

Advance Information

MAC7100EC/D
Rev. 0.1, 10/2003

MAC7100 Microcontroller
Family Hardware
Specifications



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This document provides electrical specifications, pin assignments, and package diagrams for MAC7100 family of microcontroller devices. For functional characteristics of the family, refer to the *MAC7100 Microcontroller Family Reference Manual* (MAC7100RM/D).

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1 Overview

The MAC7100 Family of microcontrollers (MCUs) are members of a pin-compatible family of 32-bit Flash-memory-based devices developed specifically for embedded automotive applications. The pin-compatible family concept enables users to select between different memory and peripheral options for scalable designs. All MAC7100 Family members are composed of a 32-bit central processing unit (ARM7TDMI-S), up to 512Kbytes of embedded Flash EEPROM for program storage, up to 32Kbytes of embedded Flash for data and/or program storage, and up to 32Kbytes of RAM. The family is implemented with an enhanced DMA (eDMA) controller to improve performance for transfers between memory and many of the on-chip peripherals. The peripheral set includes asynchronous serial communications interfaces (eSCI), serial peripheral interfaces (DSPI), inter-integrated circuit (I²C) bus controllers, FlexCAN interfaces, an enhanced modular I/O subsystem (eMIOS), 10-bit analog-to-digital converter (ATD) channels, general-purpose timers (PIT) and two special-purpose timers (RTI and SWT). The peripherals share a large number of general purpose input-output (GPIO) pins, all of which are bidirectional and available with interrupt capability to trigger wake-up from low-power chip modes.

The inclusion of a PLL circuit allows power consumption and performance to be adjusted to suit operational requirements. The operating frequency of devices in the family is up to a maximum of 50 MHz. The internal data paths between the CPU core, eDMA, memory and peripherals are all 32 bits wide, further improving performance for 32-bit applications. The

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MAC7111 and MAC7131 also offer a 16-bit wide external data bus with 22 address lines. The family of devices is capable of operating over a junction temperature range of -40° C to 150° C.

Table 1 provides a comparison of members of the MAC7100 Family and the availability of peripheral modules on the various devices.

Table 1. MAC7100 Family Device Derivatives

| Module Options | MAC7101 | MAC7111 | MAC7121 | MAC7131 | MAC7141 |
|--------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Program Flash | 512Kbytes | 512Kbytes | 512Kbytes | 512Kbytes | 512Kbytes |
| Data Flash | 32Kbytes | 32Kbytes | 32Kbytes | 32Kbytes | 32Kbytes |
| SRAM | 32Kbytes | 32Kbytes | 32Kbytes | 32Kbytes | 32Kbytes |
| External Bus | No | Yes | No | Yes | No |
| ATD Modules | 2 | 1 | 1 | 2 | 1 |
| CAN Modules | 4 | 4 | 4 | 4 | 2 |
| eSCI Modules | 4 | 4 | 4 | 4 | 2 |
| DSPI Modules | 2 | 2 | 2 | 2 | 2 |
| I ² C Modules | 1 | 1 | 1 | 1 | 1 |
| eMIOS Module | 16 channels, 16-bit | 16 channels, 16-bit | 16 channels, 16-bit | 16 channels, 16-bit | 16 channels, 16-bit |
| Timer Module | 10 channels, 24-bit | 10 channels, 24-bit | 10 channels, 24-bit | 10 channels, 24-bit | 10 channels, 24-bit |
| GPIO Pins (max.) | 111 | 111 | 84 | 127 | 71 |
| Package | 144 LQFP | 144 LQFP | 112 LQFP | 208 MAP BGA | 100 LQFP |

2 Ordering Information

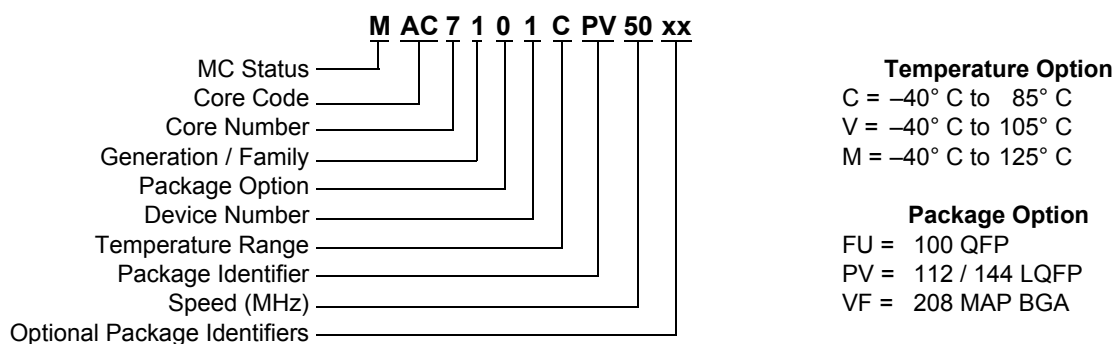


Figure 1. Order Part Number Example

3 Electrical Characteristics

This section contains electrical information for MAC7100 Family microcontrollers. The information is preliminary and subject to change without notice.

MAC7100 Family devices are specified and tested over the 5 V and 3.3 V ranges. For operation at any voltage within that range, the 3.3 V specifications generally apply. However, no production testing is done to verify operation at intermediate supply voltage levels.

3.1 Parameter Classification

The electrical parameters shown in this appendix are derived by various methods. To provide a better understanding to the designer, the following classification is used. Parameters are tagged accordingly in the column labeled “C” of the parametric tables, as appropriate.

Table 2. Parametric Value Classification

| | |
|---|--|
| P | Parameters guaranteed during production testing on each individual device. |
| C | Parameters derived by the design characterization and by measuring a statistically relevant sample size across process variations. |
| T | Parameters derived by design characterization on a small sample size from typical devices under typical conditions (unless otherwise noted). All values shown in the typical column are within this classification, even if not so tagged. |
| D | Parameters derived mainly from simulations. |

3.2 Absolute Maximum Ratings

Absolute maximum ratings are stress ratings only. Functional operation outside these maximums is not guaranteed. Stress beyond these limits may affect reliability or cause permanent damage to the device.

MAC7100 Family devices contain 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 example, either V_{SS5} or V_{DD5}).

Table 3. Absolute Maximum Ratings

| Num | Rating | Symbol | Min | Max | Unit |
|-----|---|--------------------|------|------|------|
| A1 | I/O, Regulator and Analog Supply Voltage | V_{DD5} | -0.3 | +6.0 | V |
| A2 | Digital Logic Supply Voltage ¹ | $V_{DD2.5}$ | -0.3 | +3.0 | V |
| A3 | PLL Supply Voltage ¹ | V_{DDPLL} | -0.3 | +3.0 | V |
| A4 | ATD Supply Voltage | V_{DDA} | -0.3 | +6.5 | V |
| A5 | Analog Reference | V_{RH}, V_{RL} | -0.3 | +6.0 | V |
| A6 | Voltage difference V_{DDX} to V_{DDA} | ΔV_{DDX} | -0.3 | +0.3 | V |
| A7 | Voltage difference V_{SSX} to V_{SSA} | ΔV_{SSX} | -0.3 | +0.3 | V |
| A8 | Voltage difference $V_{RH} - V_{RL}$ | $V_{RH} - V_{RL}$ | -0.3 | +6.5 | V |
| A9 | Voltage difference $V_{DDA} - V_{RH}$ | $V_{DDA} - V_{RH}$ | -6.5 | +6.5 | V |
| A10 | Digital I/O Input Voltage | V_{IN} | -0.3 | +6.0 | V |

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Table 3. Absolute Maximum Ratings (continued)

| Num | Rating | Symbol | Min | Max | Unit |
|-----|---|------------|-------|-------|------|
| A11 | XFC, EXTAL, XTAL inputs | V_{ILV} | -0.3 | +3.0 | V |
| A12 | TEST input | V_{TEST} | -0.3 | +10.0 | V |
| | Instantaneous Maximum Current ² | | | | |
| A13 | Single pin limit for XFC, EXTAL, XTAL ³ | I_{DL} | -25 | +25 | mA |
| A14 | Single pin limit for all digital I/O pins ⁴ | I_D | -25 | +25 | mA |
| A15 | Single pin limit for all analog input pins ⁴ | I_{DA} | -25 | +25 | mA |
| A16 | Single pin limit for TEST ⁵ | I_{DT} | -0.25 | 0 | mA |
| A17 | Storage Temperature Range | T_{stg} | -65 | +155 | °C |

¹ The device contains an internal voltage regulator to generate the logic and PLL supply from the I/O supply. The absolute maximum ratings apply when the device is powered from an external source.

² Input must be current limited to the value specified. To determine the value of the required current-limiting resistor, calculate resistance values using $V_{POSCLAMP} = V_{DDA} + 0.3$ V and $V_{NEGCLAMP} = -0.3$ V, then use the larger of the calculated values.

³ These pins are internally clamped to V_{SSPLL} and V_{DDPLL} .

⁴ All I/O pins are internally clamped to V_{SSX} and V_{DDX} , V_{SSR} and V_{DDR} or V_{SSA} and V_{DDA} .

⁵ This pin is clamped low to V_{SSX} , but not clamped high, and must be tied low in applications.

3.3 ESD Protection and Latch-up Immunity

All ESD testing is in conformity with CDF-AEC-Q100 Stress test qualification for Automotive Grade Integrated Circuits. During the device qualification ESD stresses were performed for the Human Body Model (HBM), the Machine Model (MM) and the Charge Device Model.

A device is defined as a failure if after exposure to ESD pulses the device no longer meets the device specification. Complete DC parametric and functional testing is performed per the applicable device specification at room temperature followed by hot temperature, unless specified otherwise.

Table 4. ESD and Latch-up Test Conditions

| Model | Description | Symbol | Value | Unit |
|------------|--|-------------|-------------|------|
| Human Body | Series Resistance | R1 | 1500 | Ohm |
| | Storage Capacitance | C | 100 | pF |
| | Number of Pulses per pin positive negative | — 3 3 | — 3 3 | |
| Machine | Series Resistance | R1 | 0 | Ohm |
| | Storage Capacitance | C | 200 | pF |
| | Number of Pulse per pin positive negative | — 3 3 | — 3 3 | |
| Latch-up | Minimum input voltage limit | | -2.5 | V |
| | Maximum input voltage limit | | 7.5 | V |

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Table 5. ESD and Latch-Up Protection Characteristics

| Num | C | Rating | Symbol | Min | Max | Unit |
|-----|---|---|-----------|--------------|-----|------|
| B1 | C | Human Body Model (HBM) | V_{HBM} | 2000 | — | V |
| B2 | C | Machine Model (MM) | V_{MM} | 200 | — | V |
| B3 | C | Charge Device Model (CDM) | V_{CDM} | 500 | — | V |
| B4 | C | Latch-up Current at $T_A = 125^\circ\text{C}$ positive negative | I_{LAT} | +100 -100 | — | mA |
| B5 | C | Latch-up Current at $T_A = 27^\circ\text{C}$ positive negative | I_{LAT} | +200 -200 | — | mA |

3.4 Operating Conditions

Unless otherwise noted, the following conditions apply to all parametric data. Refer to the temperature rating of the device (C, V, M) with respect to ambient temperature (T_A) and junction temperature (T_J). For power dissipation calculations refer to Section 3.5, “Power Dissipation and Thermal Characteristics.”

