

MWPR1516 16 KB Flash 24 MHz Cortex-M0+ Based Microcontroller

Higher integration receiver controller MCU for wireless power transfer application. Targeting battery powered products are smart phone, tablet, portable medical devices, power tools etc.

This product offers:

- AC/DC conversion and modulation/demodulation circuit for bi-directional communication to support industrial standards with foreign object detection (FOD)
- USB/adaptor power switcher to charge products with wire and wireless with priority.
- Up to 15 W with proper external transistors
- QFN package for industrial application and WLCSP package for space constrained consumer applications

MWPR1516CFM(R)
MWPR1516CALR



32-pin QFN (FM) 5 x 5 x 0.58 Pitch 0.5 mm
36-pin WLCSP (AL) 3.1 x 3.0 x 0.6 Pitch 0.4 mm

Performance

- 24 MHz ARM® Cortex®-M0+ core
- Single cycle 32-bit x 32-bit multiplier

Memories and memory interfaces

- 16 KB program flash memory
- 4 KB SRAM

System peripherals

- LDO provides 5 V and 3 A output to down system
- CNC controls the communication and provides AC protection
- High voltage input PMC module with three power modes: Run, Wait, Stop
- LVR with reset or interrupt, selectable trip points
- WDOG with independent clock source
- Serial wire debug interface

Clocks

- 32.768 kHz or 4 MHz to 24 MHz crystal oscillator
- Internal 20 kHz low-power oscillator (LPO)
- Internal clock source (ICS)
- Internal FLL with internal or external reference, precision trimming

Operating Characteristics

- Input from rectifier voltage range: 3.5 to 20 V
- Temperature range (ambient): -40 to 85°C

Human-machine interface

- One interrupt module (IRQ)
- Up to 13 general-purpose input/output (GPIO)

Communication interfaces

- One UART module
- One I2C module

Analog Modules

- One 12-bit analog-to-digital converters (ADC) with up to 4 external channels
- One programmable gain amplifier (PGA) with differential input and output
- One analog comparator (ACMP) containing a 6-bit DAC and programmable reference input

Timers

- Two 2-channel FTMs with basic TPM function
- One periodic interrupt timers (PIT)
- One FSK demodulation timer (FSKDT)
- System tick timer (SysTick)
- One real time clock (RTC)

Security and integrity modules

- 80-bit unique identification number per chip

Ordering Information

| Part Number ¹ | Memory | | Maximum number of I/O's |
|--------------------------|------------|-----------|-------------------------|
| | Flash (KB) | SRAM (KB) | |
| MWPR1516CFM(R) | 16 | 4 | 13 |
| MWPR1516CALR | 16 | 4 | 13 |

1. To confirm current availability of orderable part numbers, go to <http://www.freescale.com> and perform a part number search.

Related Resources

| Type | Description | Resource |
|------------------|--|--|
| Selector Guide | The Freescale Solution Advisor is a web-based tool that features interactive application wizards and a dynamic product selector. | Solution Advisor |
| Product Brief | The Product Brief contains concise overview/summary information to enable quick evaluation of a device for design suitability. | WPR1516PB ¹ |
| Reference Manual | The Reference Manual contains a comprehensive description of the structure and function (operation) of a device. | WPR1516RM ¹ |
| Chip Errata | The chip mask set Errata provides additional or corrective information for a particular device mask set. | WPR1516_0N49M ¹ |
| Package drawing | Package dimensions are provided in package drawings. | QFN 32-pin: 98ASA00615D ¹ WLCSP 36-pin: 98ASA00789D ¹ |

1. To find the associated resource, go to <http://www.freescale.com> and perform a search using this term.

Figure 1 shows the functional modules in the chip.

WPR1516 Family

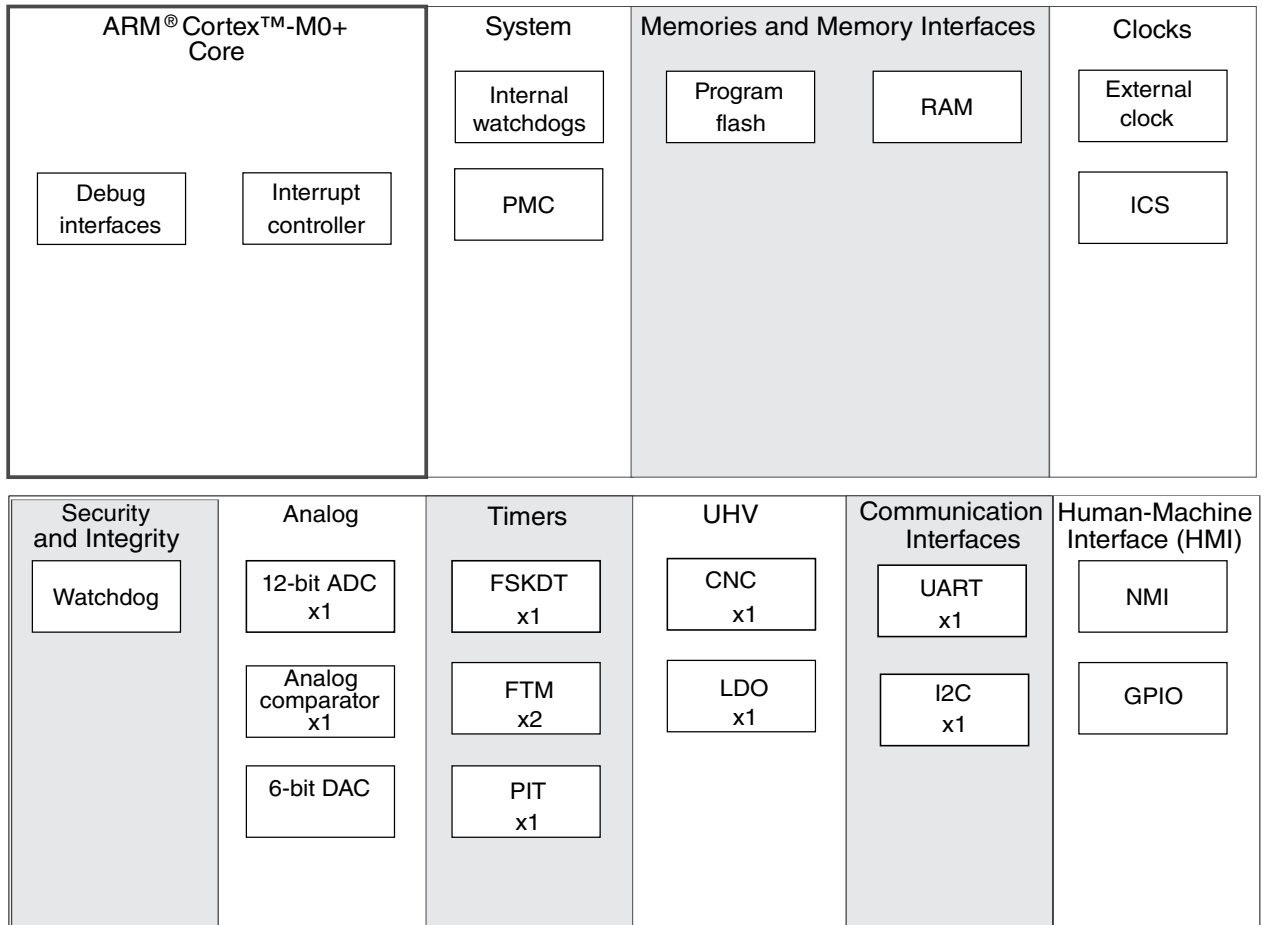


Figure 1. Functional block diagram

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1 Ratings

1.1 Thermal handling ratings

| Symbol | Description | Min. | Max. | Unit | Notes |
|------------------|-------------------------------|------|------|------|-------|
| T _{STG} | Storage temperature | -55 | 150 | °C | 1 |
| T _{SDR} | Solder temperature, lead-free | — | 260 | °C | 2 |

1. Determined according to JEDEC Standard JESD22-A103, *High Temperature Storage Life*.
2. Determined according to IPC/JEDEC Standard J-STD-020, *Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices*.

1.2 Moisture handling ratings

| Symbol | Description | Min. | Max. | Unit | Notes |
|--------|----------------------------|------|------|------|-------|
| MSL | Moisture sensitivity level | — | 3 | — | 1 |

1. Determined according to IPC/JEDEC Standard J-STD-020, *Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices*.

1.3 ESD handling ratings

| Symbol | Description ¹ | Min | Typ. | Max | Unit | Notes |
|------------------|---|-------|------|-------|------|-------|
| V _{HBM} | Electrostatic discharge voltage, human body model | -2000 | — | +2000 | V | 2 |
| V _{CDM} | Electrostatic discharge voltage, charged-device model | -500 | — | +500 | V | 3 |
| I _{LAT} | Latch-up current at ambient temperature of 85 °C | -100 | — | +100 | mA | 4 |

1. Parameter is achieved by design characterization on a small sample size from typical devices under typical conditions, unless otherwise noted.
2. Determined according to JEDEC Standard JESD22-A114, *Electrostatic Discharge (ESD) Sensitivity Testing Human Body Model (HBM)*.
3. Determined according to JEDEC Standard JESD22-C101, *Field-Induced Charged-Device Model Test Method for Electrostatic-Discharge-Withstand Thresholds of Microelectronic Components*.
4. Determined according to JEDEC Standard JESD78, *IC Latch-Up Test*.

1.4 Voltage and current operating ratings

Absolute maximum ratings are stress ratings only, and functional operation at the maximum is not guaranteed. Stress beyond the limits specified in the following table may affect device reliability or cause permanent damage to the device. For functional operating conditions, refer to the remaining tables in this document.

This device contains circuitry protecting against damage due to high static voltage or electrical fields; however, it is advised that normal precautions be taken to avoid application of any voltages higher than maximum-rated voltages to this high-impedance circuit. Reliability of operation is enhanced if unused inputs are tied to an appropriate logic voltage level (for instance, either V_{SS} or V_{DD}) or the programmable pullup resistor associated with the pin is enabled.

Table 1. Voltage and current operating ratings

| Symbol | Description | Min. | Max. | Unit |
|---------------|---|------|--------------|------|
| V_{REC} | Supply voltage from wireless receiver rectifier | 0 | 20 | V |
| $V_{AC1/AC2}$ | AC voltage input from wireless receiver coil | -0.3 | 21 | V |
| I_{VREC} | Maximum current into V_{REC} | 0 | 120 | mA |
| V_{DIO} | Digital input voltage (except $\overline{RESET_b}$, EXTAL, and XTAL) | -0.3 | $V_{DD}+0.3$ | V |
| V_{AD_IN} | Wired power input voltage | 0 | 12 | |
| V_{AIO} | <ul style="list-style-type: none"> Analog¹, \overline{RESET}, VOUT_FB, EXTAL, and XTAL input voltage VOUT and ISENS input voltage | -0.3 | $V_{DD}+0.3$ | |
| I_D | Instantaneous maximum current single pin limit <ul style="list-style-type: none"> for GPIO pins for other pins except power pins | -25 | 25 | mA |
| | | -10 | 10 | |

1. Analog pins are defined as pins that do not have an associated general-purpose I/O port function.

2 General

2.1 Nonswitching electrical specifications

2.1.1 DC electrical characteristics

This section includes information about power supply requirements and I/O pin characteristics.

