} | | ns |
| SCK Output Pulse-Width High/Low | t _{MCH} , t _{MCL} | | t _{MCK} /2 | | | ns |
| MOSI Output Hold Time After SCK Sample Edge | t _{MOH} | | t _{MCK} /2 | | | ns |
| MOSI Output Valid to Sample Edge | t _{MOV} | | t _{MCK} /2 | | | ns |
| MOSI Output Hold Time After SCK Low Idle | t _{MLH} | | | t _{MCK} /2 | | ns |
| MISO Input Valid to SCK Sample Edge Setup | t _{MIS} | | | 5 | | ns |
| MISO Input to SCK Sample Edge Hold | t _{MIH} | | | t _{MCK} /2 | | ns |
| SLAVE MODE | | | | | | |
| SPI Slave Operating Frequency | f _{SCK} | | | | 50 | MHz |
| SPI Slave SCK Period | t _{SCK} | | | 1/f _{SCK} | | ns |
| SCK Input Pulse-Width High/Low | t _{SCH} , t _{SCL} | | | t _{SCK} /2 | | |

Electrical Characteristics—SPI (continued)

(Timing specifications are guaranteed by design and not production tested.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|-----------|------------|-----|-------------|-----|---------|
| SSx Active to First Shift Edge | t_{SSE} | | | 10 | | ns |
| MOSI Input to SCK Sample Edge Rise/Fall Setup | t_{SIS} | | | 5 | | ns |
| MOSI Input from SCK Sample Edge Transition Hold | t_{SIH} | | | 1 | | ns |
| MISO Output Valid After SCLK Shift Edge Transition | t_{SOV} | | | 5 | | ns |
| SCK Inactive to SSx Inactive | t_{SSD} | | | 10 | | ns |
| SSx Inactive Time | t_{SSH} | | | $1/f_{SCK}$ | | μ s |
| MISO Hold Time After SSx Deassertion | t_{SLH} | | | 10 | | ns |

Electrical Characteristics—I²C

(Timing specifications are guaranteed by design and not production tested.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|--------------|--|------|-----|-----|---------|
| STANDARD MODE | | | | | | |
| Output Fall Time | t_{OF} | Standard mode, from $V_{IH(MIN)}$ to $V_{IL(MAX)}$ | | 150 | | ns |
| SCL Clock Frequency | f_{SCL} | | 0 | | 100 | kHz |
| Low Period SCL Clock | t_{LOW} | | 4.7 | | | μ s |
| High Time SCL Clock | t_{HIGH} | | 4.0 | | | μ s |
| Setup Time for Repeated Start Condition | $t_{SU;STA}$ | | 4.7 | | | μ s |
| Hold Time for Repeated Start Condition | $t_{HD;STA}$ | | 4.0 | | | μ s |
| Data Setup Time | $t_{SU;DAT}$ | | | 300 | | ns |
| Data Hold Time | $t_{HD;DAT}$ | | | 10 | | ns |
| Rise Time for SDA and SCL | t_R | | | 800 | | ns |
| Fall Time for SDA and SCL | t_F | | | 200 | | ns |
| Setup Time for a Stop Condition | $t_{SU;STO}$ | | 4.0 | | | μ s |
| Bus Free Time Between a Stop and Start Condition | t_{BUS} | | 4.7 | | | μ s |
| Data Valid Time | $t_{VD;DAT}$ | | 3.45 | | | μ s |

Electrical Characteristics—I²C (continued)

(Timing specifications are guaranteed by design and not production tested.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|---------------------|---|------|-----|------|-------|
| Data Valid Acknowledge Time | t _{VD;ACK} | | 3.45 | | | μs |
| FAST MODE | | | | | | |
| Output Fall Time | t _{OF} | From V _{IH(MIN)} to V _{IL(MAX)} | | 150 | | ns |
| Pulse Width Suppressed by Input Filter | t _{SP} | | | 75 | | ns |
| SCL Clock Frequency | f _{SCL} | | 0 | | 400 | kHz |
| Low Period SCL Clock | t _{LOW} | | 1.3 | | | μs |
| High Time SCL Clock | t _{HIGH} | | 0.6 | | | μs |
| Setup Time for Repeated Start Condition | t _{SU;STA} | | 0.6 | | | μs |
| Hold Time for Repeated Start Condition | t _{HD;STA} | | 0.6 | | | μs |
| Data Setup Time | t _{SU;DAT} | | | 125 | | ns |
| Data Hold Time | t _{HD;DAT} | | | 10 | | ns |
| Rise Time for SDA and SCL | t _R | | | 30 | | ns |
| Fall Time for SDA and SCL | t _F | | | 30 | | ns |
| Setup Time for a Stop Condition | t _{SU;STO} | | 0.6 | | | μs |
| Bus Free Time Between a Stop and Start Condition | t _{BUS} | | 1.3 | | | μs |
| Data Valid Time | t _{VD;DAT} | | 0.9 | | | μs |
| Data Valid Acknowledge Time | t _{VD;ACK} | | 0.9 | | | μs |
| FAST MODE PLUS | | | | | | |
| Output Fall Time | t _{OF} | From V _{IH(MIN)} to V _{IL(MAX)} | | 80 | | ns |
| Pulse Width Suppressed by Input Filter | t _{SP} | | | 75 | | ns |
| SCL Clock Frequency | f _{SCL} | | 0 | | 1000 | kHz |
| Low Period SCL Clock | t _{LOW} | | 0.5 | | | μs |
| High Time SCL clock | t _{HIGH} | | 0.26 | | | μs |
| Setup Time for Repeated Start Condition | t _{SU;STA} | | 0.26 | | | μs |
| Hold Time for Repeated Start Condition | t _{HD;STA} | | 0.26 | | | μs |
| Data Setup Time | t _{SU;DAT} | | | 50 | | ns |
| Data Hold Time | t _{HD;DAT} | | | 10 | | ns |

Electrical Characteristics—I²C (continued)

(Timing specifications are guaranteed by design and not production tested.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|--------------|------------|------|-----|-----|---------|
| Rise Time for SDA and SCL | t_R | | | 50 | | ns |
| Fall Time for SDA and SCL | t_F | | | 30 | | ns |
| Setup Time for a Stop Condition | $t_{SU;STO}$ | | 0.26 | | | μ s |
| Bus Free Time Between a Stop and Start Condition | t_{BUS} | | 0.5 | | | μ s |
| Data Valid Time | $t_{VD;DAT}$ | | 0.45 | | | μ s |
| Data Valid Acknowledge Time | $t_{VD;ACK}$ | | 0.45 | | | μ s |