Table 6. MAC7100 Family Device Operating Conditions

| Num | | Rating | Symbol | Min | Typ | Max | Unit |
|------|----------|--|------------------|------|-----|------|------------------|
| C1 | | I/O, Regulator and Analog Supply Voltage | V_{DD5} | 4.5 | 5 | 5.5 | V |
| C2 | | Digital Logic Supply Voltage ¹ | $V_{DD2.5}$ | 2.35 | 2.5 | 2.75 | V |
| C3 | | PLL Supply Voltage ¹ | V_{DDPLL} | 2.35 | 2.5 | 2.75 | V |
| C4 | | Voltage Difference V_{DDX} to V_{DDA} | ΔV_{DDX} | -0.1 | 0 | 0.1 | V |
| C5 | | Voltage Difference V_{SSX} to V_{SSA} | ΔV_{SSX} | -0.1 | 0 | 0.1 | V |
| C6 | | Oscillator Frequency | f_{osc} | 0.5 | — | 16 | MHz |
| C7 | | Bus Frequency | f_{bus} | 0.5 | — | 50 | MHz |
| C8a | MAC7100C | Operating Junction Temperature Range | T_J | -40 | — | 110 | $^\circ\text{C}$ |
| C8b | | Operating Ambient Temperature Range ² | T_A | -40 | 25 | 85 | $^\circ\text{C}$ |
| C9a | MAC7100V | Operating Junction Temperature Range | T_J | -40 | — | 130 | $^\circ\text{C}$ |
| C9b | | Operating Ambient Temperature Range ² | T_A | -40 | 25 | 105 | $^\circ\text{C}$ |
| C10a | MAC7100M | Operating Junction Temperature Range | T_J | -40 | — | 150 | $^\circ\text{C}$ |
| C10b | | Operating Ambient Temperature Range ² | T_A | -40 | 25 | 125 | $^\circ\text{C}$ |

¹ The device contains an internal voltage regulator to generate the logic and PLL supply from the I/O supply. The absolute maximum ratings apply when this regulator is disabled and the device is powered from an external source.

² Please refer to Section 3.5, “Power Dissipation and Thermal Characteristics,” for more details about the relation between ambient temperature T_A and device junction temperature T_J .

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3.4.1 5 V I/O Pins

The I/O pins operate at a nominal level of 5 V. This class of pins is comprised of the clocks, control and general purpose/peripheral pins. The internal structure of these pins is identical; however, some functionality may be disabled (for example, for analog inputs the output drivers, pull-up/down resistors are permanently disabled).

3.4.2 Oscillator Pins

The pins XFC, EXTAL, XTAL are dedicated to the oscillator and operate at a nominal level of 2.5 V.

3.5 Power Dissipation and Thermal Characteristics

Power dissipation and thermal characteristics are closely related. The user must assure that the maximum operating junction temperature is not exceeded.

Note that the JEDEC specification reserves the symbol $R_{\theta JA}$ or θ_{JA} (Theta-JA) strictly for junction-to-ambient thermal resistance on a 1s test board in natural convection environment. $R_{\theta JMA}$ or θ_{JMA} (Theta-JMA) will be used for both junction-to-ambient on a 2s2p test board in natural convection and for junction-to-ambient with forced convection on both 1s and 2s2p test boards. It is anticipated that the generic name, θ_{JA} , will continue to be commonly used.

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

$$T_J = T_A + (\Theta_{JA})$$

T_J = Junction Temperature (°C)

T_A = Ambient Temperature (°C)

P_D = Total Chip Power Dissipation (W)

Θ_{JA} = Package Thermal Resistance (°C/W)

The total power dissipation is calculated from:

$$P_D = P_{INT} + P_{IO}$$

P_{INT} = Chip Internal Power Dissipation (W)

$$P_{INT} = (I_{DD} \times V_{DD}) + (I_{DDPLL} \times V_{DDPLL}) + (I_{DDA} \times V_{DDA})$$

Two cases for P_{IO} , with the internal voltage regulator enabled and disabled, must be considered:

1. Internal Voltage Regulator disabled:

$$P_{IO} = \sum_i R_{DSON} \cdot (I_{IO_i})^2$$

P_{IO} is the sum of all output currents on I/O ports associated with V_{DDX} and V_{DDR} .

$$R_{DSON} = \frac{V_{OL}}{I_{OL}} \text{ (for outputs driven low)}$$

or

$$R_{DSON} = \frac{V_{DD5} - V_{OH}}{I_{OL}} \text{ (for outputs driven high)}$$

2. Internal voltage regulator enabled:

$$P_{INT} = (I_{DDR} \times V_{DDR}) + (I_{DDA} \times V_{DDA})$$

I_{DDR} is the current shown in Table 12 and not the overall current flowing into V_{DDR} , which additionally contains the current flowing into the external loads with output high.

3.5.1 Power Dissipation Simulation Details

Table 7. Thermal Resistance for 100 lead 14x14 mm LQFP, 0.5 mm Pitch ¹

| Rating | | | Value | Unit | Comments |
|--|-------------------------|-------------------|-------|------|----------|
| Junction to Ambient (Natural Convection) | Single layer board (1s) | R _{θJA} | 44 | °C/W | 1, 2 |
| Junction to Ambient (Natural Convection) | Four layer board (2s2p) | R _{θJMA} | 34 | °C/W | 1, 3 |
| Junction to Ambient (@ 200 ft./min.) | Single layer board (1s) | R _{θJMA} | 37 | °C/W | 1, 3 |
| Junction to Ambient (@ 200 ft./min.) | Four layer board (2s2p) | R _{θJMA} | 29 | °C/W | 1, 3 |
| Junction to Board | | R _{θJB} | 18 | °C/W | 4 |
| Junction to Case | | R _{θJC} | 7 | °C/W | 5 |
| Junction to Package Top | Natural Convection | Ψ _{JT} | 2 | °C/W | 6 |

¹ 100 LQFP, Case Outline: 983–02

Table 8. Thermal Resistance for 112 lead 20x20 mm LQFP, 0.65 mm Pitch ¹

| Rating | | | Value | Unit | Comments |
|--|-------------------------|-------------------|-------|------|----------|
| Junction to Ambient (Natural Convection) | Single layer board (1s) | R _{θJA} | 42 | °C/W | 1, 2 |
| Junction to Ambient (Natural Convection) | Four layer board (2s2p) | R _{θJMA} | 34 | °C/W | 1, 3 |
| Junction to Ambient (@ 200 ft./min.) | Single layer board (1s) | R _{θJMA} | 35 | °C/W | 1, 3 |
| Junction to Ambient (@ 200 ft./min.) | Four layer board (2s2p) | R _{θJMA} | 30 | °C/W | 1, 3 |
| Junction to Board | | R _{θJB} | 22 | °C/W | 4 |
| Junction to Case | | R _{θJC} | 7 | °C/W | 5 |
| Junction to Package Top | Natural Convection | Ψ _{JT} | 2 | °C/W | 6 |

¹ 112 LQFP, Case Outline: 987–01

Table 9. Thermal Resistance for 144 lead 20x20 mm LQFP, 0.5 mm Pitch ¹

| Rating | | | Value | Unit | Comments |
|--|-------------------------|-------------------|-------|------|----------|
| Junction to Ambient (Natural Convection) | Single layer board (1s) | R _{θJA} | 42 | °C/W | 1, 2 |
| Junction to Ambient (Natural Convection) | Four layer board (2s2p) | R _{θJMA} | 34 | °C/W | 1, 3 |
| Junction to Ambient (@ 200 ft./min.) | Single layer board (1s) | R _{θJMA} | 35 | °C/W | 1, 3 |
| Junction to Ambient (@ 200 ft./min.) | Four layer board (2s2p) | R _{θJMA} | 30 | °C/W | 1, 3 |
| Junction to Board | | R _{θJB} | 22 | °C/W | 4 |
| Junction to Case | | R _{θJC} | 7 | °C/W | 5 |
| Junction to Package Top | Natural Convection | Ψ _{JT} | 2 | °C/W | 6 |

¹ 144 LQFP, Case Outline: 918–03

Table 10. Thermal Resistance for 208 lead 17x17 mm MAP, 1.0 mm Pitch ¹

| Rating | | | Value | Unit | Comments |
|--|-------------------------|-------------------|-------|------|----------|
| Junction to Ambient (Natural Convection) | Single layer board (1s) | R _{θJA} | 46 | °C/W | 1, 2 |
| Junction to Ambient (Natural Convection) | Four layer board (2s2p) | R _{θJMA} | 29 | °C/W | 1, 3 |
| Junction to Ambient (@ 200 ft./min.) | Single layer board (1s) | R _{θJMA} | 38 | °C/W | 1, 3 |
| Junction to Ambient (@ 200 ft./min.) | Four layer board (2s2p) | R _{θJMA} | 26 | °C/W | 1, 3 |
| Junction to Board | | R _{θJB} | 19 | °C/W | 4 |
| Junction to Case | | R _{θJC} | 7 | °C/W | 5 |
| Junction to Package Top | Natural Convection | Ψ _{JT} | 2 | °C/W | 6 |

¹ 208 MAP BGA, Case Outline: 1159A-01

Comments:

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.
2. Per SEMI G38-87 and JEDEC 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 at the center lead. For fused lead packages, the adjacent lead is used.
5. Thermal resistance between the die and the case top surface as measured by the cold plate method (MIL SPEC-883 Method 1012.1).
6. Thermal characterization parameter indicating the temperature difference between package top and junction temperature per JEDEC JESD51-2. When Greek letters are not available, the thermal characterization parameter is written as Psi-JT.

Table 11. Power Dissipation 1/8 Simulation Model Packaging Parameters

| Component | Conductivity |
|--------------------|--------------|
| Mold Compound | 0.9 W/m K |
| Leadframe (Copper) | 263 W/m K |
| Die Attach | 1.7 W/m K |

3.6 Power Supply

The MAC7100 Family utilizes several pins to supply power to the oscillator, PLL, digital core, I/O ports and ATD. In the context of this section, V_{DD5} is used for V_{DDA} , V_{DDR} or V_{DDX} ; V_{SS5} is used for V_{SSA} , V_{SSR} or V_{SSX} unless otherwise noted. I_{DD5} denotes the sum of the currents flowing into the V_{DDA} , V_{DDX} , and V_{DDR} . V_{DD} is used for $V_{DD2.5}$, and V_{DDPLL} , V_{SS} is used for $V_{SS2.5}$ and V_{SSPLL} . I_{DD} is used for the sum of the currents flowing into $V_{DD2.5}$ and V_{DDPLL} .

3.6.1 Current Injection

The power supply must maintain regulation within the V_{DD5} or $V_{DD2.5}$ operating range during instantaneous and operating maximum current conditions. If positive injection current ($V_{in} > V_{DD5}$) is greater than I_{DD5} , the injection current may flow out of V_{DD5} and could result in the external power supply going out of regulation. It is important to ensure that the external V_{DD5} load will shunt current greater than the maximum injection current. The greatest risk will be when the MCU is consuming very little power (for example, if no system clock is present, or if the clock rate is very low).

3.6.2 Power Supply Pins

The $V_{DDR} - V_{SSR}$ pair supplies the internal voltage regulator. The $V_{DDA} - V_{SSA}$ pair supplies the A/D converter and the reference circuit of the internal voltage regulator. The $V_{DDX} - V_{SSX}$ pair supplies the I/O pins. $V_{DDPLL} - V_{SSPLL}$ pair supplies the oscillator and PLL.