Table 2. DC characteristics

| Symbol | Descriptions | | | Min. | Typical ¹ | Max. | Unit |
|--------------------|---|---|--|------------------------|----------------------|------------------------|------|
| — | Operating voltage | | | — | 3.13 | 5.5 | V |
| V _{OH} | Output high voltage | All I/O pins, standard-drive strength | 5 V, I _{load} = -5 mA | V _{DD} - 0.8 | — | — | V |
| I _{OHT} | Output high current | Max total I _{OH} for all ports | 5 V | — | — | -100 | mA |
| V _{OL} | Output low voltage | All I/O pins, standard-drive strength | 5 V, I _{load} = 5 mA | — | — | 0.8 | V |
| I _{OLT} | Output low current | Max total I _{OL} for all ports | 5 V | — | — | 100 | mA |
| V _{IH} | Input high voltage | All digital inputs | V _{DD} > 4.5 V | 0.70 × V _{DD} | — | — | V |
| V _{IH} | Input high voltage | All digital inputs | 3.13 V < V _{DD} ≤ 4.5 V | 0.75 × V _{DD} | — | — | V |
| V _{IL} | Input low voltage | All digital inputs | 3.13 V < V _{DD} ≤ 4.5 V | — | — | 0.30 × V _{DD} | V |
| V _{IL} | Input low voltage | All digital inputs | V _{DD} > 3.3 V | — | — | 0.35 × V _{DD} | V |
| V _{hys} | Input hysteresis | All digital inputs | — | 0.06 × V _{DD} | — | — | mV |
| I _{In} | Input leakage current | All input only pins (per pin) | V _{IN} = V _{DD} or V _{SS} | — | 0.1 | 1 | μA |
| I _{OZ} | Hi-Z (off-state) leakage current | All input / output (per pin) | V _{IN} = V _{DD} or V _{SS} | — | 0.1 | 1 | μA |
| I _{OZTOT} | Total leakage combined for all inputs and Hi-Z pins | All input only and I/O | V _{IN} = V _{DD} or V _{SS} | — | — | 2 | μA |

Table continues on the next page...

Table 2. DC characteristics (continued)

| Symbol | Descriptions | | | Min. | Typical ¹ | Max. | Unit |
|------------------------------|--|---|--|------|----------------------|------|------|
| R _{PU} | Pullup resistors | All digital inputs, when enabled (all I/O pins other than PTA6 or PTA7) | — | 30.0 | — | 50.0 | kΩ |
| R _{PU} ² | Pullup resistors | PTA6 and PTA7 | — | 30.0 | — | 60.0 | kΩ |
| I _{IC} | DC injection current ^{3, 4, 5, 6} | Single pin limit | V _{IN} < V _{SS} , V _{IN} > V _{DD} | -0.2 | — | 2 | mA |
| | | Total MCU limit, includes sum of all stressed pins | | -5 | — | 25 | |
| C _{In} | Input capacitance, all pins | | | — | — | 7 | pF |
| V _{RAM} | RAM retention voltage | | | — | — | — | V |

1. Typical values are measured at 25 °C. Characterized, not tested.
2. The specified resistor value is the actual value internal to the device. The pullup value may appear higher when measured externally on the pin.
3. This item applies to the GPIO share pads only.
4. All functional non-supply pins, except for PTA6 and PTA7, are internally clamped to V_{DD}.
5. Input must be current limited to the value specified. To determine the value of the required current-limiting resistor, calculate resistance values for positive and negative clamp voltages, then use the large one.
6. Power supply must maintain regulation within operating V_{DD} range during instantaneous and operating maximum current conditions. If the positive injection current (V_{IN} > V_{DD}) is higher than I_{DD}, the injection current may flow out of V_{DD} and could result in external power supply going out of regulation. Ensure that external V_{DD} load will shunt current higher than maximum injection current when the MCU is not consuming power, such as no system clock is present, or clock rate is very low (which would reduce overall power consumption).

Table 3. Power supply electrical characteristics

| Symbol | Description | Min. | Typical ¹ | Max. | Unit | |
|------------------------------|----------------------------------|--|----------------------|-----------------------|-----------------|----|
| V _{DD1.8} | Output voltage core | Full performance mode | 1.72 | 1.83 | 1.98 | V |
| | | Reduced power mode ² | — | 1.6 | — | V |
| V _{DDF} | Output Voltage Flash | Full performance mode | 2.6 | 2.81 | 2.9 | V |
| | | Reduced power mode ² | — | 1.69 | — | V |
| V _{DD} ³ | Output voltage V _{DD} | Full performance mode 3.5 V ≤ V _{REC} < 4.5 V | 3.13 | — | 4.5 | V |
| | | Full performance mode 4.5 V ≤ V _{REC} < 5.3 V | 4.19 | — | 5.25 | V |
| | | Full performance mode V _{REC} ≥ 5.3 V | 4.75 | 4.99 | 5.25 | V |
| | | Reduced power mode ² | 2.5 | — | 5.75 | V |
| I _{DD} | Load current V _{DD} | Full performance mode 3.5 V ≤ V _{REC} < 4.5 V | 0 | — | 28 | mA |
| | | Full performance mode 4.5 V ≤ V _{REC} < 5.3 V | 0 | — | 28 | mA |
| | | Full performance mode V _{REC} ≥ 5.3 V | 0 | — | 50 | mA |
| | | Reduced power mode ² | 0 | — | 5 | mA |
| V _{REFH} | Output voltage V _{REFH} | 4.1 V ≤ V _{REC} < 4.5 V | 3.781 | 3.8 | 3.819 | V |
| | | 4.5 V ≤ V _{REC} < 4.9 V | 3.781/ 4.179 | 3.8/ 4.2 ⁴ | 3.819/ 4.221 | V |

Table continues on the next page...

Table 3. Power supply electrical characteristics (continued)

| Symbol | Description | Min. | Typical ¹ | Max. | Unit | |
|----------------|---|--|------------------------------|-------------------------------|------------------------------|----------------------------|
| | | $V_{REC} \geq 4.9\text{ V}$ | 3.781/ 4.179/ 4.577 | 3.8/ 4.2/ 4.6 ⁴ | 3.819/ 4.221/ 4.623 | V |
| — | V_{REFH} accuracy | $V_{REC} \geq V_{REFH} + 0.3, 0-70\text{ }^\circ\text{C}$ | — | — | 0.5 | % |
| | | $V_{REC} \geq V_{REFH} + 0.3, -40-85\text{ }^\circ\text{C}$ | — | — | 0.8 | % |
| I_{REFH} | Output current V_{REFH} | $V_{REC} \geq V_{REFH} + 0.3$ | 0 | — | 5 | mA |
| V_{LVWA} | V_{DD} Low voltage warning assert level | PMC_LVCTLSTAT1[SLVWSEL] = 0b PMC_LVCTLSTAT1[SLVWSEL] = 1b | 3.43 3.94 | 3.63 4.14 | 3.83 4.34 | V |
| V_{LVWD} | V_{DD} Low voltage warning deassert level | PMC_LVCTLSTAT1[SLVWSEL] = 0b PMC_LVCTLSTAT1[SLVWSEL] = 1b | 3.54 4.08 | 3.74 4.28 | 3.94 4.48 | V |
| V_{LVRA} | V_{DD} low voltage reset assert | | 2.97 | 3.02 | — | V |
| V_{LVRD} | V_{DD} low voltage reset deassertl | | — | — | 3.13 | V |
| $V_{LVWREFHA}$ | Low voltage warning for V_{REFH} assert level | PMC_VREFHLVW[LVWCFCG]=00b PMC_VREFHLVW[LVWCFCG]=01b PMC_VREFHLVW[LVWCFCG]=10b PMC_VREFHLVW[LVWCFCG]=11b | 3.34 3.43 3.86 4.11 | 3.54 3.63 4.06 4.31 | 3.74 3.83 4.26 4.51 | V |
| $V_{LVWREFHA}$ | Low voltage warning for V_{REFH} deassert level | PMC_VREFHLVW[LVWCFCG]=00b PMC_VREFHLVW[LVWCFCG]=01b PMC_VREFHLVW[LVWCFCG]=10b PMC_VREFHLVW[LVWCFCG]=11b | 3.45 3.55 4.00 4.27 | 3.65 3.75 4.20 4.47 | 3.85 3.95 4.40 4.67 | V |
| $V_{LVR1.8A}$ | Low voltage reset for $V_{DD1.8}$ assert level | | 1.49 | 1.69 | 1.89 | V |
| $V_{LVR1.8D}$ | Low voltage reset for $V_{DD1.8}$ deassert level | | 1.56 | 1.76 | 1.96 | V |
| $V_{LVRDDFA}$ | Low voltage reset for V_{DDF} assert level | | 2.44 | 2.64 | 2.84 | V |
| $V_{LVRDDFD}$ | Low voltage reset for V_{DDF} deassert level | | 2.52 | 2.72 | 2.92 | V |
| f_{LPOCLK} | Trimmed LPOCLK output frequency | | — | 20 | — | kHz |
| df_{LPOCLK} | Trimmed LPOCLK internal clock $\Delta f / f_{NOMINAL}$ ⁵ | | -5 | — | 5 | % |
| t_{SDEL} | LPOCLK start up delay | | — | 25 | 50 | μs |
| dV_{HT} | Temperature sensor slope | | — | 5.07 | — | $\text{mV}/^\circ\text{C}$ |
| V_{HT} | Temperature sensor output voltage | | — | 1.57 | — | V |
| T_{HTIA} | High temperature interrupt assert ⁶ | | 95 | 110 | 125 | $^\circ\text{C}$ |
| T_{HTID} | High temperature interrupt deassert ⁶ | | 85 | 100 | 115 | $^\circ\text{C}$ |
| V_{BG} | Bandgap output voltage | | 1.13 | 1.2 | 1.32 | V |
| V_{HCBG} | HC Bandgap output voltage | | 1.14 | 1.15 | 1.16 | V |
| t_{STP_REC} | Recovery time from Stop | not including V_{REFH} including V_{REFH} | — — | 15 1 | — — | μs ms |

1. Typical values are measured at 25 °C.

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2. Power supply enters reduced power mode when MCU is in Stop mode.
3. V_{DD} is from V_{DD1} .
4. This typical value is configurable based on V_{REC} .
5. User need to trim the LPOCLK in order to get $\pm 5\%$ LPOCLK
6. This is junction temperature.

NOTE

Unless noted, V_{DD1} and V_{DD2} must be shorted on the application board.