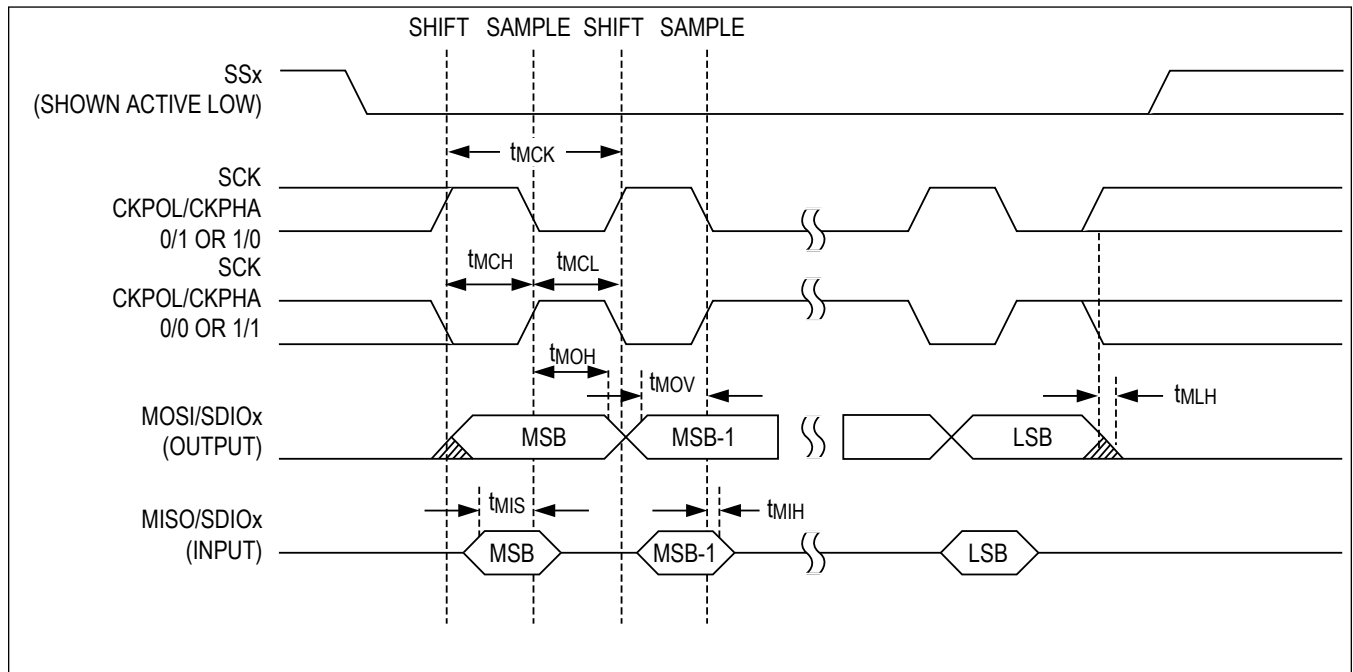


Figure 1. SPI Master Mode Timing Diagram

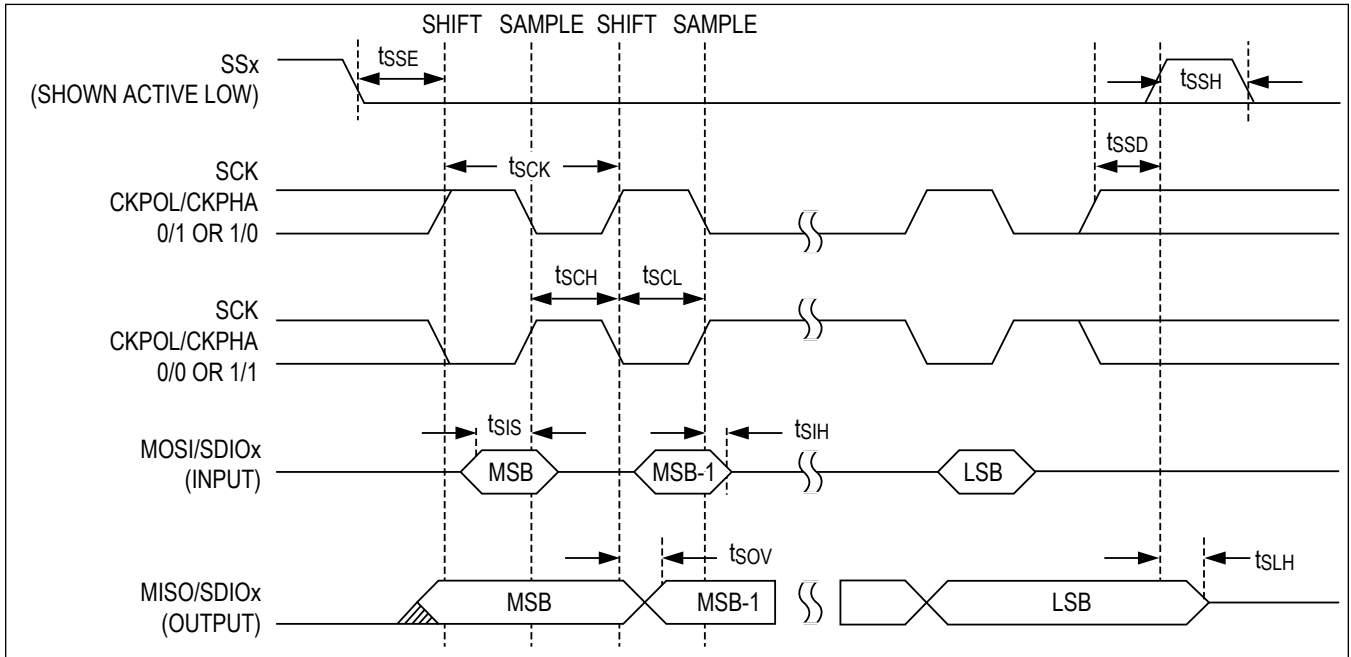


Figure 2. SPI Slave Mode Timing Diagram

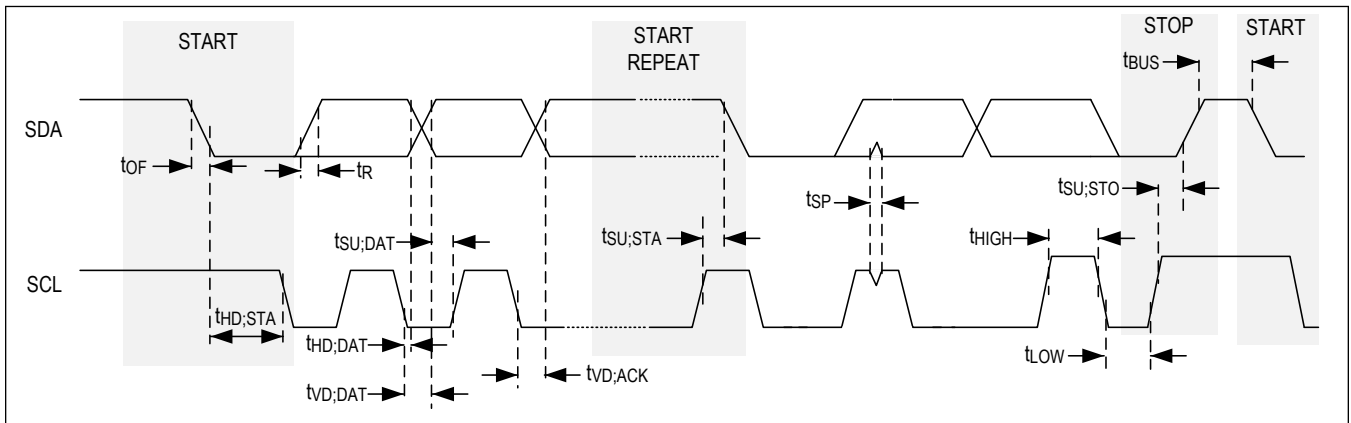
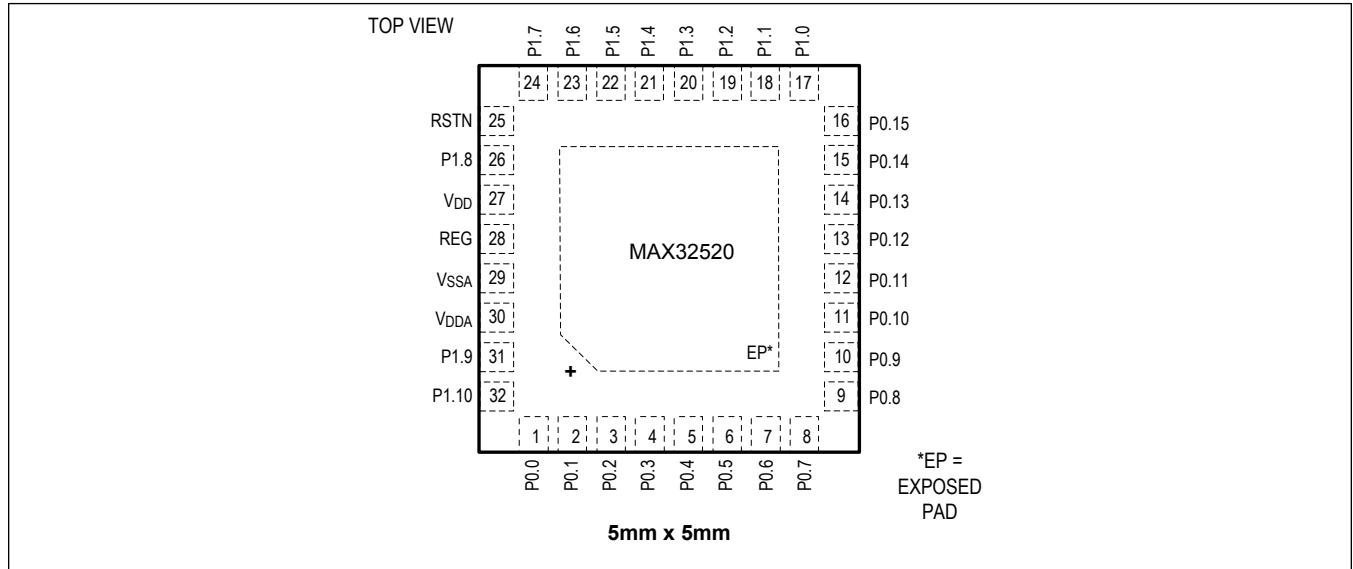


Figure 3. I²C Timing Diagram

Pin Configuration

32 TQFN



Pin Description

| PIN | NAME | FUNCTION MODE | | | FUNCTION |
|-------------|------|--------------------------|----------------------|----------------------|---|
| | | Primary Signal (Default) | Alternate Function 1 | Alternate Function 2 | |
| UART | | | | | |
| 1 | P0.0 | P0.0 | UART_RXD | — | P0.0: GPIO0 Port 0 UART_RXD: UART Data Input |