All V_{DDX} pins are internally connected by metal. All V_{SSX} pins are internally connected by metal. All $V_{SS2.5}$ pins are internally connected by metal. V_{DDA} , V_{DDX} and V_{DDR} as well as V_{SSA} , V_{SSX} and V_{SSR} are connected by anti-parallel diodes for ESD protection.

3.6.3 Supply Currents

All current measurements are without output loads. Unless otherwise noted the currents are measured in single chip mode, internal voltage regulator enabled and at 40MHz bus frequency using a 4MHz oscillator in low power mode. Production testing is performed using a square wave signal at the EXTAL input.

In expanded modes, the currents flowing in the system are highly dependent on the load at the address, data and control signals as well as on the duty cycle of those signals. No generally applicable numbers can be given. A good estimate is to take the single chip currents and add the currents due to the external loads.

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Table 12. Supply Current Characteristics

| Num | C | Rating | Symbol | Typ | Max | Unit |
|-----|---|-------------------------------------|--------------------------|------------------------|----------------|------|
| D1a | C | Run Supply Current Single Chip | $I_{DD}R_{core}$ | — ¹ | — ¹ | mA |
| | | | | — ¹ | — ¹ | mA |
| | | | | — ¹ | — ¹ | mA |
| | | | | — ¹ | — ¹ | mA |
| | | | | — ¹ | — ¹ | mA |
| D1b | C | | $I_{DD}R_{reg}$ | — ¹ | — ¹ | mA |
| | | | | — ¹ | — ¹ | mA |
| | | | | — ¹ | — ¹ | mA |
| | | | | — ¹ | — ¹ | mA |
| | | | | — ¹ | — ¹ | mA |
| D1c | C | | $I_{DD}R_{pins}$ | — ¹ | — ¹ | mA |
| | | | | — ¹ | — ¹ | mA |
| | | | | — ¹ | — ¹ | mA |
| | | | | — ¹ | — ¹ | mA |
| | | | | — ¹ | — ¹ | mA |
| D2 | C | Doze Supply Current | Run ≥ Doze ≥ Pseudo Stop | | | |
| D3a | C | Pseudo Stop Current PLL on | $I_{DD}PS_{core}$ | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| D3b | C | | $I_{DD}PS_{reg}$ | — ¹ | — ¹ | μA |
| | | | | 278 / 327 ³ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| D3c | C | | $I_{DD}PS_{pins}$ | — ¹ | — ¹ | μA |
| | | | | 4 / 5 ³ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| D4a | C | Stop Current $T_J = T_A$ assumed | $I_{DD}S_{core}$ | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| D4b | C | | $I_{DD}S_{reg}$ | — ¹ | — ¹ | μA |
| | | | | 68 | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| D4c | C | | $I_{DD}S_{pins}$ | — ¹ | — ¹ | μA |
| | | | | 4 | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |
| | | | | — ¹ | — ¹ | μA |

¹ At the time of publication, this value is yet to be determined, and will be supplied when device characterization is complete.

² 85°C, 105°C, and 125°C refer to the "C", "V", and "M" Temperature Options, respectively.

³ RTI disabled / enabled.

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3.6.4 Voltage Regulator Characteristics

Table 13. VREG Operating Conditions

| Num | C | Characteristic | Symbol | Min | Typical | Max | Unit |
|-----|---|--|--------------------------|---------------------------|-------------------------------------|---------------------------|--------------------|
| E1 | P | Input Voltages | V_{VDDRA} | 2.97 | — | 5.5 | V |
| E2 | P | Regulator Current Reduced Power Mode Shutdown Mode | I_{REG} | — — | TBD TBD | 50 40 | μA μA |
| E3 | P | Output Voltage Core Full Performance Mode Reduced Power Mode Shutdown Mode | V_{DD} | 2.45 1.60 — | 2.5 2.5 — ¹ | 2.75 2.75 — | V V V |
| E4 | P | Output Voltage PLL Full Performance Mode Reduced Power Mode ² Reduced Power Mode ³ Shutdown Mode | V_{DDPLL} | 2.35 2.00 1.60 — | 2.5 2.5 2.5 — ¹ | 2.75 2.75 2.75 — | V V V V |
| E5 | P | Low Voltage Interrupt ⁴ Assert Level Deassert Level | V_{LVIA} V_{LVID} | 4.10 4.25 | 4.37 4.52 | 4.66 4.77 | V V |
| E6 | P | Low Voltage Reset ⁵ Assert Level | V_{LVRA} | 2.25 | 2.35 | — | V |
| E7 | P | Power On Reset ⁶ Assert Level Deassert Level | V_{PORA} V_{PORD} | 0.97 — | — — | — 2.05 | V V |

¹ High Impedance Output.

² Current $I_{DDPLL} = 1mA$ (Low Power Oscillator).

³ Current $I_{DDPLL} = 3mA$ (Standard Oscillator).

⁴ Monitors V_{DDA} , active only in full performance mode. Indicated I/O and ATD performance degradation due to low supply voltage.

⁵ Monitors $V_{DD2.5}$, active only in full performance mode. Only POR is active in reduced performance mode.

⁶ Monitors $V_{DD2.5}$, active in all modes.

3.6.5 Chip Power Up and Voltage Drops

The VREG sub-modules LVI (low voltage interrupt), POR (power on reset) and LVR (low voltage reset) handle chip power-up or drops of the supply voltage. Refer to Figure 2.

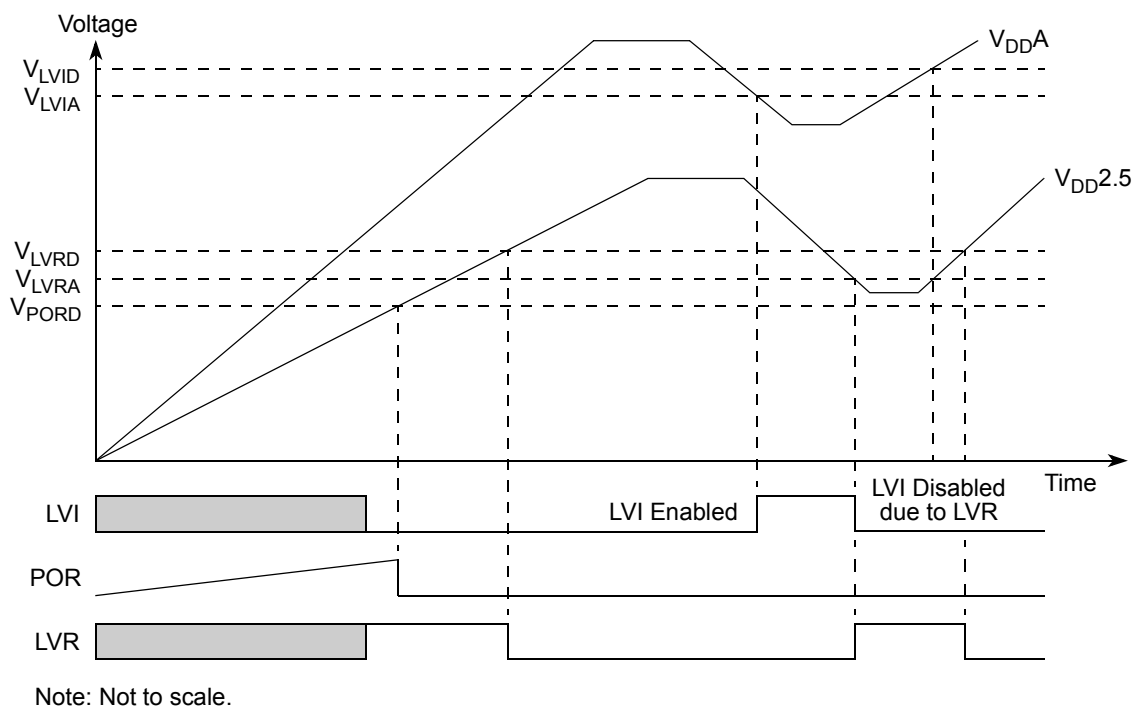


Figure 2. VREG Chip Power-up and Voltage Drops

3.6.6 Output Loads

The on-chip voltage regulator is intended to supply the internal logic and oscillator circuits. No external DC load is allowed. Capacitive loads are specified in Table 14. Capacitors with X7R dielectricum are required.

Table 14. VREG Recommended Load Capacitances

| Rating | Symbol | Min | Typ | Max | Unit |
|--|-----------------|-----|-----|-------|------|
| Load Capacitance on each $V_{DD2.5}$ pin | C_{LVDD} | 200 | 440 | 12000 | nF |
| Load Capacitance on V_{DDPLL} pin | $C_{LVDDfcPLL}$ | 90 | 220 | 5000 | nF |

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Electrical Characteristics

3.7 I/O Characteristics

This section describes the characteristics of all I/O pins in both 3.3 V and 5 V operating conditions. All parameters are not always applicable; for example, not all pins feature pull up/down resistances.

Table 15. 5 V I/O Characteristics

| Conditions shown in Table 6 unless otherwise noted | | | | | | | |
|--|---|---|------------------------|-----------------------|-----|-----------------------|---------|
| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
| F1a | P | Input High Voltage | V_{IH} | $0.65 \times V_{DD5}$ | — | — | V |
| F1b | T | Input High Voltage | V_{IH} | — | — | $V_{DD5} + 0.3$ | V |
| F2a | P | Input Low Voltage | V_{IL} | — | — | $0.35 \times V_{DD5}$ | V |
| F2b | T | Input Low Voltage | V_{IL} | $V_{SS5} - 0.3$ | — | — | V |
| F3 | C | Input Hysteresis | V_{HYS} | — | 250 | — | mV |
| F4 | P | Input Leakage Current (pins in high impedance input mode) ¹ $V_{in} = V_{DD5}$ or V_{SS5} | I_{in} | TBD | — | TBD | μA |
| F5 | P | Output High Voltage (pins in output mode) Partial Drive $I_{OH} = -2mA$ Full Drive $I_{OH} = -10mA$ | V_{OH} | $V_{DD5} - 0.8$ | — | — | V |
| F6 | P | Output Low Voltage (pins in output mode) Partial Drive $I_{OL} = +2mA$ Full Drive $I_{OL} = +10mA$ | V_{OL} | — | — | 0.8 | V |
| F7 | P | Internal Pull Up Device Current, tested at V_{IL} Max. | I_{PUL} | — | — | -130 | μA |
| F8 | P | Internal Pull Up Device Current, tested at V_{IH} Min. | I_{PUH} | -10 | — | — | μA |
| F9 | P | Internal Pull Down Device Current, tested at V_{IH} Min. | I_{PDH} | — | — | 130 | μA |
| F10 | P | Internal Pull Down Device Current, tested at V_{IL} Max. | I_{PDL} | 10 | — | — | μA |
| F11 | D | Input Capacitance | C_{in} | — | 6 | — | pF |
| F12 | T | Injection current ² Single Pin limit Total Device Limit. Sum of all injected currents | I_{ICS} I_{ICP} | -2.5 -25 | — | 2.5 25 | μA |
| F13 | P | Port Interrupt Input Pulse filtered ³ | t_{PULSE} | — | — | 3 | μs |
| F14 | P | Port Interrupt Input Pulse passed ³ | t_{PULSE} | 10 | — | — | μs |

¹ Maximum leakage current occurs at maximum operating temperature. Current decreases by approximately one-half for each 8°C to 12°C in the temperature range from 50°C to 125°C.

² Refer to Section 3.6.1, "Current Injection," for more details

³ Parameter only applies in STOP or Pseudo STOP mode.