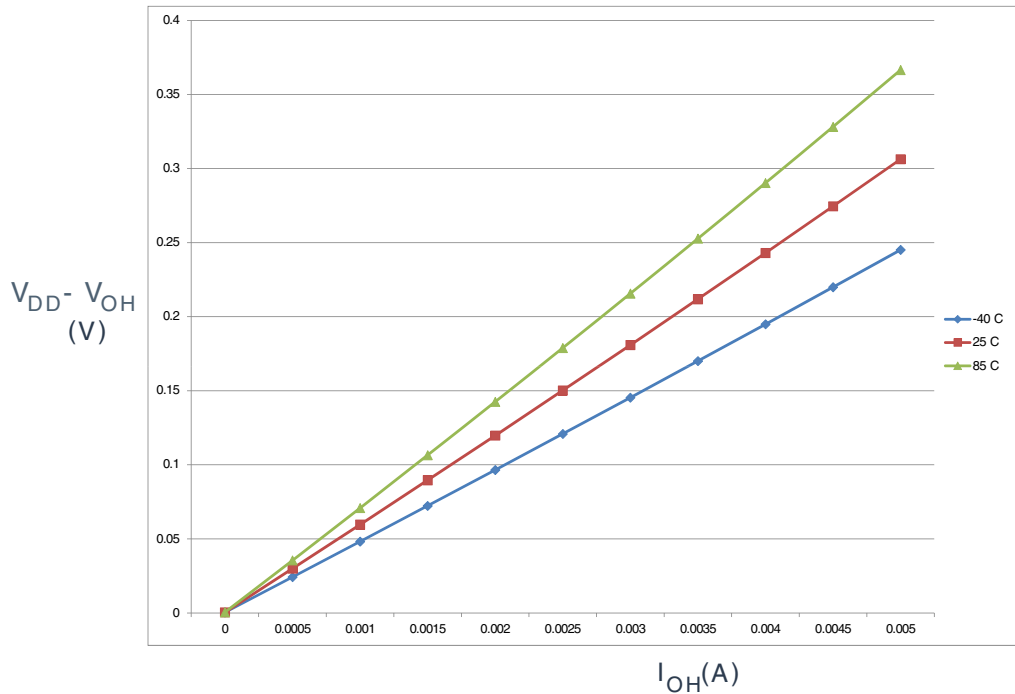


Figure 2. Typical I_{OH} Vs. $V_{DD} - V_{OH}$ (standard drive strength) ($V_{DD} = 5$ V)

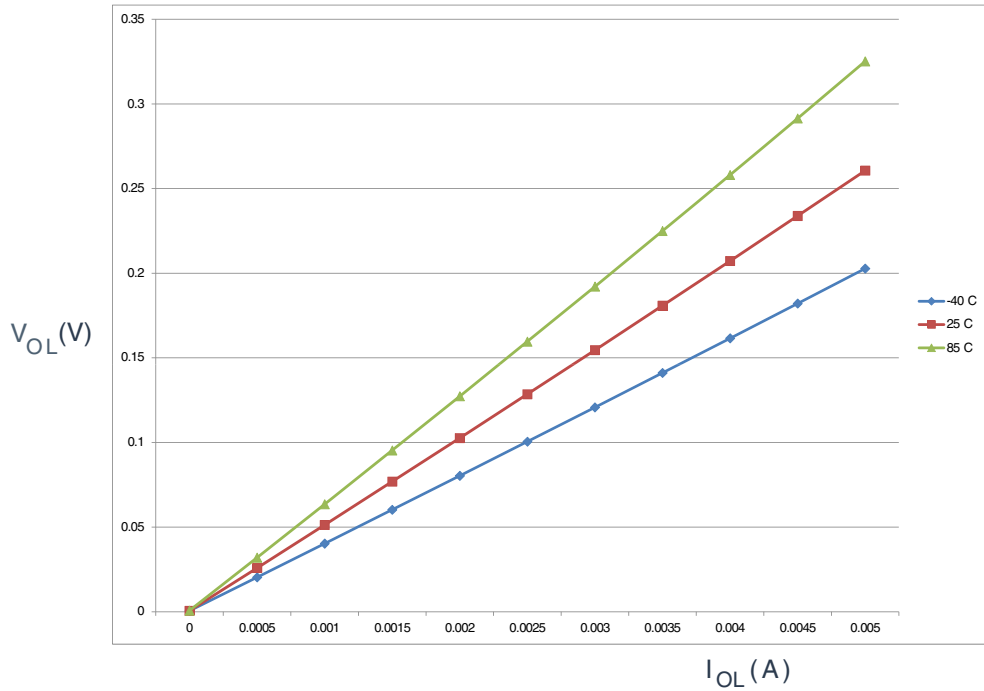


Figure 3. Typical I_{OL} Vs. V_{OL} (standard drive strength) (V_{DD} = 5 V)

2.1.2 Supply current characteristics

This section includes information about power supply current in various operating modes.

Table 4. Supply current characteristics (at 5.5 V)

| Parameter | Symbol | Bus Freq. | Typical ¹ | Max. | Unit | Temp. |
|--|-------------------|-----------|----------------------|------|------|-----------|
| Run supply current FEI mode, all modules clocks enabled; run from flash | R _I DD | 24 MHz | 13.17 | — | mA | -40–85 °C |
| | | 12 MHz | 9.37 | — | | |
| | | 6 MHz | 7.49 | — | | |
| Run supply current FEI mode, all modules clocks disabled; run from flash | R _I DD | 24 MHz | 11.17 | — | mA | -40–85 °C |
| | | 12 MHz | 8.37 | — | | |
| | | 6 MHz | 6.99 | — | | |
| Run supply current FBE mode, all modules clocks enabled; run from RAM | R _I DD | 24 MHz | 14.01 | 17 | mA | -40–85 °C |
| | | 12 MHz | 8.65 | — | | |
| | | 6 MHz | 6.60 | — | | |
| Run supply current FBE mode, all modules clocks disabled; run from RAM | R _I DD | 24 MHz | 10.61 | 13 | mA | -40–85 °C |
| | | 12 MHz | 7.65 | — | | |
| | | 6 MHz | 6.09 | — | | |
| Wait mode current FBE mode, all modules clocks enabled | W _I DD | 24 MHz | 8.23 | 10 | mA | -40–85 °C |

Table continues on the next page...

Table 4. Supply current characteristics (at 5.5 V) (continued)

| Parameter | Symbol | Bus Freq. | Typical ¹ | Max. | Unit | Temp. |
|--|------------------|-----------|----------------------|------|------|-----------|
| | | 12 MHz | 6.52 | — | | |
| | | 6 MHz | 5.53 | — | | |
| Stop mode supply current no clocks active (except CNC clock) | SI _{DD} | — | 700 | — | μA | -40–85 °C |

1. Data in Typical column was characterized at 25 °C or is typical recommended value.

2.1.3 EMC performance

Electromagnetic compatibility (EMC) performance is highly dependent on the environment in which the MCU resides. Board design and layout, circuit topology choices, location and characteristics of external components as well as MCU software operation play a significant role in EMC performance. The system designer must consult the following Freescale applications notes, available on freescale.com for advice and guidance specifically targeted at optimizing EMC performance.

- AN2321: Designing for Board Level Electromagnetic Compatibility
- AN1050: Designing for Electromagnetic Compatibility (EMC) with HCMOS Microcontrollers
- AN1263: Designing for Electromagnetic Compatibility with Single-Chip Microcontrollers
- AN2764: Improving the Transient Immunity Performance of Microcontroller-Based Applications
- AN1259: System Design and Layout Techniques for Noise Reduction in MCU-Based Systems

2.1.3.1 Radiated Emissions

Table 5. EMC radiated emissions operating behaviors for 32-pin QFN package

| Symbol | Description | Frequency band (MHz) | Typ. | Unit | Notes |
|---------------------|------------------------------------|----------------------|------|------|-------|
| V _{RE1} | Radiated emissions voltage, band 1 | 0.15–50 | 4 | dBμV | 1, 2 |
| V _{RE2} | Radiated emissions voltage, band 2 | 50–150 | 6 | dBμV | |
| V _{RE3} | Radiated emissions voltage, band 3 | 150–500 | 16 | dBμV | |
| V _{RE4} | Radiated emissions voltage, band 4 | 500–1000 | 5 | dBμV | |
| V _{RE_IEC} | IEC level | 0.15–1000 | M | — | 2, 3 |

1. Determined according to IEC Standard 61967-1, *Integrated Circuits - Measurement of Electromagnetic Emissions, 150 kHz to 1 GHz Part 1: General Conditions and Definitions* and IEC Standard 61967-2, *Integrated Circuits - Measurement of Electromagnetic Emissions, 150 kHz to 1 GHz Part 2: Measurement of Radiated Emissions—TEM Cell and Wideband TEM Cell Method*. Measurements were made while the microcontroller was running basic application code. The reported emission level is the value of the maximum measured emission, rounded up to the next whole number, from among the measured orientations in each frequency range.
2. $V_{RECT} = 5.0\text{ V}$, $T_A = 25\text{ °C}$, $f_{OSC} = 32.768\text{ kHz}$ (crystal), $f_{SYS} = 24\text{ MHz}$, $f_{BUS} = 24\text{ MHz}$
3. Specified according to Annex D of IEC Standard 61967-2, *Measurement of Radiated Emissions—TEM Cell and Wideband TEM Cell Method*

2.2 Switching specifications

2.2.1 Control timing

Table 6. Control Timing

| Rating | | Symbol | Min. | Typical ¹ | Max. | Unit |
|--|--------------------------------|--------------|----------------------|----------------------|------|------|
| Bus frequency ($t_{CYC} = 1 / f_{BUS}$) | | f_{BUS} | DC | — | 24 | MHz |
| Internal low power oscillator frequency ² | | f_{LPO} | 16 | 20 | 26 | KHz |
| External reset pulse width | | t_{EXTRST} | $1.5 \times t_{CYC}$ | — | — | ns |
| Reset low drive | | t_{RSTDRV} | $34 \times t_{CYC}$ | — | — | ns |
| External NMI pin interrupt pulse width - Asynchronous path | | t_{NMI} | 100 | — | — | ns |
| IRQ pulse width | Asynchronous path ³ | t_{ILIH} | 100 | — | — | ns |
| | Synchronous path | t_{IHIL} | $1.5 \times t_{CYC}$ | — | — | ns |
| Port rise and fall time - Normal drive strength (load = 50 pF) | — | t_{Rise} | — | 10.2 | — | ns |
| | | t_{Fall} | — | 9.5 | — | ns |

1. Typical values are based on characterization data at $V_{DD} = 5.0\text{ V}$, 25 °C unless otherwise stated.
2. It can be configured by `PMC_RC20KTRM[OSCOT]`.
3. This is the shortest pulse that is guaranteed to be recognized as a IRQ pin request.

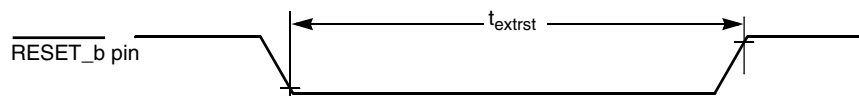


Figure 4. Reset Timing

Thermal specifications

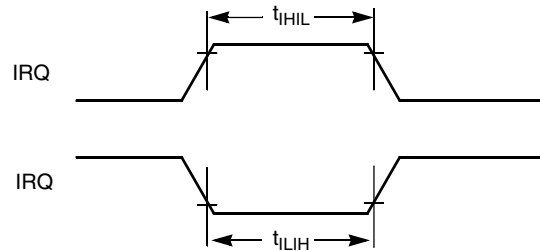


Figure 5. IRQ Timing

2.2.2 FTM module timing

Synchronizer circuits determine the shortest input pulses that can be recognized. These synchronizers operate from the timer clock.