| 2 | P0.1 | P0.1 | UART_TXD | — | P0.1: GPIO1 Port 0 UART_TXD: UART Data Output |
| SPI | | | | | |
| 3 | P0.2 | P0.2 | SPI0_DIO0 (MOSI0) | SFSPIS_DIO0 (SFSI) | P0.2: GPIO2 Port 0 SPI0_DIO0: Quad SPI I/O 0 (SPI0 Master Out Slave In) SFSPIS_DIO0: Serial Flash SPI Slave I/O 0 (SFSPIS Slave In) |
| 4 | P0.3 | P0.3 | SPI0_DIO1 (MISO0) | SFSPIS_DIO1 (SFSO) | P0.3: GPIO3 Port 0 SPI0_DIO1: Quad SPI I/O 1 (SPI0 Master In Slave Out) SFSPIS_DIO1: Serial Flash SPI I/O 1 (SFSPIS Slave Out) |
| 5 | P0.4 | P0.4 | SCK0 | SFSPIS_SCK | P0.4: GPIO4 Port 0 SCK0: SPI0 Clock SFSPIS_SCK: Serial Flash SPI Clock |
| 6 | P0.5 | P0.5 | SSEL0_0 | SFSPIS_SS0 | P0.5: GPIO5 Port 0 SSEL0_0: SPI0 Slave Select 0 SFSPIS_SS0: Serial Flash SPI Slave Select 0 |