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Table 16. 3.3 V I/O Characteristics

| Conditions shown in Table 6, with $V_{DDX} = 3.3 \text{ V} \pm 10\%$ and a temperature maximum of $+140^\circ\text{C}$ unless otherwise noted. | | | | | | | |
|--|---|---|------------------------|-----------------------|-----|-----------------------|---------------|
| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
| G1a | P | Input High Voltage | V_{IH} | $0.65 \times V_{DD5}$ | — | — | V |
| G1b | T | Input High Voltage | V_{IH} | — | — | $V_{DD5} + 0.3$ | V |
| G2a | P | Input Low Voltage | V_{IL} | — | — | $0.35 \times V_{DD5}$ | V |
| G2b | T | Input Low Voltage | V_{IL} | $V_{SS5} - 0.3$ | — | — | V |
| G3 | C | Input Hysteresis | V_{HYS} | — | 250 | — | mV |
| G4 | P | Input Leakage Current (pins in high impedance input mode) ¹ $V_{in} = V_{DD5}$ or V_{SS5} | I_{in} | TBD | — | TBD | μA |
| G5 | P | Output High Voltage (pins in output mode) Partial Drive $I_{OH} = -0.75\text{mA}$ Full Drive $I_{OH} = -4.5\text{mA}$ | V_{OH} | $V_{DD5} - 0.4$ | — | — | V |
| G6 | P | Output Low Voltage (pins in output mode) Partial Drive $I_{OL} = +0.9\text{mA}$ Full Drive $I_{OL} = +5.5\text{mA}$ | V_{OL} | — | — | 0.4 | V |
| G7 | P | Internal Pull Up Device Current, tested at V_{IL} Max. | I_{PUL} | — | — | -60 | μA |
| G8 | P | Internal Pull Up Device Current, tested at V_{IH} Min. | I_{PUH} | -6 | — | — | μA |
| G9 | P | Internal Pull Down Device Current, tested at V_{IH} Min. | I_{PDH} | — | — | 60 | μA |
| G10 | P | Internal Pull Down Device Current, tested at V_{IL} Max. | I_{PDL} | 6 | — | — | μA |
| G11 | D | Input Capacitance | C_{in} | — | 6 | — | pF |
| G12 | T | Injection current ² Single Pin limit Total Device Limit. Sum of all injected currents | I_{ICS} I_{ICP} | -2.5 -25 | — | 2.5 25 | μA |
| G13 | P | Port Interrupt Input Pulse filtered ³ | t_{PULSE} | — | — | 3 | μs |
| G14 | P | Port Interrupt Input Pulse passed ³ | t_{PULSE} | 10 | — | — | μs |

¹ Maximum leakage current occurs at maximum operating temperature. Current decreases by approximately one-half for each 8°C to 12°C in the temperature range from 50°C to 125°C .

² Refer to Section 3.6.1, "Current Injection," for more details

³ Parameter only applies in STOP or Pseudo STOP mode.

3.8 Clock and Reset Generator Electrical Characteristics

This section describes the electrical characteristics for the oscillator, phase-locked loop, clock monitor and reset generator.

3.8.1 Oscillator Characteristics

The MAC7100 Family features an internal low power loop controlled Pierce oscillator and a full swing Pierce oscillator/external clock mode. The selection of loop controlled Pierce oscillator or full swing Pierce oscillator/external clock depends on the level of the \overline{XCLKS} signal at the rising edge of the \overline{RESET} signal. Before asserting the oscillator to the internal system clock distribution subsystem, the quality of the oscillation is checked for each start from either power on, STOP or oscillator fail. t_{CQOUT} specifies the maximum time before switching to the internal self clock mode after POR or STOP if a proper oscillation is not detected. The quality check also determines the minimum oscillator start-up time t_{UPOSC} . The device also features a clock monitor. A Clock Monitor Failure is asserted if the frequency of the incoming clock signal is below the Clock Monitor Assert Frequency f_{CMFA} .

Table 17. Oscillator Characteristics

| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
|-----|---|--|--------------|------|------------------|-----------------|---------|
| H1a | C | Crystal oscillator range (loop controlled Pierce) | f_{OSC} | 4.0 | — | 16 | MHz |
| H1b | C | Crystal oscillator range (full swing Pierce) ^{1, 2} | f_{OSC} | 0.5 | — | 40 | MHz |
| H2 | P | Startup Current | I_{OSC} | 100 | — | — | μA |
| H3 | C | Oscillator start-up time (loop controlled Pierce) | t_{UPOSC} | — | TBD ³ | 50 ⁴ | ms |
| H4 | D | Clock Quality check time-out | t_{CQOUT} | 0.45 | — | 2.5 | s |
| H5 | P | Clock Monitor Failure Assert Frequency | f_{CMFA} | 50 | 100 | 200 | KHz |
| H6 | P | External square wave input frequency ² | f_{EXT} | 0.5 | — | 40 | MHz |
| H7 | D | External square wave pulse width low | t_{EXTL} | 9.5 | — | — | ns |
| H8 | D | External square wave pulse width high | t_{EXTH} | 9.5 | — | — | ns |
| H9 | D | External square wave rise time | t_{EXTR} | — | — | 1 | ns |
| H10 | D | External square wave fall time | t_{EXTF} | — | — | 1 | ns |
| H11 | D | Input Capacitance (EXTAL, XTAL pins) | C_{IN} | — | 7 | — | pF |
| H12 | C | EXTAL pin DC Operating Bias in loop controlled mode | V_{DCBIAS} | — | TBD | — | V |

¹ Depending on the crystal; a damping series resistor might be necessary

² \overline{XCLKS} negated during reset

³ $f_{OSC} = 4$ MHz, $C = 22$ pF.

⁴ Maximum value is for extreme cases using high Q, low frequency crystals

3.8.2 PLL Filter Characteristics

The oscillator provides the reference clock for the PLL. The voltage controlled oscillator (VCO) of the PLL is also the system clock source in self clock mode. In order to operate reliably, care must be taken to select proper values for external loop filter components.

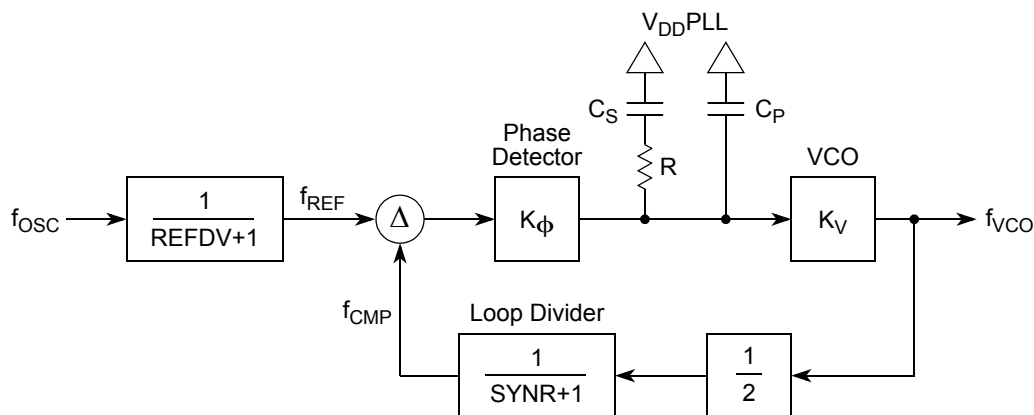


Figure 3. Basic PLL Functional Diagram

The procedure described below can be used to calculate the resistance and capacitance values using typical values for K_1 , f_1 and i_{ch} from Table 18. First, the VCO Gain at the desired VCO output frequency is approximated by:

$$K_V = K_1 \cdot e^{\frac{(f_1 - f_{VCO})}{K_1 \cdot 1V}}$$

The phase detector relationship is given by:

$$K_\Phi = -|i_{ch}| \cdot K_V$$

i_{ch} is the current in tracking mode. The loop bandwidth f_C should be chosen to fulfill the Gardner's stability criteria by at least a factor of 10, typical values are 50. $\zeta = 0.9$ ensures a good transient response.

$$f_C < \frac{2 \cdot \zeta \cdot f_{ref}}{\pi \cdot (\zeta + \sqrt{1 + \zeta^2})} \left(\frac{1}{50} \rightarrow f_C < \frac{f_{ref}}{4 \cdot 50}; (\zeta = 0.9) \right)$$

And finally the frequency relationship is defined as

$$n = \frac{f_{VCO}}{f_{ref}} = 2 \cdot (\text{synr} + 1)$$

With the above inputs the resistance can be calculated as:

$$R = \frac{2 \cdot \pi \cdot n \cdot f_C}{K_\Phi}$$

The capacitance C_S can now be calculated as:

$$C_S = \frac{2 \cdot \zeta^2}{\pi \cdot f_C \cdot R} \approx \frac{0.516}{f_C \cdot R}; (\zeta = 0.9)$$

The capacitance C_P should be chosen in the range of:

$$C_S \div 20 \leq C_P \leq C_S \div 10$$

The stabilization delays shown in Table 18 are dependant on PLL operational settings and external component selection (for example, crystal, XFC filter).

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Electrical Characteristics

3.8.2.1 Jitter Information

The basic functionality of the PLL is shown in Figure 3. With each transition of the clock f_{cmp} , the deviation from the reference clock f_{ref} is measured and input voltage to the VCO is adjusted accordingly. The adjustment is done continuously with no abrupt changes in the clock output frequency. Noise, voltage, temperature and other factors cause slight variations in the control loop resulting in a clock jitter. This jitter affects the real minimum and maximum clock periods as illustrated in Figure 4. It is important to note that the pre-scaler used by timers and serial modules will eliminate the effect of PLL jitter to a large extent.

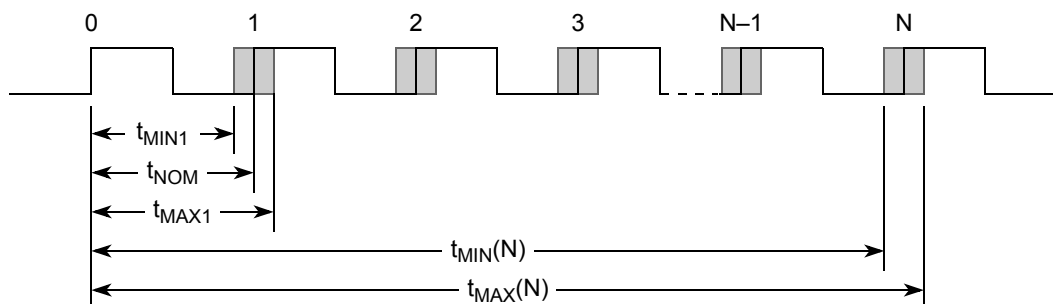


Figure 4. Jitter Definitions

The relative deviation of t_{NOM} is at its maximum for one clock period, and decreases towards zero for larger number of clock periods (N). Thus, jitter is defined as:

$$J(N) = \max\left(\left|1 - \frac{t_{MAX}(N)}{N \cdot t_{NOM}}\right|, \left|1 - \frac{t_{MIN}(N)}{N \cdot t_{NOM}}\right|\right)$$