Table 7. FTM Input Timing

| Function | Symbol | Min. | Max. | Unit |
|---------------------------|------------|------|------|---------------|
| Input capture pulse width | t_{ICPW} | 1.5 | — | t_{Timer}^1 |

1. $t_{Timer} = 1/f_{Timer}$

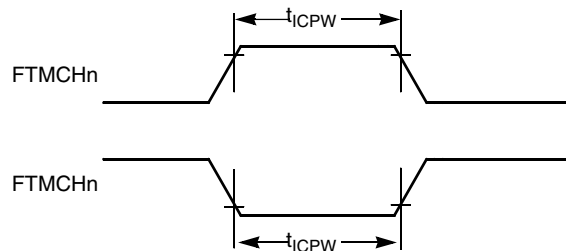


Figure 6. Timer Input Capture Pulse

2.3 Thermal specifications

2.3.1 Thermal operating requirements

Table 8. Thermal operating requirements of WLCSP package

| Symbol | Description | Min. | Max | Unit | Notes |
|--------|--------------------------|------|-----|------|-------|
| T_J | Die junction temperature | -40 | 95 | °C | |
| T_A | Ambient temperature | -40 | 85 | °C | 1 |

1. Maximum T_A can be exceeded only if the user ensures that T_J does not exceed the maximum. The simplest method to determine T_J is: $T_J = T_A + \theta_{JA} \times \text{chip power dissipation}$.

Table 9. Thermal operating requirements of QFN package

| Symbol | Description | Min. | Max | Unit | Notes |
|----------------|--------------------------|------|-----|------|-------|
| T _J | Die junction temperature | -40 | 105 | °C | |
| T _A | Ambient temperature | -40 | 85 | °C | 1 |

1. Maximum T_A can be exceeded only if the user ensures that T_J does not exceed the maximum. The simplest method to determine T_J is: $T_J = T_A + \theta_{JA} \times \text{chip power dissipation}$.

2.3.2 Thermal characteristics

This section provides information about operating temperature range, power dissipation, and package thermal resistance. Power dissipation on I/O pins is usually small compared to the power dissipation in on-chip logic and voltage regulator circuits, and it is user-determined rather than being controlled by the MCU design. To take P_{I/O} into account in power calculations, determine the difference between actual pin voltage and V_{SS} or V_{DD} and multiply by the pin current for each I/O pin. Except in cases of unusually high pin current (heavy loads), the difference between pin voltage and V_{SS} or V_{DD} will be very small.

Table 10. Thermal Attributes

| Board type | Symbol | Description | 32 QFN | 36 WLCSP | Unit | Notes |
|-------------------|-------------------|--|--------|----------|------|-------|
| Single-layer (1S) | R _{θJA} | Thermal resistance, junction to ambient (natural convection) | 97 | 129.8 | °C/W | 1, 2 |
| Four-layer (2s2p) | R _{θJA} | Thermal resistance, junction to ambient (natural convection) | 33 | 71.4 | °C/W | 1, 3 |
| Single-layer (1S) | R _{θJMA} | Thermal resistance, junction to ambient (200 ft./min. air speed) | 81 | 116.5 | °C/W | 1, 3 |
| Four-layer (2s2p) | R _{θJMA} | Thermal resistance, junction to ambient (200 ft./min. air speed) | 27 | 68.0 | °C/W | 1, 3 |
| — | R _{θJB} | Thermal resistance, junction to board | 12 | 48.6 | °C/W | 4 |
| — | R _{θJC} | Thermal resistance, junction to case | 1.3 | 8.1 | °C/W | 5 |
| — | Ψ _{JT} | Thermal characterization parameter, junction to package top outside center (natural convection) | 3 | 0.2 | °C/W | 6 |
| — | Ψ _{JB} | Thermal characterization parameter, junction to package bottom outside center (natural convection) | — | 14.3 | °C/W | 7 |

1. Junction temperature is a function of die size, on-chip power dissipation, package thermal resistance, mounting site (board) temperature, ambient temperature, air flow, power dissipation of other components on the board, and board thermal resistance.

Peripheral operating requirements and behaviors

2. JESD51-2 with the single layer board (JESD51-3) horizontal.
3. Per JEDEC JESD51-6 with the board (JESD51-7) horizontal.
4. Thermal resistance between the die and the printed circuit board per JEDEC JESD51-8. Board temperature is measured on the top surface of the board near the package.
5. Thermal resistance between the die and the solder pad on the bottom of the package. Interface resistance is ignored.
6. Thermal characterization parameter indicating the temperature difference between package top and the junction temperature per JEDEC JESD51-2. When Greek letters are not available, the thermal characterization parameter is written as Psi-JT.
7. Thermal characterization parameter indicating the temperature difference between package bottom center and the junction temperature per JEDEC JESD51-12. When Greek letters are not available, the thermal characterization parameter is written as Psi-JB.

The average chip-junction temperature (T_J) in °C can be obtained from:

$$T_J = T_A + (P_D \times \theta_{JA})$$

Where:

T_A = Ambient temperature, °C

θ_{JA} = Package thermal resistance, junction-to-ambient, °C/W

$$P_D = P_{INT} + P_{I/O}$$

$P_{INT} = I_{DD} \times V_{DD}$, Watts - chip internal power

$P_{I/O}$ = Power dissipation on input and output pins - user determined

For most applications, $P_{I/O} \ll P_{INT}$ and can be neglected. An approximate relationship between P_D and T_J (if $P_{I/O}$ is neglected) is:

$$P_D = K \div (T_J + 273 \text{ °C})$$

Solving the equations above for K gives:

$$K = P_D \times (T_A + 273 \text{ °C}) + \theta_{JA} \times (P_D)^2$$

Where K is a constant pertaining to the particular part. K can be determined by measuring P_D (at equilibrium) for an known T_A . Using this value of K, the values of P_D and T_J can be obtained by solving the above equations iteratively for any value of T_A .

3 Peripheral operating requirements and behaviors

3.1 UHV modules

3.1.1 LDO electrical characteristics

This section provides data about the LDO module electrical characteristics.

Table 11. LDO electrical characteristics

| Symbol | Description | | Min. | Typical | Max. | Unit |
|-------------------|--|--|------------|--|------|------|
| V _{OUT1} | Regulated output voltage | | 4.2 | 5 | 5.2 | V |
| V _{OUTA} | Output voltage accuracy | | — | 2 ² | — | % |
| V _{TH1} | Over voltage protection de-assert | LDO_CR[OVTHLD]=00b LDO_CR[OVTHLD]=01b LDO_CR[OVTHLD]=10b LDO_CR[OVTHLD]=11b | — | 4.27 4.62 5.33 5.78 | — | V |
| V _{TH2} | Over voltage protection assert | LDO_CR[OVTHLD]=00b LDO_CR[OVTHLD]=01b LDO_CR[OVTHLD]=10b LDO_CR[OVTHLD]=11b | — | 4.8 5.2 6.0 6.5 | — | V |
| I _{LIM} | Current limit threshold, with sample resistor: | 33 mΩ 100 mΩ | 0.3 0.1 | N x 1.4/(511 x 10 x R _{sense}) ³ | — | A |
| I _{TH1} | Over current protection threshold | LDO_CR[OCTHLD]=000b LDO_CR[OCTHLD]=001b LDO_CR[OCTHLD]=010b LDO_CR[OCTHLD]=011b LDO_CR[OCTHLD]=100b LDO_CR[OCTHLD]=101b LDO_CR[OCTHLD]=110b LDO_CR[OCTHLD]=111b | — | 1.05/(10 x R _{sense}) 1.10/(10 x R _{sense}) 1.15/(10 x R _{sense}) 1.20/(10 x R _{sense}) 1.25/(10 x R _{sense}) 1.30/(10 x R _{sense}) 1.35/(10 x R _{sense}) 1.40/(10 x R _{sense}) | — | A |

1. V_{OUT} is configurable by LDO_VTRM[VTRM], it must be lower than 5.2 V. User can check the voltage dropout of MOSFET to avoid over power consumption.
2. This value is affected by the precision of the output voltage divider resistor.
3. N is configured by LDO_VTRM[VTRM].

3.1.2 Programmable gain amplifier (PGA) electronic characterizations

This section includes information about PGA.

Table 12. PGA electrical characteristics (4.5 V ≤ VDDA ≤ 5.5 V)

| Symbol | Description | Min. | Typical | Max. | Unit | |
|----------------------|--|--------------------|---------|------|--------|-----|
| Gain | Programmable gain | PGA_CTRL[GAIN]=00b | — | 8 | — | |
| | | PGA_CTRL[GAIN]=01b | | 10 | | |
| | | PGA_CTRL[GAIN]=10b | | 15 | | |
| | | PGA_CTRL[GAIN]=11b | | 20 | | |
| dGain/dT | Gain versus temperature | — | 10 | — | ppm/°C | |
| V _{OS} | Input referred offset voltage ¹ | -12 | — | 12 | mV | |
| dV _{OS} /dT | Input referred offset voltage versus temperature | — | 20 | — | μV/°C | |
| I _{IN_BIAS} | Input BIAS current | — | — | 250 | μA | |
| Bw(-3 dB) | PGA -3 dB bandwidth | PGA_CTRL[GAIN]=00b | — | — | 2.0 | MHz |
| | | PGA_CTRL[GAIN]=01b | | | 1.6 | |
| | | PGA_CTRL[GAIN]=10b | | | 1.0 | |
| | | PGA_CTRL[GAIN]=11b | | | 0.8 | |
| PSRR | Power supply rejection ratio | — | -60 | — | dB | |
| CMRR | Common mode rejection ratio | — | -60 | — | dB | |
| VR_CM_IN | Input common mode voltage | 4.5 | 5 | 5.5 | V | |
| VR_DM_IN | Input differential mode voltage | PGA_CTRL[GAIN]=00b | — | — | 250 | mV |
| | | PGA_CTRL[GAIN]=01b | | | 200 | |
| | | PGA_CTRL[GAIN]=10b | | | 130 | |
| | | PGA_CTRL[GAIN]=11b | | | 100 | |

1. The output referred offset of PGA is digitized by the on-chip ADC and stored in certain memory of each chip, customer can access the data to perform system level calibration.

3.1.3 Communication and clamp controller (CNC) electronic characterizations

This section includes information about FSK Zero-Crossing, VREC and VAD analog comparators.