32 TQFN

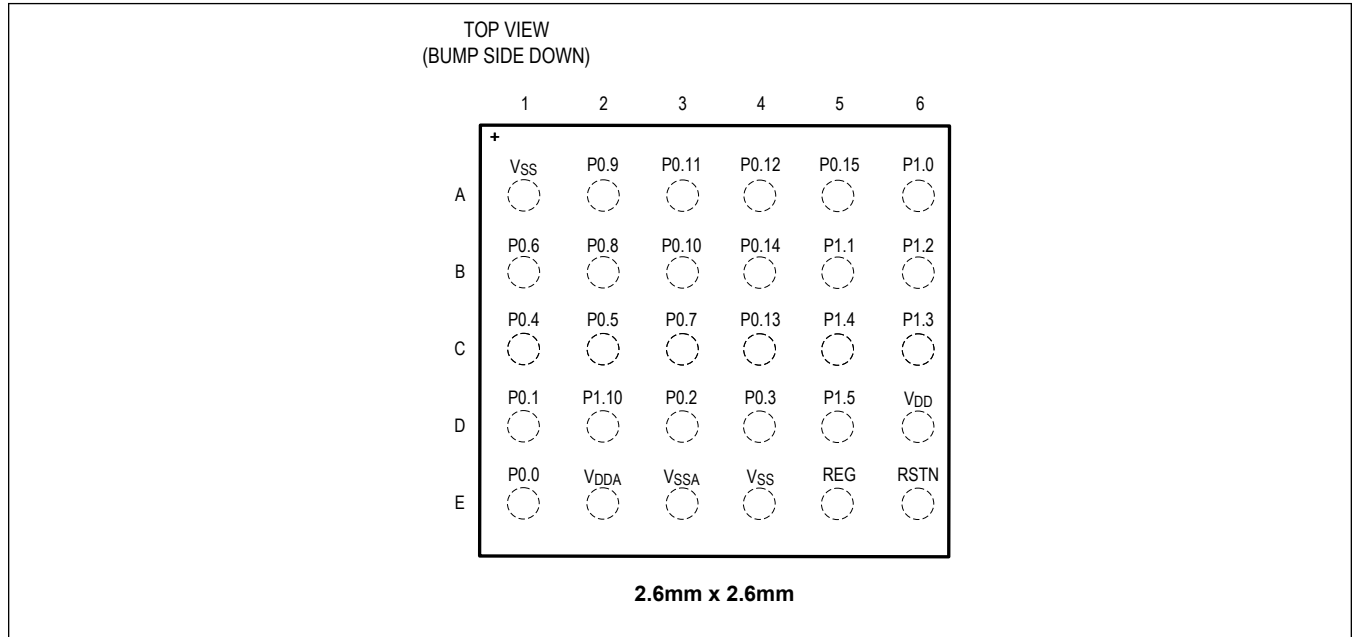
| PIN | NAME | FUNCTION MODE | | | FUNCTION |
|-----------------------|-------|--------------------------|----------------------|----------------------|---|
| | | Primary Signal (Default) | Alternate Function 1 | Alternate Function 2 | |
| 7 | P0.6 | P0.6 | SSEL0_1 | SFSPIS_SS1 | P0.6: GPIO6 Port 0 SSEL0_1: SPI0 Slave Select 1 SFSPIS_SS1: Serial Flash SPI Slave Select 1 |
| 8 | P0.7 | P0.7 | SPI0_DIO2 | SFSPIS_DIO2 | P0.7: GPIO7 Port 0 SPI0_DIO2: Quad SPI I/O 2 SFSPIS_DIO2: Serial Flash SPI I/O 2 |
| 9 | P0.8 | P0.8 | SPI0_DIO3 | SFSPIS_DIO3 | P0.8: GPIO8 Port 0 SPI0_DIO3: Quad SPI I/O3 SFSPIS_DIO3: Serial Flash SPI I/O 3 |
| 12 | P0.11 | P0.11 | MISO1 | — | P0.11: GPIO11 Port 0 MISO1: SPI1 Master In Slave Out |
| 13 | P0.12 | P0.12 | MOSI1 | — | P0.12: GPIO12 Port 0 MOSI1: SPI1 Master Out Slave In |
| 14 | P0.13 | P0.13 | SCK1 | — | P0.13: GPIO13 Port 0 SCK1: SPI1 Clock |
| 15 | P0.14 | P0.14 | SSEL1_0 | — | P0.14: GPIO14 Port 0 SSEL1_0: SPI1 Slave Select 0 |
| 16 | P0.15 | P0.15 | SSEL1_1 | — | P0.15: GPIO15 Port 0 SSEL1_1: SPI1 Slave Select 1 |
| I²C | | | | | |
| 10 | P0.9 | P0.9 | SDA | — | P0.9: GPIO9 Port 0 SDA: I2C Data |
| 11 | P0.10 | P0.10 | SCL | — | P0.10: GPIO10 Port 0 SCL: I2C Clock |
| TIMER | | | | | |
| 17 | P1.0 | P1.0 | TCLK0 | — | P1.0: GPIO0 Port 1 TCLK0: Timer 0 Clock I/O |
| 18 | P1.1 | P1.1 | TCLK1 | — | P1.1: GPIO1 Port 1 TCLK1: Timer 1 Clock I/O |
| 23 | P1.6 | P1.6 | TCLK2 | SSEL1_2 | P1.6: GPIO6 Port 1 TCLK2: Timer 2 Clock I/O SSEL1_2: SPI1 Slave Select 2 |
| 24 | P1.7 | P1.7 | TCLK3 | SSEL1_3 | P1.7: GPIO7 Port 1 TCLK3: Timer 3 Clock I/O SSEL1_3: SPI1 Slave Select 3 |
| JTAG | | | | | |
| 19 | P1.2 | P1.2 | TDI | — | P1.2: GPIO2 Port 1 TDI: JTAG Test Data Input |
| 20 | P1.3 | P1.3 | TDO | — | P1.3: GPIO3 Port 1 TDO: JTAG Test Data Output |
| 21 | P1.4 | P1.4 | TMS/SWDIO | — | P1.4: GPIO4 Port 1 TMS/SWDIO: JTAG Mode Select / Single Wire Debug I/O |

32 TQFN

| PIN | NAME | FUNCTION MODE | | | FUNCTION |
|-------------------------|------------------|--------------------------|----------------------|----------------------|---|
| | | Primary Signal (Default) | Alternate Function 1 | Alternate Function 2 | |
| 22 | P1.5 | P1.5 | TCK/SWCLK | — | P1.5: GPIO5 Port 1 TCK/SWCLK: JTAG Test Clock / Single Wire Debug Clock |
| EXTERNAL TAMPER | | | | | |
| 26 | P1.8 | P1.8 | EXT_SENS_OUT | — | P1.8: GPIO8 Port 1 EXT_SENS_OUT: External Sensor Output |
| 31 | P1.9 | P1.9 | EXT_SENS_IN | — | P1.9: GPIO9 Port 1 EXT_SENS_IN: External Sensor Input |
| 32 | P1.10 | P1.10 | TAMPER_OUT | — | P1.10: GPIO10 Port 1 TAMPER_OUT: External Tamper Detection Output. This pin is active when external tamper is detected. |
| POWER AND SYSTEM | | | | | |
| 27 | V _{DD} | V _{DD} | — | — | V _{DD} : Core and I/O supply voltage. Bypass V _{DD} with 1µf and 100nF capacitors with ESR <100mΩ |
| 28 | REG | REG | — | — | REG: Regulator Capacitor. Bypass REG with 1µf and 100nF capacitors with ESR < 100mΩ |
| 29 | V _{SSA} | V _{SSA} | — | — | V _{SSA} : 1.8V Analog Ground |
| 30 | V _{DDA} | V _{DDA} | — | — | V _{DDA} : 1.8V Analog Power Supply. Bypass V _{DDA} with 1µf and 100nF capacitors with ESR < 100mΩ |
| — | EP | V _{SS} | — | — | Exposed Pad. Ground. |
| 25 | RSTN | RSTN | — | — | RSTN: Hardware Reset (Active-Low) Input. The device remains in reset while this pin is in its active state. When the pin transitions to its inactive state, the device performs a warm reset (resetting all logic) and begins execution. This pin has an internal pullup to the V _{DD} supply. This pin should be left unconnected if the system design does not provide a reset signal to the device. |

Pin Configuration

30 WLP



Pin Description

| PIN | NAME | FUNCTION MODE | | | FUNCTION |
|-------------|------|--------------------------|----------------------|----------------------|--|
| | | Primary Signal (Default) | Alternate Function 1 | Alternate Function 2 | |
| UART | | | | | |
| E1 | P0.0 | P0.0 | UART_RXD | — | P0.0: GPIO0 Port 0 UART_RXD: UART Data Input |
| D1 | P0.1 | P0.1 | UART_TXD | — | P0.1: GPIO1 Port 0 UART_TXD: UART Data Output |
| SPI | | | | | |
| D3 | P0.2 | P0.2 | SPI0_DIO0 (MOSI0) | SFSPIS_DIO0 (SFSl) | P0.2: GPIO2 Port 0 SPI0_DIO0: Quad SPI I/O 0 (SPI0 Master Out Slave In) SFSPIS_DIO0: Serial Flash SPI Slave I/O 0 (SFSPI Slave In) |
| D4 | P0.3 | P0.3 | SPI0_DIO1 (MISO0) | SFSPIS_DIO1 (SFSo) | P0.3: GPIO3 Port 0 SPI0_DIO1: Quad SPI I/O 1 (SPI0 Master In Slave Out) SFSPIS_DIO1: Serial Flash SPI I/O 1 (SFSPI Slave Out) |
| C1 | P0.4 | P0.4 | SCK0 | SFSPIS_SCK | P0.4: GPIO4 Port 0 SCK0: SPI0 Clock SFSPIS_SCK: Serial SPI Clock |