For $N < 100$, the following equation is a good fit for the maximum jitter:

$$J(N) = \frac{j_1}{\sqrt{N}} + j_2$$

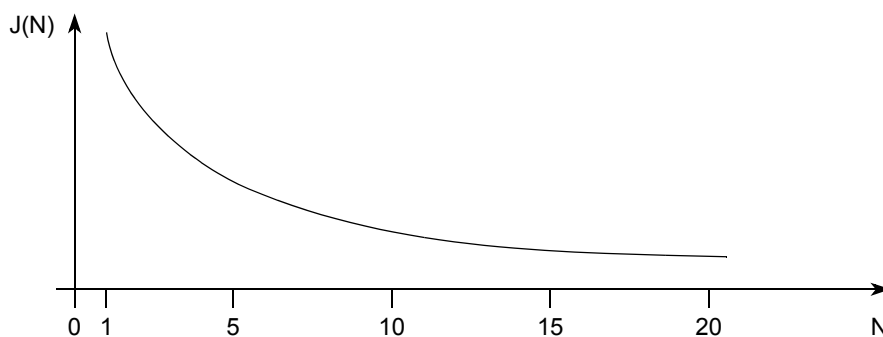


Figure 5. Maximum Bus Clock Jitter Approximation

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Electrical Characteristics

3.8.3 PLL Characteristics

Table 18. PLL Characteristics

| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
|-----|---|--|-------------------|-----|------------------|----------------|----------------|
| J1 | | PLL reference frequency, crystal oscillator range ¹ | f_{REF} | 0.5 | — | 16 | MHz |
| J2 | P | Self Clock Mode frequency | f_{SCM} | 1 | — | 5.5 | MHz |
| J3 | D | VCO locking range | f_{VCO} | 8 | — | 40 | MHz |
| J4 | D | Lock Detector transition from Acquisition to Tracking mode | $ \Delta_{trk} $ | 3 | — | 4 | % ² |
| J5 | D | Lock Detection | $ \Delta_{Lock} $ | 0 | — | 1.5 | % ² |
| J6 | D | Un-Lock Detection | $ \Delta_{unl} $ | 0.5 | — | 2.5 | % ² |
| J7 | D | Lock Detector transition from Tracking to Acquisition mode | $ \Delta_{unt} $ | 6 | — | 8 | % ² |
| J8 | C | PLLON Total Stabilization delay (Auto Mode) ³ | t_{stab} | — | 0.5 ⁴ | 3 ⁵ | ms |
| J9 | D | PLLON Acquisition mode stabilization delay ³ | t_{acq} | — | 0.3 ⁵ | 1 ⁴ | ms |
| J10 | D | PLLON Tracking mode stabilization delay ³ | t_{al} | — | 0.2 ⁵ | 2 ⁴ | ms |
| J11 | D | Charge pump current acquisition mode | $ i_{ch} $ | — | 38.5 | — | μA |
| J12 | D | Charge pump current tracking mode | $ i_{ch} $ | — | 3.5 | — | μA |
| J13 | D | Jitter fit VCO loop gain parameter | K_1 | — | −100 | — | MHz/V |
| J14 | D | Jitter fit VCO loop frequency parameter | f_1 | — | 60 | — | MHz |
| J15 | C | Jitter fit parameter 1 | j_1 | — | — | TBD | % ⁴ |
| J16 | C | Jitter fit parameter 2 | j_2 | — | — | TBD | % ⁴ |

¹ V_{DDPLL} at 2.5 V.

² Percentage deviation from target frequency

³ PLL stabilization delay is highly dependent on operational requirement and external component values (for example, crystal and XFC filter component values). Notes 4 and 5 show component values for a typical configurations. Appropriate XFC filter values should be chosen based on operational requirement of system.

⁴ $f_{REF} = 4$ MHz, $f_{SYS} = 25$ MHz (REFDV = 0x03, SYNRR = 0x01), $C_S = 4.7$ nF, $C_P = 470$ pF, $R_S = 10$ K Ω .

⁵ $f_{REF} = 4$ MHz, $f_{SYS} = 8$ MHz (REFDV = 0x00, SYNRR = 0x01), $C_S = 33$ nF, $C_P = 3.3$ nF, $R_S = 2.7$ K Ω .

3.8.4 Crystal Monitor Time-out

The time-out Table 19 shows the delay for the crystal monitor to trigger when the clock stops, either at the high or at the low level. The corresponding clock period with an ideal 50% duty cycle is twice this time-out value.

Table 19. Crystal Monitor Time-Outs

| Min | Typ | Max | Unit |
|-----|-----|------|---------|
| 6 | 10 | 18.5 | μs |

3.8.5 Clock Quality Checker

The timing for the clock quality check is derived from the oscillator and the VCO frequency range in Table 18. These numbers define the upper time limit for the individual check windows to complete.

Table 20. CRG Maximum Clock Quality Check Timings

| Clock Check Windows | Value | Unit |
|---------------------|-------------|------|
| Check Window | 9.1 to 20.0 | ms |
| Timeout Window | 0.46 to 1.0 | s |

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Electrical Characteristics

3.8.6 Startup

Table 21 summarizes several startup characteristics explained in this section. Refer to the *MAC7100 Microcontroller Family Reference Manual (MAC7100RM/D)* for a detailed description of the startup behavior.

Table 21. CRG Startup Characteristics

| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
|-----|---|---|-------------|------|-----|------|-----------|
| K1 | T | POR release level | V_{PORR} | — | — | 2.07 | V |
| K2 | T | POR assert level | V_{PORA} | 0.97 | — | — | V |
| K3 | D | Reset input pulse width, minimum input time | PW_{RSTL} | 2 | — | — | t_{osc} |
| K4 | D | Startup from Reset | n_{RST} | 192 | — | 196 | n_{osc} |
| K5 | D | Interrupt pulse width, \overline{IRQ} edge-sensitive mode | PW_{IRQ} | 20 | — | — | ns |
| K6 | D | Wait recovery startup time | t_{WRS} | — | — | 14 | t_{cyc} |

3.8.6.1 Power On and Low Voltage Reset (POR and LVR)

The release level V_{PORR} and the assert level V_{PORA} are derived from the $V_{DD2.5}$ supply. The assert level V_{LVRA} is derived from the $V_{DD2.5}$ supply. They are also valid if the device is powered externally. After releasing the POR or LVR reset, the oscillator and the clock quality check are started. If after a time t_{CQOUT} no valid oscillation is detected, the MCU will start using the internal self-generated clock. The fastest startup time possible is given by t_{uposc} (refer to Table 17).

3.8.6.2 SRAM Data Retention

The SRAM contents integrity is guaranteed if the PORF bit in the CRGFLG register is not set following a reset operation.

3.8.6.3 External Reset

When external reset is asserted for a time greater than PW_{RSTL} , the CRG module generates an internal reset and the CPU starts fetching the reset vector without doing a clock quality check, if there was stable oscillation before reset.

3.8.6.4 Stop Recovery

The MCU can be returned to run mode from the stop mode by an external interrupt. A clock quality check is performed in the same manner as for POR before releasing the clocks to the system.

3.8.6.5 Pseudo Stop and Doze Recovery

Recovery from pseudo stop and doze modes are essentially the same, since the oscillator is not stopped in either mode. The controller is returned to run mode by internal or external interrupts or other wakeup events in the system. After t_{WRS} , the CPU fetches an interrupt vector if the wakeup event was an interrupt, or continues to execute code if the wakeup event was not an interrupt.

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3.9 External Bus Timing Specifications

Table 22 lists processor bus input timings, which are shown in Figure 6, Figure 7 and Figure 8.

NOTE

All processor bus timings are synchronous; that is, input setup/hold and output delay with respect to the rising edge of a reference clock. The reference clock is the CLKOUT output.

All other timing relationships can be derived from these values.

Table 22. External Bus Input Timing Specifications

| Num | C | Rating ¹ | Symbol | Min | Max | Unit |
|----------------|---|--|-------------|-----|-----|------|
| L1 | | CLKOUT | t_{CYC} | 23 | — | ns |
| Control Inputs | | | | | | |
| L2a | | Control input valid to CLKOUT high ² | t_{CVCH} | 13 | — | ns |
| L3a | | CLKOUT high to control inputs invalid ² | t_{CHCII} | 0 | — | ns |
| Data Inputs | | | | | | |
| L4 | | Data input (DATA[15:0]) valid to CLKOUT high | t_{DIVCH} | 9 | — | ns |
| L5 | | CLKOUT high to data input (DATA[15:0]) invalid | t_{CHDII} | 0 | — | ns |

¹ Timing specifications have been indicated taking into account the full drive strength for the pads.

² TA pins are being referred to as control inputs.

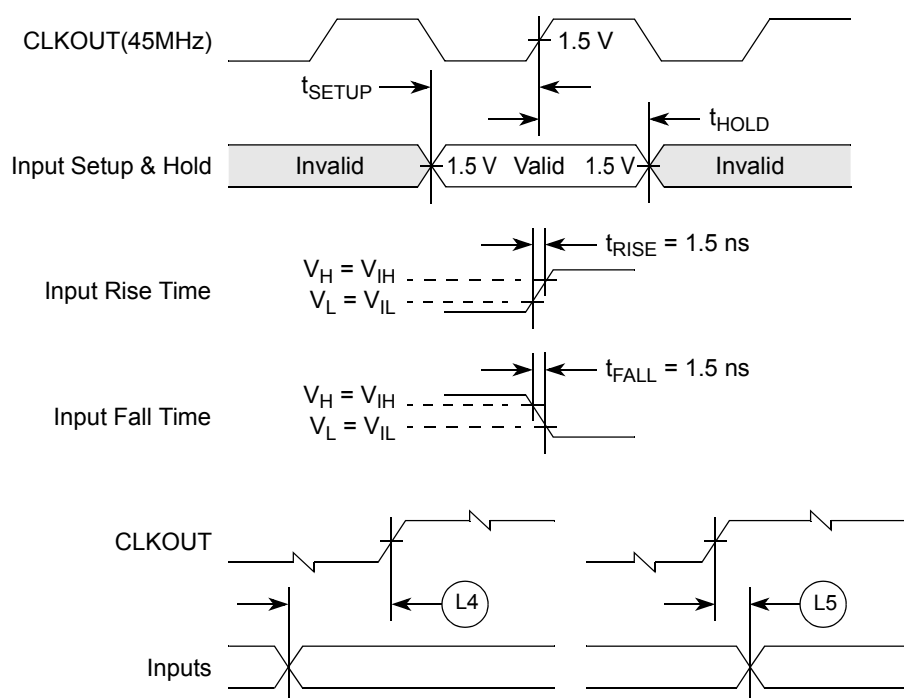


Figure 6. General Input Timing Requirements

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Electrical Characteristics

3.9.1 Read and Write Bus Cycles

Table 23 lists processor bus output timings. Read/write bus timings listed in Table 23 are shown in Figure 7 and Figure 8.