Table 13. FSK analog comparator electrical specifications

| Symbol | Characteristic | Min. | Typical | Max. | Unit | |
|------------------|------------------------------|----------------------------|---------|-----------------------|------|----|
| V _{DDA} | Supply voltage | 3.5 | — | 5.5 | V | |
| I _{DDA} | Power consumption | — | 270 | — | μA | |
| V _{AIN} | Analog input range | V _{SS} | — | V _{DD} - 1.4 | V | |
| V _{AIO} | Analog input offset voltage | — | — | 20 | mV | |
| V _H | Analog comparator hysteresis | CNC_ANACFG1[ZCDHYST] = 00b | — | 0 | — | mV |
| | | CNC_ANACFG1[ZCDHYST] = 01b | | 18 | | |

Table 13. FSK analog comparator electrical specifications

| Symbol | Characteristic | Min. | Typical | Max. | Unit |
|--------|----------------------------|------|---------|------|------|
| | CNC_ANACFG1[ZCDHYST] = 10b | | 40 | | |
| | CNC_ANACFG1[ZCDHYST] = 11b | | 60 | | |

Table 14. CNC over-voltage protect (OVP) and low-voltage protect (LVP) electrical specifications

| Symbol | Characteristic | Min. | Typical | Max. | Unit | |
|-----------------------|--------------------|----------------------------|---------|------|------|---|
| V _{REC-OVP} | VREC OVP assert | CNC_ANACFG1[VRECOVLVL]=00b | — | 25.7 | — | V |
| | | CNC_ANACFG1[VRECOVLVL]=01b | 21.5 | 22.5 | 23.2 | |
| | | CNC_ANACFG1[VRECOVLVL]=10b | 19.3 | 20.3 | 21.2 | |
| | | CNC_ANACFG1[VRECOVLVL]=11b | 16.4 | 17.1 | 18 | |
| V _{REC-OVPR} | VREC OVP de-assert | CNC_ANACFG1[VRECOVLVL]=00b | — | 20.4 | — | V |
| | | CNC_ANACFG1[VRECOVLVL]=01b | 17 | 17.8 | 18.4 | |
| | | CNC_ANACFG1[VRECOVLVL]=10b | 15.2 | 16.2 | 16.8 | |
| | | CNC_ANACFG1[VRECOVLVL]=11b | 12.8 | 13.5 | 14 | |
| V _{REC-LVP} | VREC LVP assert | 4.3 | 4.5 | 4.7 | V | |
| V _{REC-LVPR} | VREC LVP de-assert | 4.9 | 5.1 | 5.3 | V | |
| V _{AD-OVP} | VAD OVP assert | 5.5 | 5.7 | 5.9 | V | |
| V _{AD-OVPR} | VAD OVP de-assert | 5.15 | 5.3 | 5.5 | V | |
| V _{AD-OK} | VAD LVP assert | 4.15 | 4.3 | 4.55 | V | |
| V _{AD-OK} | VAD LVP de-assert | 3.95 | 4.0 | 4.25 | V | |

3.2 Core modules

3.2.1 SWD electricals

Table 15. SWD full voltage range electricals

| Symbol | Description | Min. | Max. | Unit |
|--------|--|------|------|------|
| J1 | SWD_CLK frequency of operation <ul style="list-style-type: none"> Serial wire debug | 0 | 24 | MHz |
| J2 | SWD_CLK cycle period | 1/J1 | — | ns |
| J3 | SWD_CLK clock pulse width <ul style="list-style-type: none"> Serial wire debug | 20 | — | ns |
| J4 | SWD_CLK rise and fall times | — | 3 | ns |

Table continues on the next page...

Table 15. SWD full voltage range electricals (continued)

| Symbol | Description | Min. | Max. | Unit |
|--------|---|------|------|------|
| J9 | SWD_DIO input data setup time to SWD_CLK rise | 10 | — | ns |
| J10 | SWD_DIO input data hold time after SWD_CLK rise | 3 | — | ns |
| J11 | SWD_CLK high to SWD_DIO data valid | — | 35 | ns |
| J12 | SWD_CLK high to SWD_DIO high-Z | 0 | — | ns |

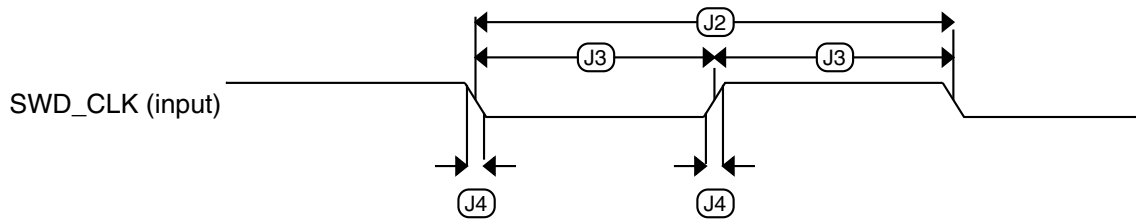


Figure 7. Serial wire clock input timing

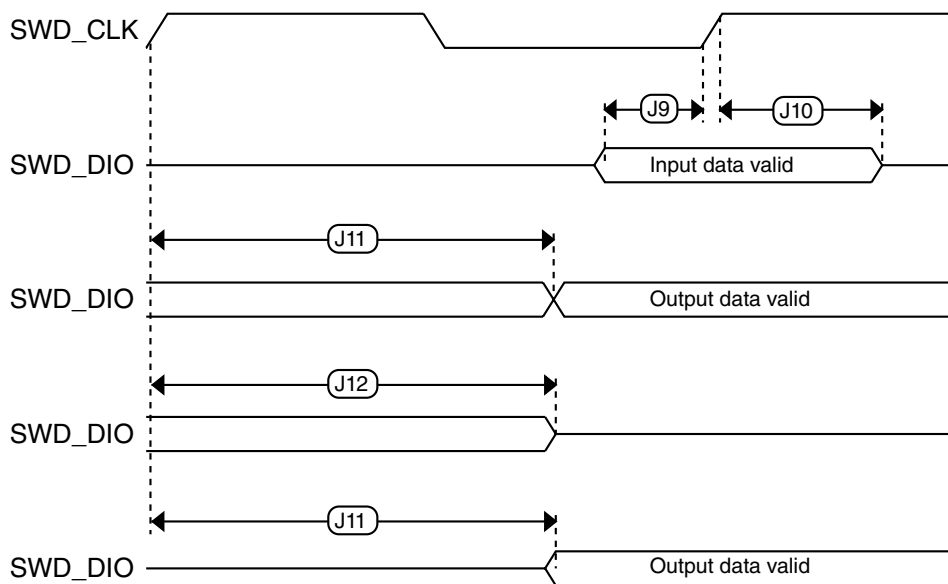


Figure 8. Serial wire data timing

3.3 Clock modules

3.3.1 External oscillator (OSC) and ICS characteristics

Table 16. OSC and ICS specifications (temperature range = -40 to 85 °C ambient)

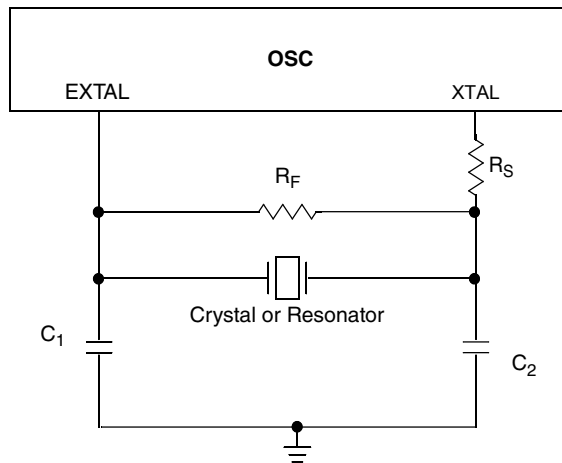
| Characteristic | | Symbol | Min | Typical ¹ | Max | Unit |
|--|--|----------------------|-----------------------|----------------------|---------|------------|
| Crystal or resonator frequency | Low range (RANGE = 0) | f_{lo} | 31.25 | 32.768 | 39.0625 | kHz |
| | High range (RANGE = 1) | f_{hi} | 4 | — | 24 | MHz |
| Load capacitors | | C1, C2 | See Note ² | | | |
| Feedback resistor | Low Frequency, Low-Power Mode ³ | R_F | — | — | — | M Ω |
| | Low Frequency, High-Gain Mode | | — | 10 | — | M Ω |
| | High Frequency, Low-Power Mode | | — | 1 | — | M Ω |
| | High Frequency, High-Gain Mode | | — | 1 | — | M Ω |
| Series resistor - Low Frequency | Low-Power Mode ³ | R_S | — | 0 | — | k Ω |
| | High-Gain Mode | | — | 200 | — | k Ω |
| Series resistor - High Frequency | Low-Power Mode ³ | R_S | — | 0 | — | k Ω |
| Series resistor - High Frequency, High-Gain Mode | 4 MHz | R_S | — | 0 | — | k Ω |
| | 8 MHz | | — | 0 | — | k Ω |
| | 16 MHz | | — | 0 | — | k Ω |
| | 24 MHz | | — | 0 | — | k Ω |
| Crystal start-up time low range = 32.768 kHz crystal; High range = 24 MHz crystal ^{4,5} | Low range, low power | t_{CSTL} | — | 1000 | — | ms |
| | Low range, high gain | | — | 800 | — | ms |
| | High range, low power | t_{CSTH} | — | 3 | — | ms |
| | High range, high gain | | — | 1.5 | — | ms |
| Internal reference start-up time | | t_{IRST} | — | 20 | 50 | μ s |
| Internal reference clock (IRC) frequency trim range | | f_{int_t} | 31.25 | — | 39.0625 | kHz |
| Internal reference clock frequency, factory trimmed | T = 25 °C, V _{DD} = 5 V | f_{int_ft} | — | 37.5 | — | kHz |
| DCO output frequency range | FLL reference = f_{int_t} , f_{lo} , or $f_{hi}/RDIV$ | f_{dco} | 40 | — | 50 | MHz |
| Factory trimmed internal oscillator accuracy | T = 25 °C, V _{DD} = 5 V | Δf_{int_ft} | -0.5 | — | 0.5 | % |
| Deviation of IRC over temperature when trimmed at T = 25 °C, V _{DD} = 5 V | Over temperature range from -40 °C to 85 °C | Δf_{int_t} | -1 | — | 0.5 | % |
| | Over temperature range from 0 °C to 85 °C | Δf_{int_t} | -0.5 | — | 0.5 | |
| Frequency accuracy of DCO output using factory trim value | Over temperature range from -40 °C to 85 °C | Δf_{dco_ft} | -2 | — | 1.5 | % |
| | Over temperature range from 0 °C to 85 °C | Δf_{dco_ft} | -1 | — | 1.5 | |

Table continues on the next page...

**Table 16. OSC and ICS specifications (temperature range = -40 to 85 °C ambient)
(continued)**

| Characteristic | Symbol | Min | Typical ¹ | Max | Unit |
|---|---------------|-----|----------------------|-----|-------------|
| FLL acquisition time ^{4,6} | $t_{Acquire}$ | — | — | 2 | ms |
| Long term jitter of DCO output clock (averaged over 2 ms interval) ⁷ | C_{Jitter} | — | 0.02 | 0.2 | % f_{dco} |

1. Data in Typical column was characterized at 5.0 V, 25 °C or is typical recommended value.
2. See crystal or resonator manufacturer's recommendation.
3. Load capacitors (C_1, C_2), feedback resistor (R_F) and series resistor (R_S) are incorporated internally when RANGE = HGO = 0.
4. This parameter is characterized and not tested on each device.
5. Proper PC board layout procedures must be followed to achieve specifications.
6. This specification applies to any time the FLL reference source or reference divider is changed, trim value changed, or changing from FLL disabled (FBELP, FBILP) to FLL enabled (FEI, FEE, FBE, FBI). If a crystal/resonator is being used as the reference, this specification assumes it is already running.
7. Jitter is the average deviation from the programmed frequency measured over the specified interval at maximum f_{BUS} . Measurements are made with the device powered by filtered supplies and clocked by a stable external clock signal. Noise injected into the FLL circuitry via V_{DD} and V_{SS} and variation in crystal oscillator frequency increase the C_{Jitter} percentage for a given interval.

**Figure 9. Typical crystal or resonator circuit**

3.4 Memories and memory interfaces

3.4.1 NVM specifications

This section provides details about program / erase times, program / erase endurance for the flash memory.