30 WLP

| PIN | NAME | FUNCTION MODE | | | FUNCTION |
|-----------------------|-------|--------------------------|----------------------|----------------------|---|
| | | Primary Signal (Default) | Alternate Function 1 | Alternate Function 2 | |
| C2 | P0.5 | P0.5 | SSEL0_0 | SFSPIS_SS0 | P0.5: GPIO5 Port 0 SSEL0_0: SPI0 Slave Select 0 SFSPIS_SS0: Serial Flash SPI Slave Select 0 |
| B1 | P0.6 | P0.6 | SSEL0_1 | SFSPIS_SS1 | P0.6: GPIO6 Port 0 SSEL0_1: SPI0 Slave Select 1 SFSPIS_SS1: Serial Flash SPI Slave Select 1 |
| C3 | P0.7 | P0.7 | SPI0_DIO2 | SFSPIS_DIO2 | P0.7: GPIO7 Port 0 SPI0_DIO2: Quad SPI I/O 2 SFSPIS_DIO2: Serial Flash SPI I/O 2 |
| B2 | P0.8 | P0.8 | SPI0_DIO3 | SFSPIS_DIO3 | P0.8: GPIO8 Port 0 SPI0_DIO3: Quad SPI I/O 3 SFSPIS_DIO3: Serial Flash SPI I/O 3 |
| A3 | P0.11 | P0.11 | MISO1 | — | P0.11: GPIO11 Port 0 MISO1: SPI1 Master In Slave Out |
| A4 | P0.12 | P0.12 | MOSI1 | — | P0.12: GPIO12 Port 0 MOSI1: SPI1 Master Out Slave In |
| C4 | P0.13 | P0.13 | SCK1 | — | P0.13: GPIO13 Port 0 SCK1: SPI1 Clock |
| B4 | P0.14 | P0.14 | SSEL1_0 | — | P0.14: GPIO14 Port 0 SSEL1_0: SPI1 Slave Select 0 |
| A5 | P0.15 | P0.15 | SSEL1_1 | — | P0.15: GPIO15 Port 0 SSEL1_1: SPI1 Slave Select 1 |
| I²C | | | | | |
| A2 | P0.9 | P0.9 | SDA | — | P0.9: GPIO9 Port 0 SDA: I2C Data |
| B3 | P0.10 | P0.10 | SCL | — | P0.10: GPIO10 Port 0 SCL: I2C Clock |
| TIMER | | | | | |
| A6 | P1.0 | P1.0 | TCLK0 | — | P1.0: GPIO0 Port 1 TCLK0: Timer 0 Clock I/O |
| B5 | P1.1 | P1.1 | TCLK1 | — | P1.1: GPIO1 Port 1 TCLK1: Timer 1 Clock I/O |
| JTAG | | | | | |
| B6 | P1.2 | P1.2 | TDI | — | P1.2: GPIO2 Port 1 TDI: JTAG Test Data Input |
| C6 | P1.3 | P1.3 | TDO | — | P1.3: GPIO3 Port 1 TDO: JTAG Test Data Output |
| C5 | P1.4 | P1.4 | TMS/SWDIO | — | P1.4: GPIO4 Port 1 TMS/SWDIO: JTAG Mode Select / Single Wire Debug I/O |
| D5 | P1.5 | P1.5 | TCK/SWCLK | — | P1.5: GPIO5 Port 1 TCK/SWCLK: JTAG Test Clock / Single Wire Debug Clock |

30 WLP

| PIN | NAME | FUNCTION MODE | | | FUNCTION |
|-------------------------|------------------|--------------------------|----------------------|----------------------|---|
| | | Primary Signal (Default) | Alternate Function 1 | Alternate Function 2 | |
| POWER AND SYSTEM | | | | | |
| D6 | V _{DD} | V _{DD} | — | — | V _{DD} : Core and I/O Supply Voltage. Bypass V _{DD} with 1µf and 100nF capacitors with ESR < 100mΩ. |
| E5 | REG | REG | — | — | REG: Regulator Capacitor. Bypass REG with 1µf and 100nF capacitors with ESR < 100mΩ. |
| E3 | V _{SSA} | V _{SSA} | — | — | V _{SSA} : 1.8V Analog Ground |
| E2 | V _{DDA} | V _{DDA} | — | — | V _{DDA} : 1.8V Analog Power Supply. Bypass V _{DDA} with 1µf and 100nF capacitors with ESR < 100mΩ. |
| E4, A1 | V _{SS} | V _{SS} | — | — | Ground |
| E6 | RSTN | RSTN | — | — | RSTN: Hardware Reset (Active-Low) Input. The device remains in reset while this pin is in its active state. When the pin transitions to its inactive state, the device performs a warm reset (resetting all logic) and begins execution. This pin has an internal pullup to the V _{DD} supply. This pin should be left unconnected if the system design does not provide a reset signal to the device. |
| D2 | P1.10 | P1.10 | TAMPER_OUT | — | P1.10: GPIO10 Port 1 TAMPER_OUT: External Tamper Detection Output. This pin is active when external tamper is detected. |

Detailed Description

DeepCover embedded security solutions cloak sensitive data under multiple layers of advanced physical security to provide the most secure key storage possible. The DeepCover secure microcontroller MAX32520 provides an interoperable, secure, and cost-effective solution to build new generations of trusted embedded systems and communication devices such as wireless access points. The MAX32520 incorporates Maxim's patented ChipDNA™ PUF technology. ChipDNA technology involves a physically unclonable function (PUF) that enables cost-effective protection against invasive physical attacks. Using the random variation of semiconductor device characteristics that naturally occur during wafer fabrication, the ChipDNA circuit generates a unique output value that is repeatable over time, temperature, and operating voltage. Attempts to probe or observe ChipDNA operation modifies the underlying circuit characteristics to prevent the discovery of the unique value used by the chip cryptographic functions. The MAX32520 utilizes the ChipDNA output as key content to cryptographically secure all device stored data and optionally, under user control, as the private key for the ECDSA signing operation. The MAX32520 integrates an Arm Cortex-M4 processor, 2MB of flash, 136KB of system RAM + 34KB ECC, 8KB of one-time-programmable (OTP) memory and 128KB of boot ROM.