Table 23. External Bus Output Timing Specifications

| Num | C | Rating | Symbol | Min | Max | Unit |
|-------------------------------|---|--|-------------|------------------|-------------------|------|
| Control Outputs | | | | | | |
| L6a | | CLKOUT high to chip selects valid ¹ | t_{CHCV} | — | $0.5t_{CYC} + 10$ | ns |
| L6b | | CLKOUT high to byte select ($\overline{BS}[1:0]$) valid ² | t_{CHBV} | — | $0.5t_{CYC} + 10$ | ns |
| L6c | | CLKOUT high to output select (\overline{OE}) valid ³ | t_{CHOV} | — | $0.5t_{CYC} + 10$ | ns |
| L7a | | CLKOUT high to control output ($\overline{BS}[1:0]$, \overline{OE}) invalid | t_{CHCOI} | $0.5t_{CYC} + 2$ | — | ns |
| L7b | | CLKOUT high to chip selects invalid | t_{CHCI} | $0.5t_{CYC} + 2$ | — | ns |
| Address and Attribute Outputs | | | | | | |
| L8 | | CLKOUT high to address (ADDR[21:0]) and control (R/W) valid | t_{CHAV} | — | 10 | ns |
| L9 | | CLKOUT high to address (ADDR[21:0]) and control (R/W) invalid | t_{CHAI} | 2 | — | ns |
| Data Outputs | | | | | | |
| L10 | | CLKOUT high to data output (DATA[15:0]) valid | t_{CHDOV} | — | 13 | ns |
| L11 | | CLKOUT high to data output (DATA[15:0]) invalid | t_{CHDOI} | 2 | — | ns |
| L12 | | CLKOUT high to data output (DATA[15:0]) high impedance | t_{CHDOZ} | — | 9 | ns |

¹ \overline{CS}_n transitions after the falling edge of CLKOUT.

² \overline{BS}_n transitions after the falling edge of CLKOUT.

³ \overline{OE} transitions after the falling edge of CLKOUT.

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Electrical Characteristics

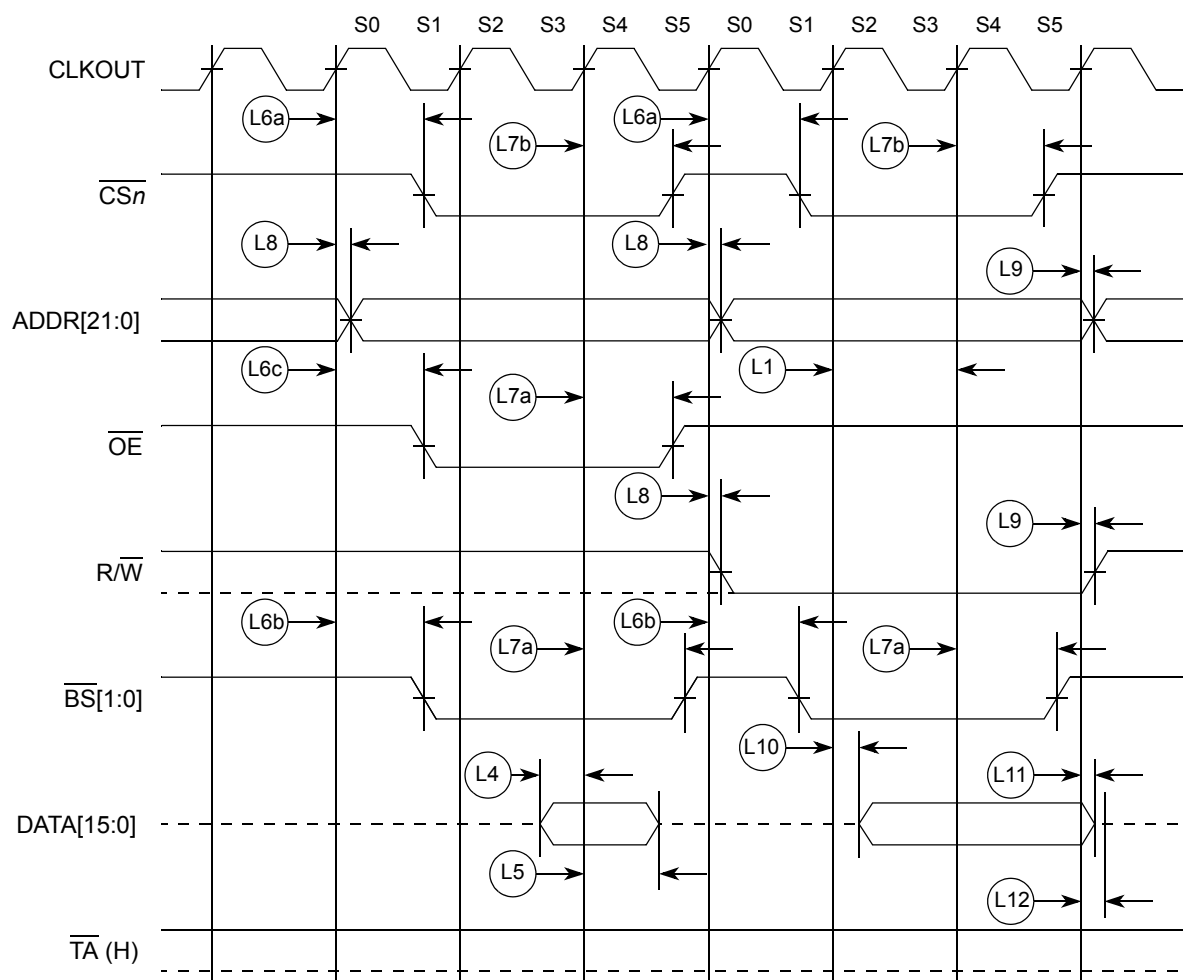


Figure 7. Read/Write (Internally Terminated) Bus Timing

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Electrical Characteristics

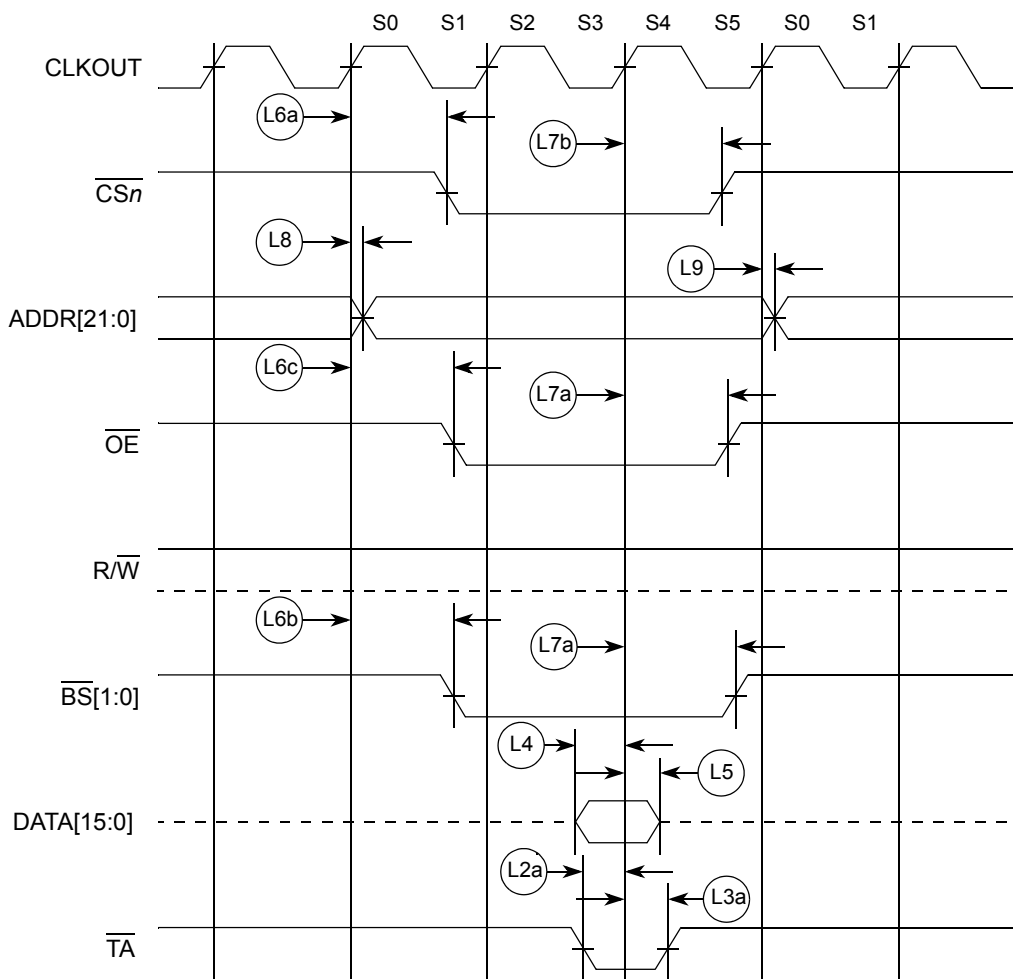


Figure 8. Read Bus Cycle Terminated by \overline{TA}

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Electrical Characteristics

3.10 Analog-to-Digital Converter Characteristics

Table 24 and Table 25 show conditions under which the ATD operates. The following constraints exist to obtain full-scale, full range results: $V_{SSA} \leq V_{RL} \leq V_{IN} \leq V_{RH} \leq V_{DDA}$. This constraint exists because the sample buffer amplifier cannot drive beyond the ATD power supply levels. If the input level goes outside of this range it will effectively be clipped.

Table 24. ATD Operating Characteristics in 5 V Range

| Conditions shown in Table 6 unless otherwise noted | | | | | | | |
|--|---|--|------------------------------|-------------------------------|--------|-------------------------------|-------------------|
| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
| M1 | D | Reference Potential Low High | V_{RL} V_{RH} | V_{SSA} $V_{DDA} \div 2$ | — — | $V_{DDA} \div 2$ V_{DDA} | V V |
| M2 | C | Differential Reference Voltage ¹ | $V_{RH} - V_{RL}$ | 4.50 | 5.00 | 5.25 | V |
| M3 | D | ATD Clock Frequency | f_{ATDCLK} | 0.5 | — | 2.0 | MHz |
| M4 | D | ATD 10-bit Conversion PeriodClock Cycles ² @ 2.0MHz f_{ATDCLK} | N_{CONV10} T_{CONV10} | 14 7 | — — | 28 14 | Cycles μs |
| M5 | D | ATD 8-bit Conversion PeriodClock Cycles ² @ 2.0MHz f_{ATDCLK} | N_{CONV8} T_{CONV8} | 12 6 | — — | 26 13 | Cycles μs |
| M6 | D | Recovery Time ($V_{DDA} = 5.0$ V) | t_{REC} | — | — | 20 | μs |
| M7 | P | Reference Supply current 1 ATD module enabled | I_{REF} | — | — | 0.375 | mA |
| M8 | P | Reference Supply current 2 ATD modules enabled | I_{REF} | — | — | 0.750 | mA |

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

² Minimum time assumes final sample period of 2 ATD clocks; maximum time assumes final sample period of 16 ATD clocks.

Table 25. ATD Operating Characteristics in 3.3 V Range

| Conditions shown in Table 6, with $V_{DDX} = 3.3$ V $\pm 10\%$ and a temperature maximum of +140°C unless otherwise noted. | | | | | | | |
|--|---|--|------------------------------|-------------------------------|--------|-------------------------------|-------------------|
| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
| N1 | D | Reference Potential Low High | V_{RL} V_{RH} | V_{SSA} $V_{DDA} \div 2$ | — — | $V_{DDA} \div 2$ V_{DDA} | V V |
| N2 | C | Differential Reference Voltage ¹ | $V_{RH} - V_{RL}$ | 3.0 | 3.3 | 3.6 | V |
| N3 | D | ATD Clock Frequency | f_{ATDCLK} | 0.5 | — | 2.0 | MHz |
| N4 | D | ATD 10-bit Conversion PeriodClock Cycles ² Conv, Time at 2.0MHz ATD Clock f_{ATDCLK} | N_{CONV10} T_{CONV10} | 14 7 | — — | 28 14 | Cycles μs |
| N5 | D | ATD 8-bit Conversion PeriodClock Cycles ² Conv, Time at 2.0MHz ATD Clock f_{ATDCLK} | N_{CONV8} T_{CONV8} | 12 6 | — — | 26 13 | Cycles μs |
| N6 | D | Recovery Time ($V_{DDA} = 5.0$ V) | t_{REC} | — | — | 20 | μs |
| N7 | P | Reference Supply current 1 ATD module enabled | I_{REF} | — | — | 0.375 | mA |
| N8 | P | Reference Supply current 2 ATD modules enabled | I_{REF} | — | — | 0.250 | mA |

¹ Full accuracy is not guaranteed when differential voltage is less than 3.0 V

² Minimum time assumes final sample period of 2 ATD clocks; maximum time assumes final sample period of 16 ATD clocks.