Table 17. Flash characteristics

| Characteristic | Symbol | Min. ¹ | Typical ² | Max. ³ | Unit ⁴ |
|--|----------------------|-------------------|----------------------|-------------------|-------------------|
| NVM Bus frequency | f _{NVMBUS} | 1 | — | 25 | MHz |
| NVM Operating frequency | f _{NVMOP} | 0.8 | 1 | 1.05 | MHz |
| Erase Verify All Blocks | t _{VFYALL} | — | — | 4653 | t _{CYC} |
| Erase Verify Flash Block | t _{RD1BLK} | — | — | 4626 | t _{CYC} |
| Erase Verify Flash Section | t _{RD1SEC} | — | — | 482 | t _{CYC} |
| Read Once | t _{RDONCE} | — | — | 464 | t _{CYC} |
| Program Flash (2 words) | t _{PGM2} | 0.14 | 0.14 | 0.35 | ms |
| Program Flash (4 words) | t _{PGM4} | 0.23 | 0.23 | 0.56 | ms |
| Program Once | t _{PGMONCE} | 0.22 | 0.23 | 0.23 | ms |
| Erase All Blocks | t _{ERSALL} | 95.54 | 100.31 | 100.56 | ms |
| Erase Flash Block | t _{ERSBLK} | 95.54 | 100.31 | 100.56 | ms |
| Erase Flash Sector | t _{ERSPG} | 19.11 | 20.06 | 20.10 | ms |
| Unsecure Flash | t _{UNSECU} | 95.55 | 100.31 | 100.57 | ms |
| Configure NVM | t _{CONFNVM} | — | — | 381 | t _{CYC} |
| Verify Backdoor Access Key | t _{VFYKEY} | — | — | 482 | t _{CYC} |
| Set User Margin Level | t _{MLOADU} | — | — | 420 | t _{CYC} |
| FLASH Program/erase endurance T _L to T _H = -40 °C to 105 °C | n _{FLPE} | 10 k | 100 k | — | Cycles |
| Data retention at an average junction temperature of T _{JAVG} = 85 °C after up to 10,000 program / erase cycles | t _{D_RET} | 15 | 100 | — | years |

1. Minimum times are based on maximum f_{NVMOP} and maximum f_{NVMBUS}
2. Typical times are based on typical f_{NVMOP} and maximum f_{NVMBUS}
3. Maximum times are based on typical f_{NVMOP} and typical f_{NVMBUS} plus aging
4. t_{CYC} = 1 / f_{NVMBUS}

Program and erase operations do not require any special power sources other than the normal V_{DD} supply. For more detailed information about program and erase operations, see the Memory section.

3.5 Analog

3.5.1 IFR measurement conditions

The value stored in the IFR is measured under the conditions of the following table.

Table 18. IFR measurement conditions

| Symbol | Descriptions | Value | Unit |
|------------|---|----------|------|
| V_{REFH} | ADC reference voltage | 5 | V |
| V_{REC} | Supply voltage from wireless receiver rectifier | 5 | V |
| V_{DDX} | I/O supply voltage | 5 | V |
| f_{BUS} | Bus frequency | 24 | MHz |
| T_A | Ambient temperature | 25 | °C |
| — | Code execution | From RAM | — |
| — | NVM activity | — | — |

3.5.2 ADC characteristics

This section describes the ADC characteristics.

Table 19. ADC Operating Conditions

| Characteristic | | Symbol | Min | Typ | Max | Unit |
|--|-------------------|-------------------|---------------|-----|---------------|------------------|
| Reference potential | Low | V_{RL} | V_{SSA} | — | $V_{DDA} / 2$ | V |
| | High | V_{RH} | $V_{DDA} / 2$ | — | V_{DDA} | V |
| Differential reference voltage ¹ | | $V_{RH} - V_{RL}$ | 3.13 | 5.0 | 5.5 | V |
| ADC Clock Frequency (derived from bus clock via the prescaler bus) | | f_{ATDCLK} | 0.25 | — | 8.33 | MHz |
| Buffer amplifier turn on time (delay after module start / recovery from Stop mode) | | t_{REC} | — | — | 1 | µs |
| ADC disable time | | $t_{DISABLE}$ | — | — | 3 | bus clock cycles |
| ADC Conversion Period ² | 12-bit resolution | N_{CONV12} | 19 | — | 39 | ADC clock cycles |
| | 10-bit resolution | N_{CONV10} | 18 | — | 38 | |
| | 8-bit resolution | N_{CONV8} | 16 | — | 36 | |

1. Full accuracy is not guaranteed when differential voltage is less than 4.50 V.

2. The minimum time assumes a sample time of four ATD clock cycles. The maximum time assumes a sample time of 24 ATD clock cycles.

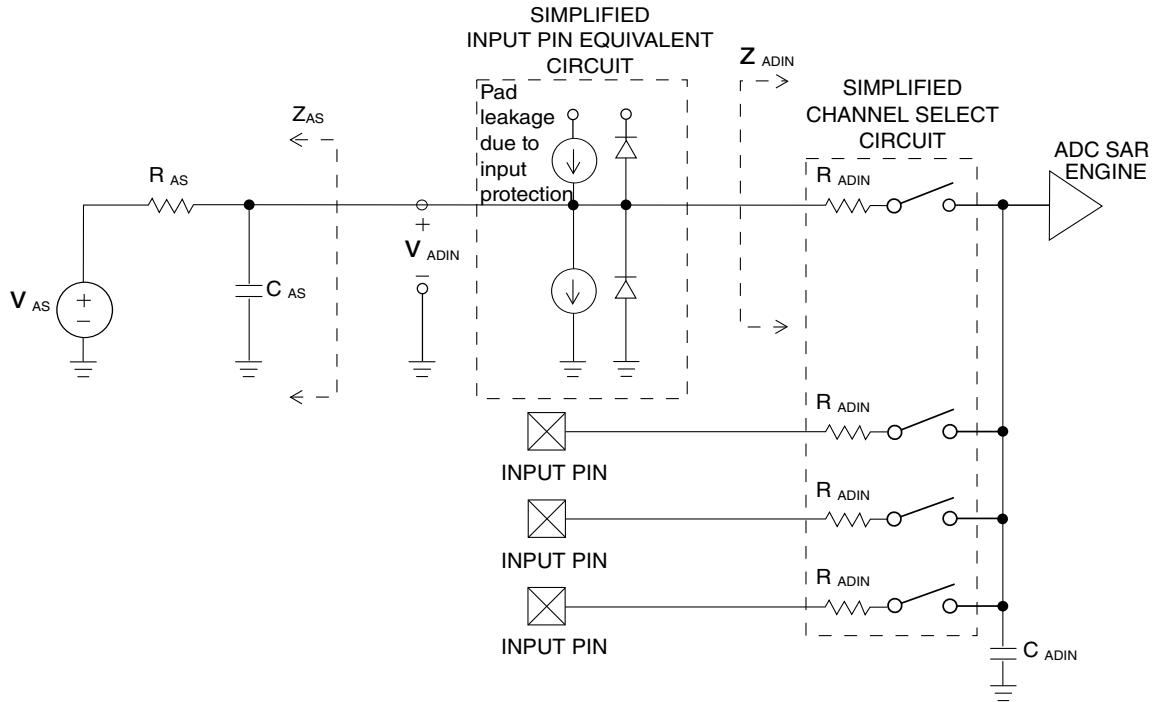


Figure 10. ADC Input Impedance Equivalency Diagram

Table 20. ADC Electrical Characteristics

| Characteristic | Symbol | Min | Typical | Max | Unit |
|---|-----------|------|---------|------|------------|
| Max input source resistance | R_S | — | — | 1 | K Ω |
| Total input capacitance Non sampling | C_{INN} | — | — | 10 | pF |
| Total input capacitance sampling | C_{INS} | — | — | 16 | |
| Input internal Resistance | R_{INA} | — | 5 | 15 | K Ω |
| Disruptive analog input current | I_{NA} | 0.25 | — | 2.5 | mA |
| Coupling ratio positive current injection | K_p | — | — | 1E-4 | A/A |
| Coupling ratio negative current injection | K_n | — | — | 5E-3 | A/A |

Table 21. ADC Conversion Performance

| Characteristic ¹ | | Symbol | Min | Typical | Max | Unit |
|-----------------------------|--------|--------|------|-----------|-----|--------|
| Resolution | 12-Bit | LSB | — | 1.25 | — | mV |
| Differential Nonlinearity | 12-Bit | DNL | -4 | ± 2 | 4 | counts |
| Integral Nonlinearity | 12-Bit | INL | -5 | ± 2.5 | 5 | counts |
| Absolute Error ² | 12-Bit | AE | -7 | ± 4 | 7 | counts |
| Resolution | 10-Bit | LSB | — | 5 | — | mV |
| Differential Nonlinearity | 10-Bit | DNL | -1 | ± 0.5 | 1 | counts |
| Integral Nonlinearity | 10-Bit | INL | -2.5 | ± 1 | 2.5 | counts |
| Absolute Error ² | 10-Bit | AE | -3 | ± 2 | 3 | counts |

Table continues on the next page...

Table 21. ADC Conversion Performance (continued)

| Characteristic ¹ | | Symbol | Min | Typical | Max | Unit |
|-----------------------------|-------|--------|------|---------|-----|--------|
| Resolution | 8-Bit | LSB | — | 20 | — | mV |
| Differential Non-linearity | 8-Bit | DNL | -0.5 | ±0.3 | 0.5 | counts |
| Integral Non-linearity | 8-Bit | INL | -1 | ±0.5 | 1 | counts |
| Absolute Error ² | 8-Bit | AE | -1.5 | ±1 | 1.5 | counts |

1. The 8-bit and 10-bit mode operation is structurally tested in production test. Absolute values are tested in 12-bit mode.
2. These values include the quantization error which is inherently 1/2 count for any ADC.

NOTE

Supply voltage $V_{DDA} = 5.12$ V. External $V_{REF} = V_{RH} - V_{RL} = 5.12$ V. $f_{ADCCLK} = 8.0$ MHz The values are tested to be valid with no IO PORT output drivers switching simultaneous with conversions.