In addition to hardware crypto functions, the MAX32520 provides a FIPS/NIST-compliant true random number generator, as well as environmental and tamper detection circuitry to facilitate system-level security for the application.

The MAX32520 microcontroller includes multiple communication interfaces: two SPI ports, one UART, and an I²C bus. The four on-chip timers also support PWM output generation for direct control of external devices. One of the SPI ports has a serial flash emulation mode to allow direct code fetching and thus enable a secure boot for a host microcontroller.

Arm Cortex-M4 with FPU Processor

The Arm Cortex-M4 with FPU processor combines high-efficiency signal processing functionality with flexible low-power operating modes. The features of this implementation of the familiar Arm Cortex-M4 architecture include:

- Floating point unit (FPU)
- Memory protection unit
- Full debug support level
 - Debug access port (DAP)
 - Breakpoints
 - Flash patch
 - Halting debug
 - Development and debug interface
- NVIC support
 - Programmable IRQ generation for each interrupt source
 - Unique vectors for each interrupt channel
 - 8 programmable priority levels support nesting and preemption
 - External GPIO interrupts grouped by GPIO port
- DSP supports single instruction multiple data (SIMD) path DSP extensions, providing:
 - 4 parallel 8-bit add/sub
 - 2 parallel 16-bit add/sub
 - 2 parallel MACs
 - 32- or 64-bit accumulate
 - Signed, unsigned, data with or without saturation

Memory

Internal Flash Memory

2MB of internal flash memory provides nonvolatile storage of program and data memory. The flash memory can be fully AES encrypted using a 256-bit, PUF-generated key. In this case, the memory content is decrypted on the fly for execution. Firmware encryption through AES- and PUF-generated encryption key provides unmatched level of software

IP protection.

A dedicated state machine enables direct access to the flash block. Thanks to this state machine the MAX32520 can emulate a serial flash and the content of the flash is directly accessible from a host CPU. The typical application is the support of the secure boot function for a host processor.

Internal SRAM

The internal 170KB SRAM provides low-power retention of application information in all power modes except shutdown. The SRAM can be configured as 136KB + 34KB ECC SEC-DED.

The internal SRAM can be divided into granular banks that create a flexible SRAM retention architecture. This data retention feature is optional and configurable. This granularity allows the application to minimize its power consumption by only retaining the most essential data.

Internal ROM and Boot Loader

Upon assertion and deassertion of system reset, the Arm Cortex-M4 is reset and begins program execution of internal ROM code. A secure bootloader is implemented to provide trusted boot, secure flash upload, and flash integrity verification upon reboot.

A built-in public key authentication scheme allows secure firmware updates from both UART and SPI interfaces.

Clocking Scheme

The high-frequency internal oscillator operates at a nominal frequency of 120MHz. It is the primary clock source for the digital logic and peripherals. Select a 7.3728MHz internal oscillator to optimize active power consumption. A nanopower 8kHz ring oscillator is also available. Wakeup is possible from either the 7.3728MHz internal oscillator or the 120MHz internal oscillator.

ChipDNA Physically Unclonable Function (PUF)

Physically unclonable functions exploits the natural silicon manufacturing variations to generate unpredictable values that are statistically unique per chip. The MAX32520 uses PUF to generate unique keys while providing ultimate resistance against reverse-engineered based attacks.

The PUF instance present in the MAX32520 generates the flash encryption key. It can also provide a unique ECDSA private key for device strong authentication. The associated public key can be further exported and signed by a certification authority.

True Random Number Generator

Random numbers are a vital part of a secure application, providing random numbers that can be used for cryptographic seeds or strong encryption keys to ensure data privacy.

Software can use random numbers to trigger asynchronous events that result in nondeterministic behavior. This is helpful in thwarting replay attacks or key search approaches. An effective true random number generator (TRNG) must be continuously updated by a high-entropy source.

The provided TRNG is continuously driven by a physically-unpredictable entropy source. It generates a 128-bit true random number in 128 system clock cycles.

The TRNG can support the system-level validation of many security standards such as FIPS 140-2, SP800-90, PCI-PED, and Common Criteria. Contact Maxim for details of compliance with specific standards.

Serial Flash Emulation

One of the SPI ports provides the ability for a host microcontroller to use the device as an external serial flash for secure boot. The full capacity of flash memory is accessible and the amount of flash accessible can also be restricted. This feature provides a highly secure boot function for non-secure host microcontrollers. The device recognizes serial flash JEDEC commands.

Cryptographic Functions

AES Engine

The dedicated hardware-based AES engine supports the following algorithms:

- AES-128
- AES-192
- AES-256

ECDSA Engine

The ECDSA engine enables ECDSA signature and verification for following key lengths:

- 256 bits
- 384 bits
- 521 bits

Brainpool and NIST curves are supported.

SHA Engine

The SHA engine supports following SHA algorithms:

- SHA-1
- SHA-256
- SHA-384
- SHA-512

RSA

A crypto API enables RSA computation with key lengths up to 4096 bits.

UART

The universal asynchronous receiver-transmitter (UART) interface supports full-duplex asynchronous communication, including:

- 16-byte send/receive FIFO
- Full-duplex operation for asynchronous data transfers
- Interrupts available for frame error, parity error, Rx FIFO overrun, and FIFO full/partially full conditions
- Automatic parity and frame error detection
- Independent baud-rate generator
- Programmable 9th bit parity support
- Multidrop support
- Start/stop bit support
- Baud Rate Generation with $\pm 2\%$
- Maximum baud rate 1843.2kB
- Two DMA channels can be connected (read and write FIFOs)
- Programmable word size (5 bits to 8 bits)

Note: No hardware flow control using RTS/CTS.

I²C Interface

The I²C interface is a bidirectional, two-wire serial bus that provides a medium-speed communications network. It can operate as a one-to-one, one-to-many or many-to-many communications medium. The I²C master/slave interface to a wide variety of I²C-compatible peripherals. This engine support both standard mode and fast mode I²C standards. It provides the following features:

- Master or slave mode operation
- Supports standard (7-bit) addressing or 10-bit addressing

- Support for clock stretching to allow slower slave devices to operate on higher speed busses
- Multiple transfer rates
 - Standard mode: 100kbps
 - Fast mode: 400kbps
 - Fast mode plus: 1000kbps
- Internal filter to reject noise spikes
- Receiver FIFO depth of 16 bytes
- Transmitter FIFO depth of 16 bytes

SPI

The serial peripheral interface (SPI) is a synchronous interface allowing multiple SPI-compatible devices to be interconnected.

The provided SPI supports the following features:

- Full-duplex, synchronous communication of 8-/16-bit characters
- 4-wire interface plus
 - 1 additional slave select (SPI0)
 - 3 additional slave selects (SPI1)
- Master and slave mode of operation
- Master mode data transfer rate of up to one-fourth of the APB clock frequency
- Slave mode data transfer rate of up to one-eighth of the APB clock frequency
- Dedicated baud rate generator
- 8 x 16 transmit and receive FIFOs
- Transmit and receive DMA support

The MAX32520 has two SPI ports SPI0 and SPI1.