3.10.1 Factors Influencing Accuracy

Three factors — source resistance, source capacitance and current injection — have an influence on the accuracy of the ATD.

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Electrical Characteristics

3.10.1.1 Source Resistance

Due to the input pin leakage current as specified in Table 15 in conjunction with the source resistance there will be a voltage drop from the signal source to the ATD input. The maximum specified source resistance R_S , results in an error of less than 1/2 LSB (2.5 mV) at the maximum leakage current. If the device or operating conditions are less than the worst case, or leakage-induced errors are acceptable, larger values of source resistance are allowed.

3.10.1.2 Source Capacitance

When sampling, an additional internal capacitor is switched to the input. This can cause a voltage drop due to charge sharing with the external capacitance and the pin capacitance. For a maximum sampling error of the input voltage ≤ 1 LSB, then the external filter capacitor must be calculated as, $C_f \geq 1024 \times (C_{INS} - C_{INN})$.

3.10.1.3 Current Injection

There are two cases to consider:

1. A current is injected into the channel being converted. The channel being stressed has conversion values of 0x3FF (0xFF in 8-bit mode) for analog inputs greater than V_{RH} and 0x000 for values less than V_{RL} unless the current is higher than specified as disruptive condition.
2. Current is injected into pins in the neighborhood of the channel being converted. A portion of this current is picked up by the channel (coupling ratio K), This additional current impacts the accuracy of the conversion depending on the source resistance. The additional input voltage error on the converted channel can be calculated as $V_{ERR} = K \times R_S \times I_{INJ}$, with I_{INJ} being the sum of the currents injected into the two pins adjacent to the converted channel.

Table 26. ATD Electrical Characteristics

| Conditions are shown in Table 6 unless otherwise noted | | | | | | | |
|--|---|---|------------------------|------|-----|-----|------------|
| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
| P1 | C | Max input Source Resistance | R_S | — | — | 1 | K Ω |
| P2 | T | Total Input Capacitance | C_{INN} C_{INS} | — | — | 10 | pF |
| | | Non Sampling Sampling | | — | — | 22 | pF |
| P3 | C | Disruptive Analog Input Current | I_{NA} | -2.5 | — | 2.5 | mA |
| P4 | C | Coupling Ratio positive current injection | K_p | — | — | TBD | A/A |
| P5 | C | Coupling Ratio negative current injection | K_n | — | — | TBD | A/A |

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Electrical Characteristics

3.10.2 ATD Accuracy

Table 27 and Table 28 specify the ATD conversion performance excluding any errors due to current injection, input capacitance and source resistance.

Table 27. ATD Conversion Performance in 5 V Range

| Conditions shown in Table 6 unless otherwise noted. $V_{REF} = V_{RH} - V_{RL} = 5.12 \text{ V}$, resulting in one 8 bit count = 20 mV and one 10 bit count = 5 mV $f_{ATDCLK} = 2.0 \text{ MHz}$, $4.5 \text{ V} \leq V_{DDA} \leq 5.5 \text{ V}$ | | | | | | | |
|--|---|------------------------------------|--------|------|------|-----|--------|
| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
| Q1 | P | 10-bit Resolution | LSB | — | 5 | — | mV |
| Q2 | P | 10-bit Differential Nonlinearity | DNL | −1 | — | 1 | Counts |
| Q3 | P | 10-bit Integral Nonlinearity | INL | −2.5 | ±1.5 | 2.5 | Counts |
| Q4 | P | 10-bit Absolute Error ¹ | AE | −3 | ±2.0 | 3 | Counts |
| Q5 | P | 8-bit Resolution | LSB | — | 20 | — | mV |
| Q6 | P | 8-bit Differential Nonlinearity | DNL | −0.5 | — | 0.5 | Counts |
| Q7 | P | 8-bit Integral Nonlinearity | INL | −1.0 | ±0.5 | 1.0 | Counts |
| Q8 | P | 8-bit Absolute Error ¹ | AE | −1.5 | ±1.0 | 1.5 | Counts |

¹ These values include the quantization error which is inherently 1/2 count for any A/D converter.

Table 28. ATD Conversion Performance in 3.3 V Range

| Conditions shown in Table 6 unless otherwise noted. $V_{REF} = V_{RH} - V_{RL} = 5.12 \text{ V}$, resulting in one 8 bit count = 20 mV and one 10 bit count = 5 mV $f_{ATDCLK} = 2.0 \text{ MHz}$, $4.5 \text{ V} \leq V_{DDA} \leq 5.5 \text{ V}$ | | | | | | | |
|--|---|------------------------------------|--------|------|------|-----|--------|
| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
| R1 | P | 10-bit Resolution | LSB | — | 3.25 | — | mV |
| R2 | P | 10-bit Differential Nonlinearity | DNL | −1.5 | — | 1.5 | Counts |
| R3 | P | 10-bit Integral Nonlinearity | INL | −3.5 | ±1.5 | 3.5 | Counts |
| R4 | P | 10-bit Absolute Error ¹ | AE | −5 | ±2.0 | 5 | Counts |
| R5 | P | 8-bit Resolution | LSB | — | 13 | — | mV |
| R6 | P | 8-bit Differential Nonlinearity | DNL | −0.5 | — | 0.5 | Counts |
| R7 | P | 8-bit Integral Nonlinearity | INL | −1.5 | ±1.0 | 1.5 | Counts |
| R8 | P | 8-bit Absolute Error ¹ | AE | −1.5 | ±1.0 | 1.5 | Counts |

¹ These values include the quantization error which is inherently 1/2 count for any A/D converter.

For the following definitions see also Figure 8.

Differential Non-Linearity (DNL) is defined as the difference between two adjacent switching steps.

$$DNL(i) = \frac{V_i - V_{i-1}}{1 \text{ LSB}} - 1$$

The Integral Non-Linearity (INL) is defined as the sum of all DNLs:

$$INL(n) = \sum_{i=1}^n DNL(i) = \frac{V_n - V_0}{1 \text{ LSB}} - n$$

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Electrical Characteristics

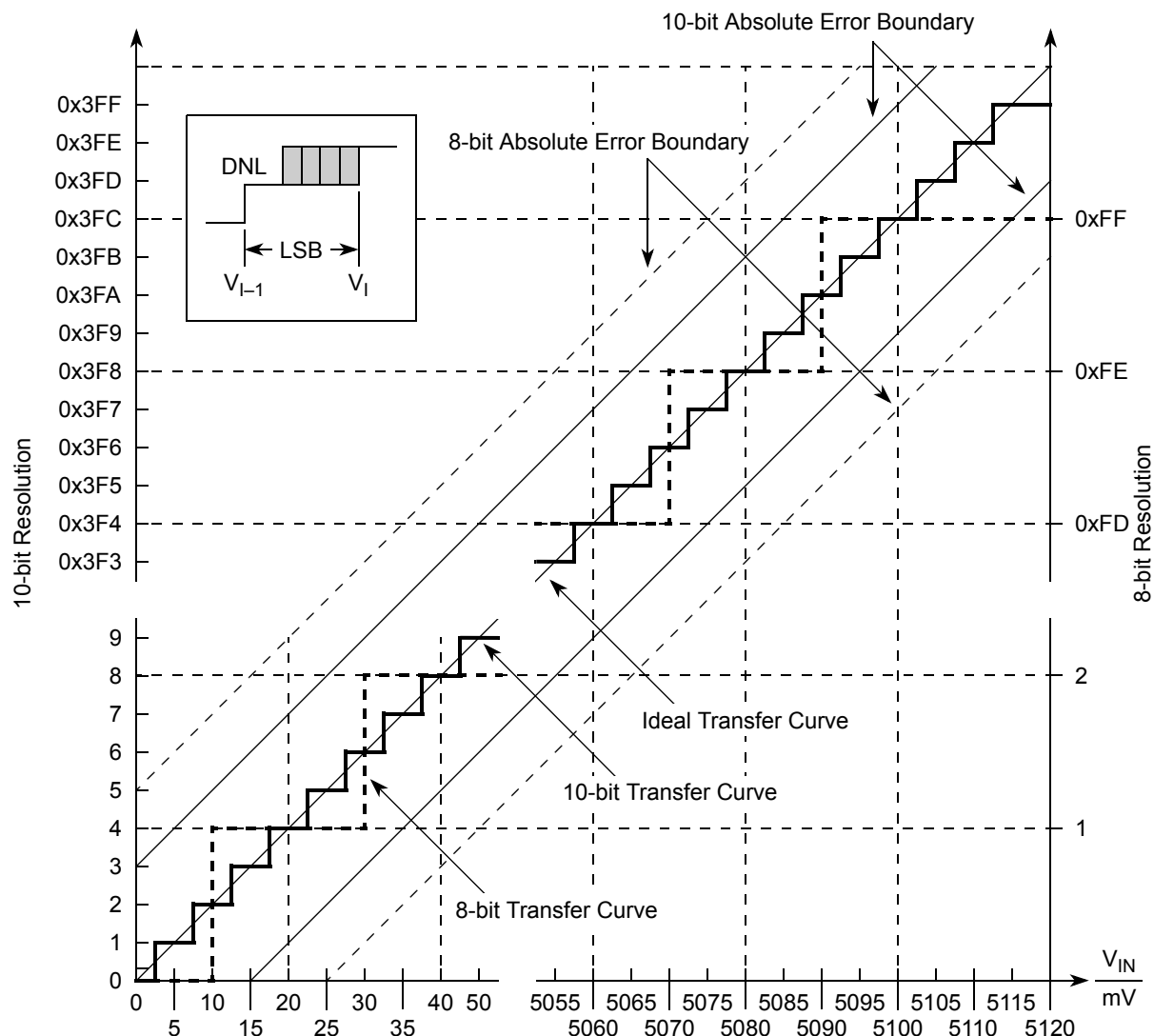


Figure 9. ATD Accuracy Definitions

NOTE

Figure 8 shows only definitions, for specification values refer to Table 27.

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Electrical Characteristics

3.10.3 ATD Electrical Specifications

Table 29 lists the DC electrical characteristics for the ATD module. Table 27 lists the analog-to-digital conversion performance specifications.