3.5.3 Analog comparator (ACMP) electricals**Table 22. Comparator electrical specifications**

| Characteristic | Symbol | Min | Typical | Max | Unit |
|---|--------------|----------------|---------|-----------|------------------|
| Supply current (Operation mode) | I_{DDA} | — | 10 | 20 | μA |
| Supply current, low-speed mode (EN = 1, PMODE = 0) | I_{DDL5} | — | 18 | 20 | μA |
| Analog input voltage | V_{AIN} | $V_{SS} - 0.3$ | — | V_{DDA} | V |
| Analog input offset voltage | V_{AIO} | — | — | 40 | mV |
| Analog comparator hysteresis (HYST=0) | V_H | — | 15 | 20 | mV |
| Analog comparator hysteresis (HYST=1) | V_H | — | 20 | 30 | mV |
| Analog comparator initialization delay ¹ | | — | — | 40 | μs |
| Supply current (Off mode) | I_{DDAOFF} | — | 60 | — | nA |
| 6-bit DAC current adder (enabled) | I_{DAC6b} | — | 7 | — | μA |
| Propagation Delay | t_D | — | 0.4 | 1 | μs |
| 6-bit DAC integral non-linearity | INL | -0.5 | — | 0.5 | LSB ² |
| 6-bit DAC differential non-linearity | DNL | -0.3 | — | 0.3 | LSB ² |

1. Comparator initialization delay is defined as the time between software writes to change control inputs (writes to DACEN, VRSEL, PSEL, MSEL, VOSEL) and the comparator output settling to a stable level.
2. $1 \text{ LSB} = V_{\text{reference}}/64$

3.6 Communication interfaces

3.6.1 Inter-Integrated Circuit Interface (I2C) timing

Table 23. I2C timing

| Characteristic | Symbol | Standard Mode | | Fast Mode ¹ | | Unit |
|--|---------------|------------------|-------------------|----------------------------|------------------|---------|
| | | Minimum | Maximum | Minimum | Maximum | |
| SCL Clock Frequency | f_{SCL} | 0 | 100 | 0 | 400 ² | kHz |
| Hold time (repeated) START condition. After this period, the first clock pulse is generated. | $t_{HD}; STA$ | 4 | — | 0.6 | — | μs |
| LOW period of the SCL clock | t_{LOW} | 4.7 | — | 1.3 | — | μs |
| HIGH period of the SCL clock | t_{HIGH} | 4 | — | 0.6 | — | μs |
| Set-up time for a repeated START condition | $t_{SU}; STA$ | 4.7 | — | 0.6 | — | μs |
| Data hold time for I ² C bus devices | $t_{HD}; DAT$ | 0 ³ | 3.45 ⁴ | 0 ⁵ | 0.9 ³ | μs |
| Data set-up time | $t_{SU}; DAT$ | 250 ⁶ | — | 100 ^{4, 7} | — | ns |
| Rise time of SDA and SCL signals | t_r | — | 1000 | $20 + 0.1C_b$ ⁸ | 300 | ns |
| Fall time of SDA and SCL signals | t_f | — | 300 | $20 + 0.1C_b$ ⁷ | 300 | ns |
| Set-up time for STOP condition | $t_{SU}; STO$ | 4 | — | 0.6 | — | μs |
| Bus free time between STOP and START condition | t_{BUF} | 4.7 | — | 1.3 | — | μs |
| Pulse width of spikes that must be suppressed by the input filter | t_{SP} | N/A | N/A | 0 | 50 | ns |

1. Fast mode is fully supported on all pins at $V_{DD} > 2.7$ V. If $V_{DD} < 2.7$ V, only pins that support high drive strength can support fast mode with maximum bus loading.
2. The maximum SCL Clock Frequency in Fast mode with maximum bus loading can only be achieved when using the High drive pins (see [Voltage and current operating behaviors](#)) or when using the Normal drive pins and $V_{DD} \geq 2.7$ V.
3. The master mode I²C deasserts ACK of an address byte simultaneously with the falling edge of SCL. If no slaves acknowledge this address byte, then a negative hold time can result, depending on the edge rates of the SDA and SCL lines.
4. The maximum $t_{HD}; DAT$ must be met only if the device does not stretch the LOW period (t_{LOW}) of the SCL signal.
5. Input signal Slew = 10 ns and Output Load = 50 pF
6. Set-up time in slave-transmitter mode is 1 IPBus clock period, if the TX FIFO is empty.
7. A Fast mode I²C bus device can be used in a Standard mode I²C bus system, but the requirement $t_{SU}; DAT \geq 250$ ns must then be met. This is automatically the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the LOW period of the SCL signal, then it must output the next data bit to the SDA line $t_{rmax} + t_{SU}; DAT = 1000 + 250 = 1250$ ns (according to the Standard mode I²C bus specification) before the SCL line is released.
8. C_b = total capacitance of the one bus line in pF.

Dimensions

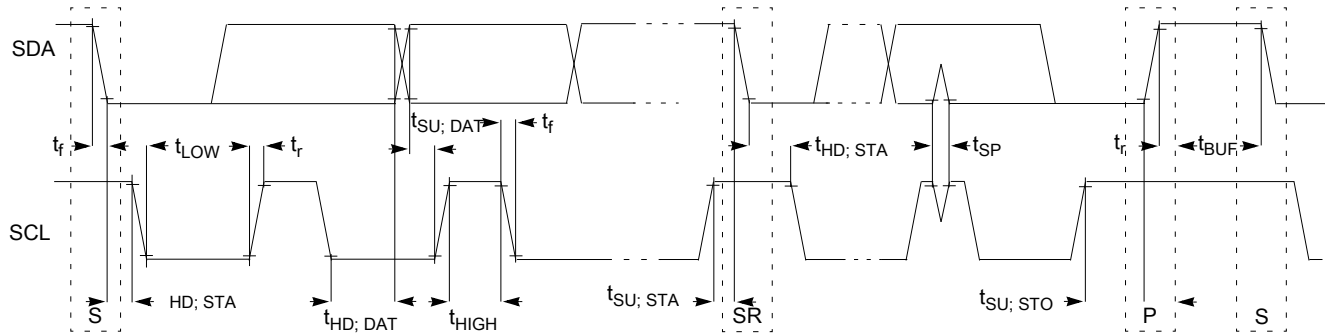


Figure 11. Timing definition for fast and standard mode devices on the I²C bus

4 Dimensions

4.1 Obtaining package dimensions

Package dimensions are provided in package drawings.

To find a package drawing, go to freescale.com and perform a keyword search for the drawing's document number:

| If you want the drawing for this package | Then use this document number |
|--|-------------------------------|
| 32-pin QFN | 98ASA00615D |
| 36-pin WLCSP | 98ASA00789D |

5 Pinout

5.1 Signal multiplexing and pin assignments

The following table shows the signals available on each pin and the locations of these pins on the devices supported by this document.

NOTE

VDD1 and VDD2 must be short on PCB.

PTA6 and PTA7 are true open drain pins. The external pullup resistor must be added to make them output correct values in using I2C0, GPIO, and UART0.

The NC pin must be floating, and do not tie it to the any of the VDD or VSS.

| 32 QFN | 36 WLC SP | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 |
|--------|-----------|----------------------------|---------------|---------------|-----------|-----------|----------|
| — | C3 | VSS1 | VSS1 | VSS1 | | | |
| — | C4 | VSS1 | VSS1 | VSS1 | | | |
| — | D3 | VDD1 | VDD1 | VDD1 | | | |
| — | D4 | VDD1 | VDD1 | VDD1 | | | |
| 1 | A1 | VREC | VREC | VREC | | | |
| 2 | A2 | VDD1 | VDD1 | VDD1 | | | |
| 3 | A3 | VSS1 | VSS1 | VSS1 | | | |
| 4 | B3 | PTA0 | DISABLED | PTA0 | SBAR_IN1 | EXTAL | |
| 5 | B4 | PTA1 | DISABLED | PTA1 | SBAR_OUT0 | XTAL | |
| 6 | A4 | PTA2 | DISABLED | PTA2 | BUSOUT | SBAR_OUT1 | FTM0_CH0 |
| 7 | A5 | PTA3 | DISABLED | PTA3 | CLAMP | ACMP0_OUT | FTM0_CH1 |
| 8 | A6 | PTA4 | SWDIO | PTA4 | SWDIO | | FTM1_CH0 |
| 9 | B6 | PTA5 | SWCLK | PTA5 | SWCLK | | FTM1_CH1 |
| 10 | B5 | PTA6 | DISABLED | PTA6 | I2C0_SDA | UART0_RX | |
| 11 | C5 | PTA7 | DISABLED | PTA7 | I2C0_SCL | UART0_TX | |
| 12 | C6 | VSS2/ VSSA | VSS2/ VSSA | VSS2/ VSSA | | | |
| 13 | D6 | VDD2/ VDDA | VDD2/ VDDA | VDD2/ VDDA | | | |
| 14 | E6 | PTB0/ RESET_b/ NMI_b | RESET_b | PTB0 | IRQ | NMI_b | RESET_b |
| 15 | D5 | PTB1 | DISABLED | PTB1 | ADCAD0 | SBAR_IN0 | |
| 16 | E5 | PTB2 | DISABLED | PTB2 | ADCAD1 | ACMP0_IN0 | |
| 17 | F6 | PTB3 | DISABLED | PTB3 | ADCAD2 | ACMP0_IN1 | |
| 18 | E4 | PTB4 | DISABLED | PTB4 | ADCAD3 | | |
| 19 | F5 | VSS3 | VSS3 | VSS3 | | | |
| 20 | F4 | VREFH | VREFH | VREFH | | | |
| 21 | F3 | VOUT_FB | VOUT_FB | VOUT_FB | | | |
| 23 | F2 | VOUT | VOUT | VOUT | | | |
| 24 | F1 | ISENS | ISENS | ISENS | | | |
| 25 | E2 | CLC1 | CLC1 | CLC1 | | | |
| 26 | D2 | VLC | VLC | VLC | | | |
| 27 | E1 | GD | GD | GD | | | |
| 28 | D1 | VBOOT | VBOOT | VBOOT | | | |
| 29 | C2 | AD_IN | AD_IN | AD_IN | | | |
| 30 | B2 | AD_EN | AD_EN | AD_EN | | | |

Pinout

| 32 QFN | 36 WLC SP | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 |
|--------|-----------|----------|---------|------|------|------|------|
| 31 | C1 | AC1 | AC1 | AC1 | | | |
| 32 | B1 | AC2 | AC2 | AC2 | | | |

5.2 Device pin assignment

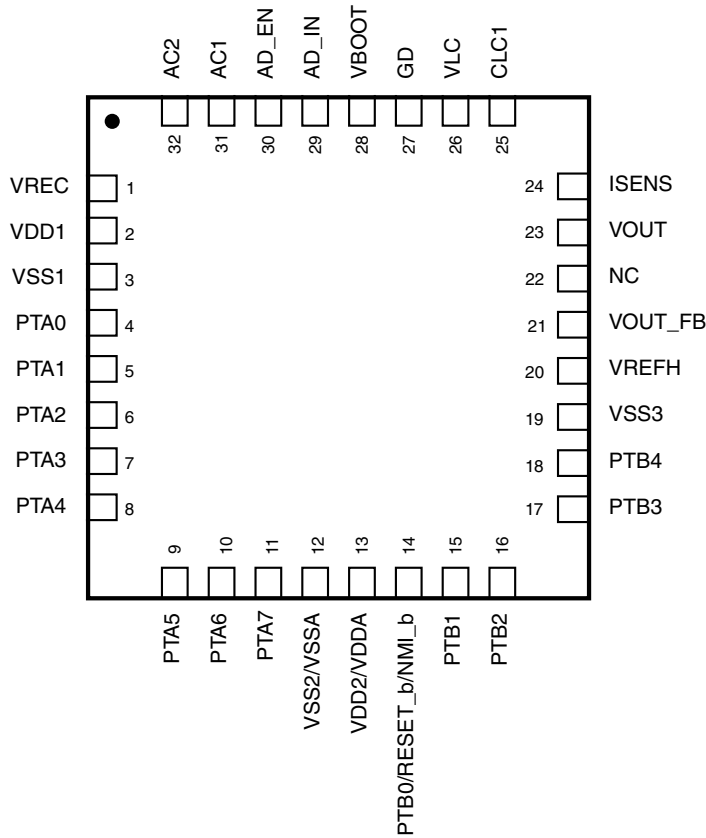


Figure 12. 32-pin QFN package

NOTE

The NC pin must be floating, and do not tie it to the VDD or VSS.

| | | | | | | | |
|---|-------|-------|---------|-------|------|----------------------------|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| A | VREC | VDD1 | VSS1 | PTA2 | PTA3 | PTA4 | A |
| B | AC2 | AD_EN | PTA0 | PTA1 | PTA6 | PTA5 | B |
| C | AC1 | AD_IN | VSS1 | VSS1 | PTA7 | VSS2/ VSSA | C |
| D | VBOOT | VLC | VDD1 | VDD1 | PTB1 | VDD2/ VDDA | D |
| E | GD | CLC1 | CLC2 | PTB4 | PTB2 | PTB0/ RESET_b/ NML_b | E |
| F | ISENS | VOUT | VOUT_FB | VREFH | VSS3 | PTB3 | F |
| | 1 | 2 | 3 | 4 | 5 | 6 | |

Figure 13. 36-pin WLCSP package

6 Ordering Parts

6.1 Determining valid orderable parts

Valid orderable part numbers are provided on the web. To determine the orderable part numbers for this device, go to freescale.com and perform a part number search for the following device numbers: WPR1516.