Debug and Development Interface (SWD/JTAG)

Development versions of the device are available with a serial wire debug or JTAG interface that is used only during application development and debugging. The interface is used for code loading, ICE debug activities and for control of boundary scan activities. Devices in mass production must have the debugging/development interface disabled.

The Ordering Information section contains unique part numbers for devices with the debugging/development interface enabled or disabled.

Interrupt Sources

The Arm nested vector interrupt controller (NVIC) provides a high-speed, deterministic interrupt response, interrupt masking, and multiple interrupt sources. Each peripheral is connected to the NVIC and can have multiple interrupt flags to indicate the specific source of the interrupt within the peripheral.

Standard DMA Controller

The standard DMA (direct memory access) controller provides a means to off-load the CPU for memory/peripheral data transfer leading to a more power-efficient system. It allows automatic one-way data transfer between two entities. These entities can be either memories or peripherals. The transfers are done without using CPU resources. The following transfer modes are supported:

- 4 channel
- Peripheral to data memory
- Data memory to peripheral
- Data memory to data memory

All DMA transactions consist of an AHB burst read into the DMA FIFO followed immediately by an AHB burst write from the FIFO.

Programmable Timers

Four 32-bit timers provide timing, capture/compare, or generation of pulse-width modulated (PWM) signals.

- 32-bit up/down autoreload
- Programmable 16-bit prescaler
- PWM output generation
- Capture, compare, and capture/compare capability
- GPIOs can be assigned as external timer inputs, clock gating or capture, limited to an input frequency of 1/4 of the peripheral clock frequency
- Timer output pin
- Timer interrupt

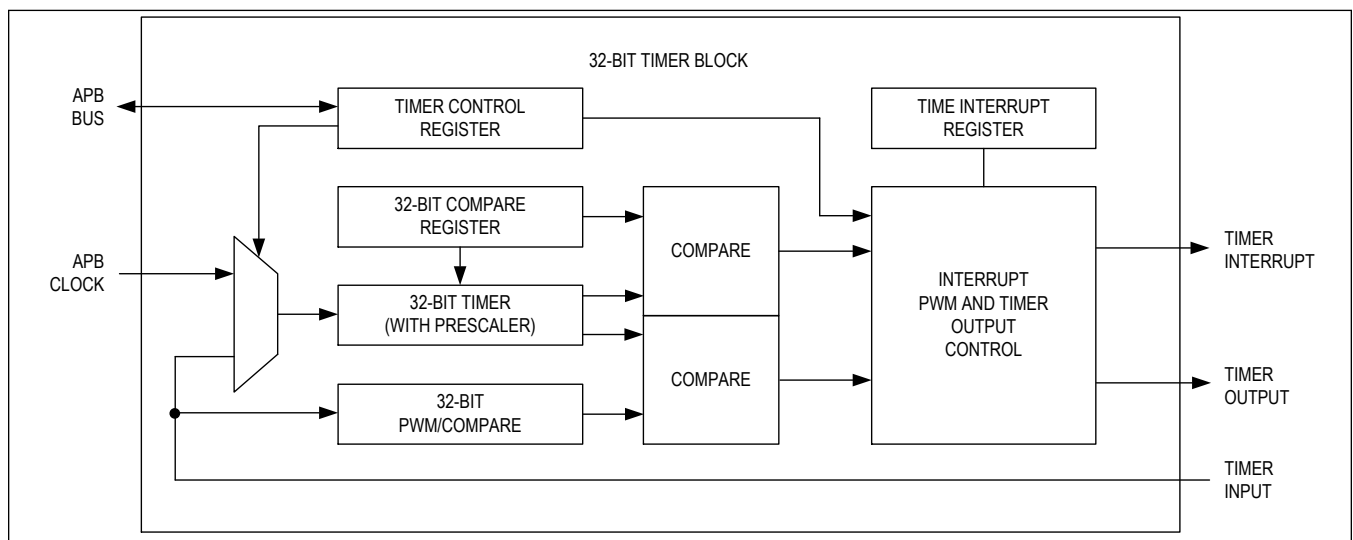


Figure 4. Timer Block Diagram, 32-Bit Mode

Watchdog Timer

A watchdog timer (WDT) is provided. The watchdog uses a 32-bit timer with prescaler to generate the watchdog reset. When enabled, the watchdog timer must be written prior to timeout. Failure to write the watchdog timer prior to the pre-programmed interval time results in a watchdog timeout. The WDT1 is set on reset if a watchdog expiration caused the system reset. The clock source for the watchdog timer is the system clock.

Power Management

Active Mode

In this mode, the CPU is executing application code and all digital and analog peripherals are available on-demand. Dynamic clocking disables peripherals not in use, providing the optimal mix of high-performance and low-power consumption.

Sleep Mode

This mode consumes less power, but wakes faster because the clocks can optionally be enabled.

The device status is as follows:

- The CPU is asleep
- Peripherals are on
- Standard DMA blocks are available for optional use.

DeepSleep Mode

This mode corresponds to the Arm Cortex-M4 DeepSleep mode. In this mode, CPU and critical peripheral configuration settings and all volatile memory is preserved.

The device status is as follows:

- The CPU is off.
- The GPIO pins retain their state.
- The transition from DeepSleep to Active mode is faster than the transition from Backup mode because system initialization is not required.
- The system oscillators are all disabled to provide additional power savings over Sleep mode.
 - 120MHz high-speed oscillator
 - 7.3728MHz oscillator

Backup Mode

This mode places the CPU in a static, low-power state that supports a fast wake-up to Active mode feature.

The device status is as follows:

- CPU is off.
- Only 72KB, 64KB, 32KB, or 8KB of the SRAM can be retained.

Wake-Up Sources

The sources of wake-up from the Sleep, DeepSleep, and Backup operating modes can be summarized in Table 1.

Table 1. Wake-Up Sources

| OPERATING MODE | WAKE-UP SOURCE |
|----------------|--|
| Sleep | Interrupts (GPIO, all peripherals), RSTN assertion |
| DeepSleep | Interrupts (GPIO), RSTN assertion |
| Backup | Interrupts (GPIO), RSTN assertion |