7 Part Identification

7.1 Description

Part numbers for the chip have fields that identify the specific part. You can use the values of these fields to determine the specific part you have received.

7.2 Format

Part numbers for this device have the following format:

Q WPR## FFF R T PP N

7.3 Fields

This table lists the possible values for each field in the part number (not all combinations are valid):

| Field | Description | Values |
|-------|---------------------------|--|
| Q | Qualification status | <ul style="list-style-type: none"> M = Fully qualified, general market flow P = Prequalification |
| WPR## | WPR family | <ul style="list-style-type: none"> WPR15 |
| FFF | Program flash memory size | <ul style="list-style-type: none"> 16 = 16 KB |
| R | Silicon revision | <ul style="list-style-type: none"> (Blank) = Main A = Revision after main |
| T | Temperature range (°C) | <ul style="list-style-type: none"> C = -40 to 85 °C |
| PP | Package identifier | <ul style="list-style-type: none"> FM=32 QFN (5 mm x 5 mm) AL=36 WLCSP (3.1 mm x 3.0 mm) |
| N | Packaging type | <ul style="list-style-type: none"> R = Tape and reel (Blank) = Trays |

7.4 Example

This is an example part number:

MWPR1516CFM

8 Terminology and guidelines

8.1 Definition: Operating requirement

An *operating requirement* is a specified value or range of values for a technical characteristic that you must guarantee during operation to avoid incorrect operation and possibly decreasing the useful life of the chip.

8.1.1 Example

This is an example of an operating requirement:

| Symbol | Description | Min. | Max. | Unit |
|-----------------|---------------------------|------|------|------|
| V _{DD} | 1.0 V core supply voltage | 0.9 | 1.1 | V |

8.2 Definition: Operating behavior

Unless otherwise specified, an *operating behavior* is a specified value or range of values for a technical characteristic that are guaranteed during operation if you meet the operating requirements and any other specified conditions.

8.2.1 Example

This is an example of an operating behavior:

| Symbol | Description | Min. | Max. | Unit |
|-----------------|--|------|------|------|
| I _{WP} | Digital I/O weak pullup/pulldown current | 10 | 130 | μA |

8.3 Definition: Attribute

An *attribute* is a specified value or range of values for a technical characteristic that are guaranteed, regardless of whether you meet the operating requirements.

8.3.1 Example

This is an example of an attribute:

| Symbol | Description | Min. | Max. | Unit |
|--------|---------------------------------|------|------|------|
| CIN_D | Input capacitance: digital pins | — | 7 | pF |

8.4 Definition: Rating

A *rating* is a minimum or maximum value of a technical characteristic that, if exceeded, may cause permanent chip failure:

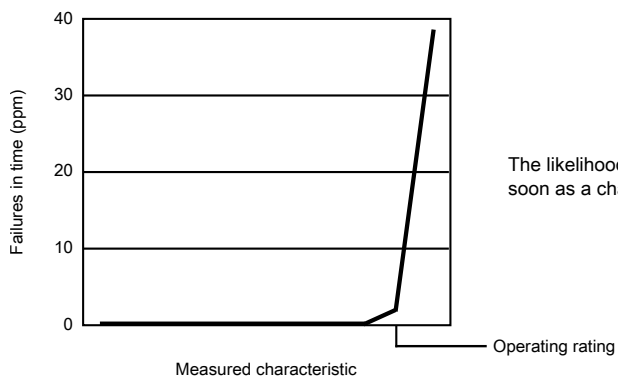
- *Operating ratings* apply during operation of the chip.
- *Handling ratings* apply when the chip is not powered.

8.4.1 Example

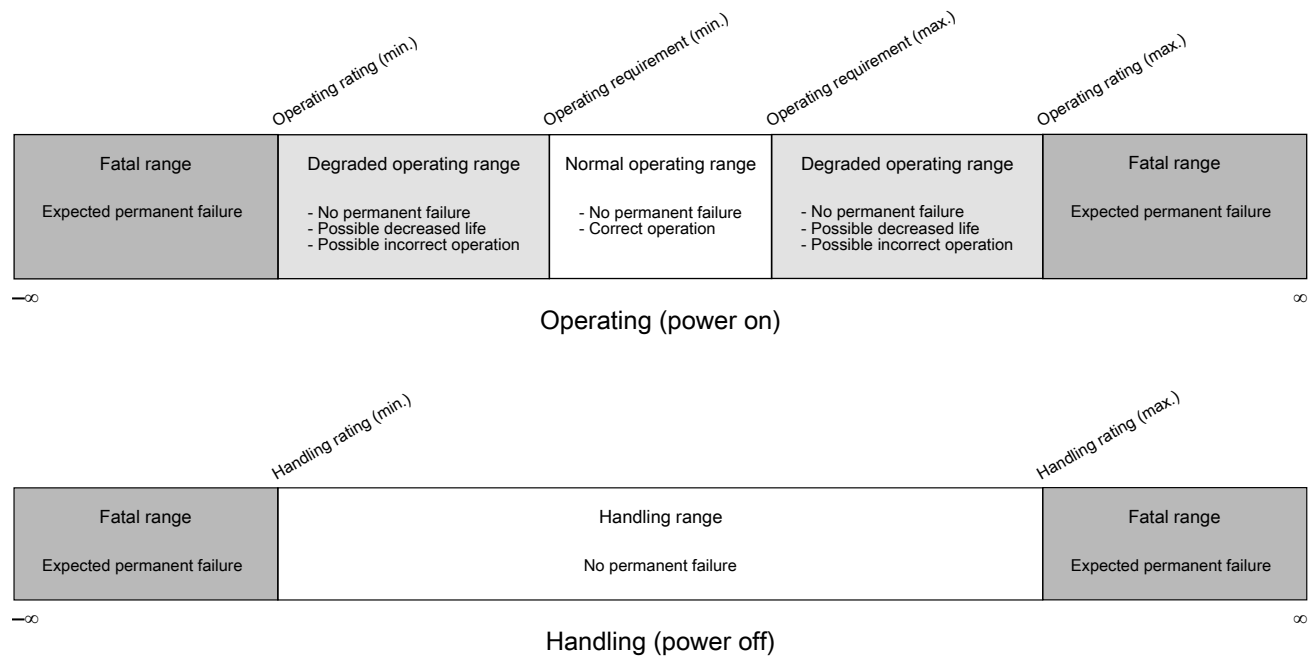
This is an example of an operating rating:

| Symbol | Description | Min. | Max. | Unit |
|-----------------|---------------------------|------|------|------|
| V _{DD} | 1.0 V core supply voltage | -0.3 | 1.2 | V |

8.5 Result of exceeding a rating



8.6 Relationship between ratings and operating requirements



8.7 Guidelines for ratings and operating requirements

Follow these guidelines for ratings and operating requirements:

- Never exceed any of the chip's ratings.
- During normal operation, don't exceed any of the chip's operating requirements.
- If you must exceed an operating requirement at times other than during normal operation (for example, during power sequencing), limit the duration as much as possible.

8.8 Definition: Typical value

A *typical value* is a specified value for a technical characteristic that:

- Lies within the range of values specified by the operating behavior
- Given the typical manufacturing process, is representative of that characteristic during operation when you meet the typical-value conditions or other specified conditions

Typical values are provided as design guidelines and are neither tested nor guaranteed.

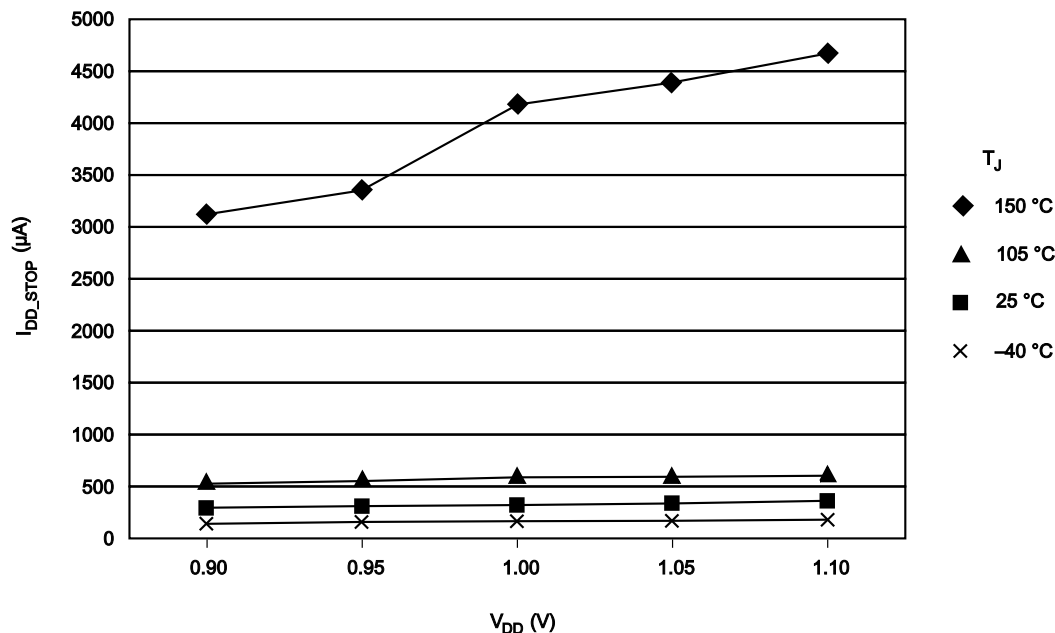
8.8.1 Example 1

This is an example of an operating behavior that includes a typical value:

| Symbol | Description | Min. | Typ. | Max. | Unit |
|----------|--|------|------|------|---------|
| I_{WP} | Digital I/O weak pullup/pulldown current | 10 | 70 | 130 | μA |

8.8.2 Example 2

This is an example of a chart that shows typical values for various voltage and temperature conditions:



8.9 Typical value conditions

Typical values assume you meet the following conditions (or other conditions as specified):

Table 24. Typical value conditions

| Symbol | Description | Value | Unit |
|----------|----------------------|-------|------|
| T_A | Ambient temperature | 25 | °C |
| V_{DD} | 3.3 V supply voltage | 3.3 | V |

9 Revision history

The following table provides a revision history for this document.

Table 25. Revision history

| Rev. No. | Date | Substantial Changes |
|----------|--------|-------------------------|
| 2 | 1/2015 | Initial public release. |

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