Security Monitor**Internal Sensor**

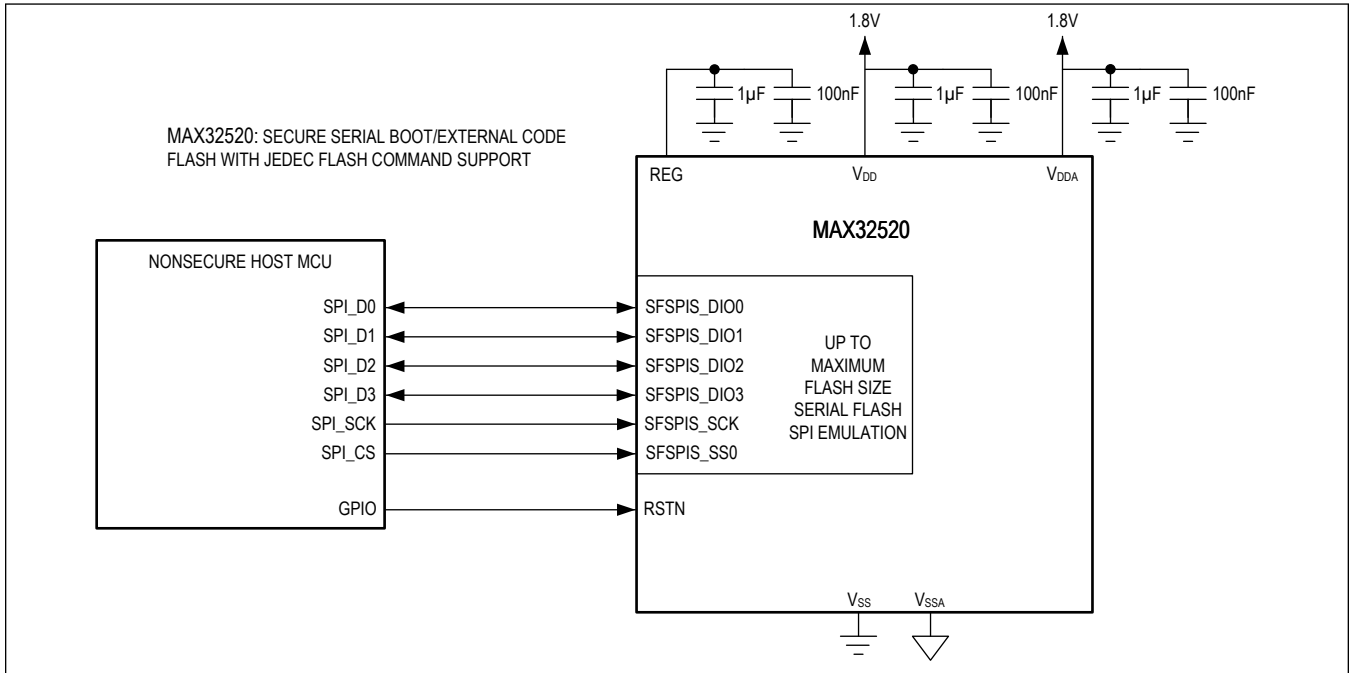
The behavior of the system is constantly monitored by a range of internal sensors. The internal sensors include environmental sensors such as die shield sensor, fault detection sensors and temperature sensor. Furthermore, there are core sensors monitoring internal core voltage on all rails.

External Tamper Sensors

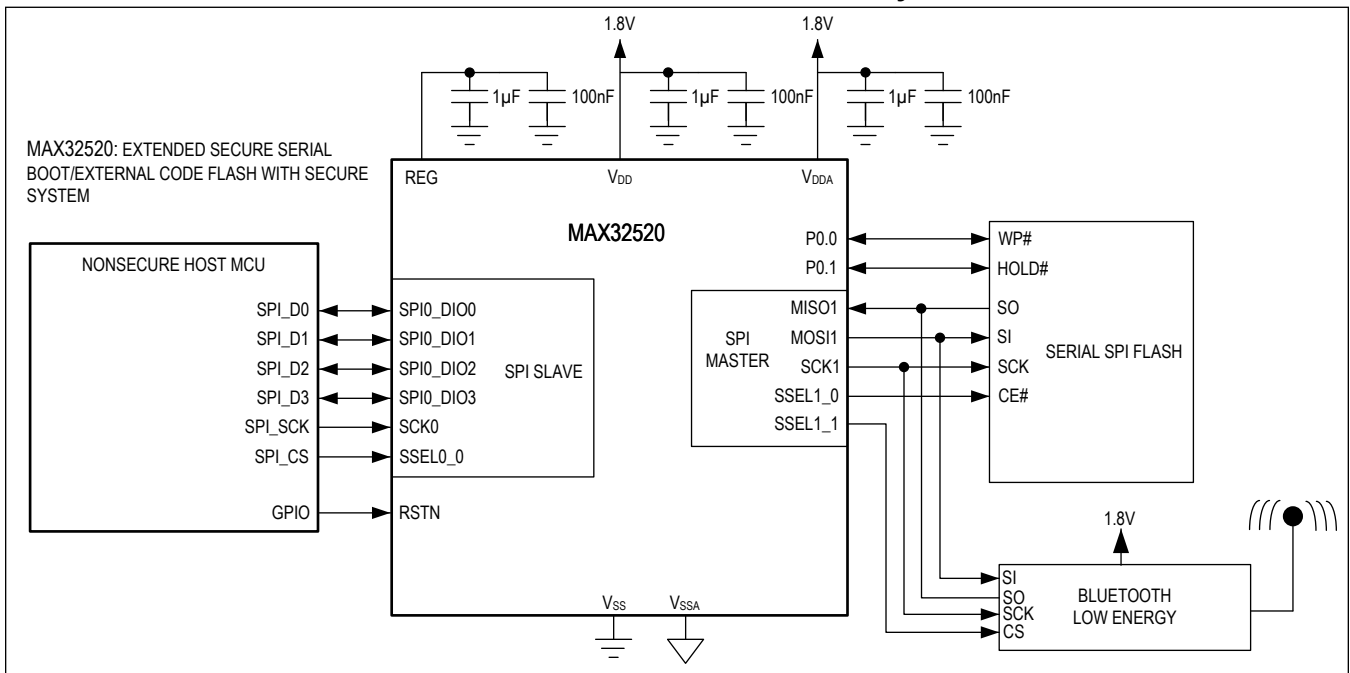
The device provides an external dynamic tamper sensor. The external tamper sensor uses two pins (EXT_SENSOR_IN, EXT_SENSOR_OUT) that provide a random, changing pattern generated by an internal, true random entropy source. The two pins can be connected to a mesh or user-defined, normally-closed tamper switch. External tamper detection triggers both predefined and user-customizable reactions. Tamper detection also toggles the TAMPER_OUT pin so that MAX32520 can signal tamper detection to external devices.

Typical Application Circuits

Secure Serial Boot/External Code Flash with JEDEC Flash Command Support



Extended Secure Serial Boot/External Code Flash with Secure System



Ordering Information

| PART | DEBUG INTERFACE | PIN-PACKAGE |
|----------------|-----------------|-------------|
| MAX32520-BNJ+ | Yes | 32 TQFN |
| MAX32520-BNS+ | No | 32 TQFN |
| MAX32520-BNS+T | No | 32 TQFN |
| MAX32520/W+JU* | Yes | 30 WLP |
| MAX32520/W+U* | No | 30 WLP |
| MAX32520/W+T* | No | 30 WLP |

+Denotes a lead(Pb)-free/RoHS-compliant package.

T = Tape and reel. Full reel.

*Future product—contact factory for availability.

Revision History

| REVISION NUMBER | REVISION DATE | DESCRIPTION | PAGES CHANGED |
|-----------------|---------------|-----------------|---------------|
| 0 | 6/19 | Initial release | — |

For pricing, delivery, and ordering information, please visit Maxim Integrated's online storefront at <https://www.maximintegrated.com/en/storefront/storefront.html>.

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