Table 29. ATD Electrical Characteristics (Operating) ¹

| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
|-----|---|---|--------------------------|----------------------|-----|----------------------|--------|
| S1 | | Reference Potential ² Low | V_{RL} | V_{SSA} | — | $V_{DDA} \div 2$ | V |
| S2 | | High | V_{RH} | $V_{DDA} \div 2$ | — | V_{DDA} | V |
| S3 | | Voltage Difference $V_{RH} - V_{RL}$ ³ | $V_{RH} - V_{RL}$ | 4.5 | — | 5.5 | V |
| S4 | | Analog Input Voltage | V_{INDC} | −0.3 | — | $V_{DDA} + 0.3$ | V |
| S5 | | Digital Input High | V_{IH} | $0.7 \times V_{DDA}$ | — | $V_{DDA} + 0.3$ | V |
| S6 | | Digital Input Low | V_{IL} | $V_{SSA} - 0.3$ | — | $0.2 \times V_{DDA}$ | V |
| S7 | | Analog Supply Current Run | $I_{DDA_{run}}$ | — | TBD | TBD | mA |
| | | −40°C | | — | TBD | TBD | mA |
| | | 25°C | | — | TBD | TBD | mA |
| | | 85°C ⁴ | | — | TBD | TBD | mA |
| | | 105°C ⁴ | | — | TBD | TBD | mA |
| | | 125°C ⁴ | | — | TBD | TBD | mA |
| S8 | | Pseudo Stop | $I_{DDA_{pseudo_stop}}$ | — | TBD | TBD | μA |
| | | −40°C | | — | 17 | TBD | μA |
| | | 25°C | | — | TBD | TBD | μA |
| | | 85°C ⁴ | | — | TBD | TBD | μA |
| | | 105°C ⁴ | | — | TBD | TBD | μA |
| | | 125°C ⁴ | | — | TBD | TBD | μA |
| S9 | | Stop (low power) | $I_{DDA_{stop}}$ | — | TBD | TBD | μA |
| | | −40°C | | — | 17 | TBD | μA |
| | | 25°C | | — | TBD | TBD | μA |
| | | 85°C ⁴ | | — | TBD | TBD | μA |
| | | 105°C ⁴ | | — | TBD | TBD | μA |
| | | 125°C ⁴ | | — | TBD | TBD | μA |
| S10 | | Reference Supply Current | I_{REF} | — | 200 | 250 | μA |
| S11 | | Input Injection Current ⁵ | I_{INJ} | — | — | 2 | mA |
| S12 | | Input Current, Off Channel ⁶ | I_{OFF} | −200 | — | 200 | nA |
| S13 | | Total Input Capacitance Not Sampling | C_{INN} | — | — | 10 | pF |
| S14 | | Sampling | C_{INS} | — | — | 15 | pF |
| S15 | | Disruptive Analog Input Current ⁷ | I_{NA} | −3 | — | 3 | mA |
| S16 | | Coupling Ratio ⁸ | K | — | — | 10^{-4} | A/A |
| S17 | | Incremental Error due to injection current (All channels with $10k < R_s < 100k$) ⁹ | | — | — | ±1 | Counts |
| S18 | | Incremental Error due to injection current (Channel under test $R_s=10k$, $I_{INJ}=\pm 3mA$) ⁹ | | — | — | ±1 | Counts |
| S19 | | Incremental Capacitance during Sampling ¹⁰ | C_{SAMP} | — | — | 5 | pF |

¹ All voltages referred to V_{SSA} , −40 to 125°C, $V_{DDA} = 5.0 \text{ V} \pm 10\%$ and 2.0 MHz conversion rate unless otherwise noted. Refer to Table 6 for additional operating conditions.

² To obtain full-scale, full-range results, $V_{SSA} < V_{RL} < V_{INDC} < V_{RH} < V_{DDA}$. Sample buffer amp cannot drive beyond the power supply levels. If the input level goes outside of this range, it will effectively be clipped.

³ Full accuracy is not guaranteed when the differential reference voltage is less than 4.5 V.

⁴ 85°C, 105°C, and 125°C refer to the "C", "V", and "M" Temperature Options, respectively.

⁵ The input injection current is specified to 1 count of error.

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- ⁶ Maximum leakage occurs at maximum operating temperature. Current decreases by approximately one-half for each 8 to 12 °C, in the ambient temperature range of 50 to 125 °C.
- ⁷ Below disruptive current conditions, the channel being stressed has conversion values of 0x3FF for analog inputs greater than V_{RH} and 0x000 for values less than V_{RL} . This assumes that $V_{DDA} \geq AV_{RH}$ and $V_{RL} \geq V_{SSA}$ due to the presence of the sample amplifier. Other channels are not affected by non-disruptive conditions.
- ⁸ Coupling Ratio, K, is defined as the ratio of the output current, I_{OUT} , measured on the pin under test to the injection current, I_{INJ} , when both adjacent pins are overstressed with the specified injection current. $K = I_{OUT} \div I_{INJ}$. The input voltage error on the channel under test is calculated as $V_{err} = I_{INJ} \times K \times R_S$.
- ⁹ Total injection current is determined by the number of channels injecting (for example, 15), external injection voltage ($V_{INJ} - V_{POSCLAMP}$ or $V_{INJ} - V_{NEGCLAMP}$), and the external source impedance, R_S , wherein all input channels have the same values. To determine the error voltage on the converted channel, only the two adjacent channels are expected to contribute to the error voltage: $V_{errj} = (V_{INJ} - V_{CLAMP}) \times K \times 2$.
- ¹⁰ For a maximum sampling error of the input voltage ≤ 1 LSB, then the external filter capacitor, $C_f \geq 1024 \times C_{SAMP}$. The value of C_{SAMP} in the new design may be reduced, or increased slightly.

Table 30. ATD Performance Specifications ¹

| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
|-----|---|---|--------|------|-----|-----|------------|
| T1 | D | 10-bit Resolution | LSB | — | 5 | — | mV |
| T2 | D | 10-bit Differential Nonlinearity ² | DNL | –1 | — | 1 | Counts |
| T3 | D | 10-bit Integral Nonlinearity ² | INL | –2 | — | 2 | Counts |
| T4 | D | 10-bit Absolute Error ^{2, 3} | AE | –2.5 | — | 2.5 | Counts |
| T5 | D | Max input Source Impedance ⁴ | R_S | — | — | 100 | k Ω |

¹ All voltages referred to V_{SSA} , $V_{DDA} = 5.0 \text{ V} \pm 10\%$, ATD clock = 2.1 Mhz., –40 to 125 °C.

² Note: 1 LSB = 1 Count (At $V_{REF} = 5.12 \text{ V}$, one 8 bit count = 20 mV, one 10-bit count = 5 mV)

³ These values include quantization error which is inherently 1/2 count for any A/D converter.

⁴ This value is based on error attributed to the specified leakage value of TBD nA resulting in an error of less than 1/2 LSB (2.5 mV). If operating conditions are less than worst case or leakage-induced error is acceptable, larger values of source resistance is allowable.

3.10.4 ATD Timing Specifications

Table 31. ATD Timing Specifications

| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
|-----|---|--|------------------------------|---------|--------|----------|---------------------------|
| U1 | D | ATD Module Clock Frequency | F_{clk} | — | — | 25.0 | MHz |
| U2 | D | ATD Conversion Clock Frequency | F_{atdclk} | 0.5 | — | 2.0 | MHz |
| U3 | D | ATD 10-bit Conversion Period Clock Cycles Conv. Time | N_{CONV10} T_{CONV10} | 14 7 | — — | 28 14 | Cycles μsec |
| U4 | D | Stop Recovery Time ($V_{DDA} = 5.0 \text{ V}$) | T_{SR} | — | — | 100 | μsec |

Table 32. ATD External Trigger Timing Specifications

| Num | C | Parameter | Symbol | Min | Max | Unit |
|-----|---|-----------------------------------|--------------|-----|--|---------|
| V1 | D | ETRIG Minimum Period | T_{PERIOD} | — | 1 sample + 1 conv. + 1 ATD clock | CYCLE |
| V2 | D | ETRIG Minimum Pulse Width | t_{PW} | 2 | — | SYS CLK |
| V3 | D | ETRIG Level Recovery ¹ | t_{LR} | 1 | — | SYS CLK |
| V4 | D | Conversion Start Delay | t_{DLY} | — | 2 | SYS CLK |

¹ Time prior to end of conversion that the ETRIG pin must be deactivated so that another conversion sequence does not start.

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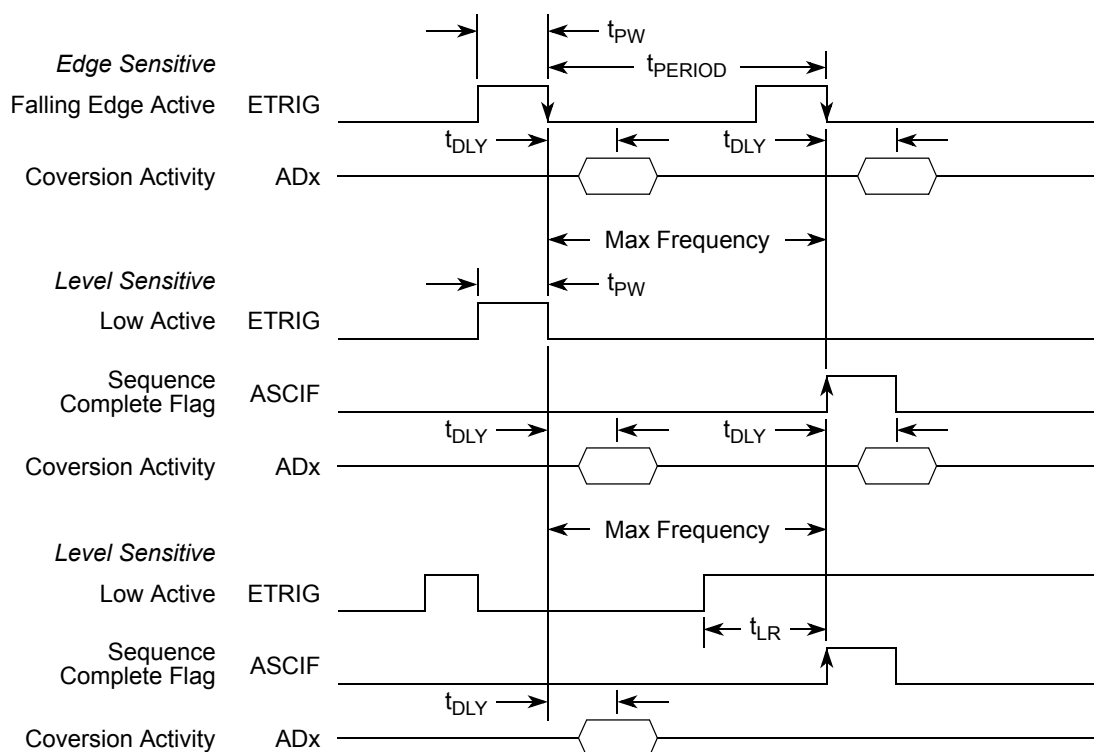


Figure 10. ATD External Trigger Timing Diagram

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Electrical Characteristics

3.11 Serial Peripheral Interface Electrical Specifications

3.11.1 Master Mode

Figure 11 and Figure 12 illustrate master mode timing. Timing values are shown in Table 33.

Table 33. SPI Master Mode Timing Characteristics ¹

| Conditions are shown in Table 6 unless otherwise noted, C _{LOAD} = 200pF on all outputs | | | | | | | |
|--|---|---|-------------------|-----------------------|-----|-----------------------|------------------|
| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
| W1a | P | Operating Frequency | f _{op} | DC | — | 1/4 | f _{bus} |
| W1b | P | SCK Period t _{sck} = 1/f _{op} | t _{sck} | 4 | — | 2048 | t _{bus} |
| W2 | D | Enable Lead Time | t _{lead} | 1/2 | — | — | t _{sck} |
| W3 | D | Enable Lag Time | t _{lag} | 1/2 | — | — | t _{sck} |
| W4 | D | Clock (SCK) High or Low Time | t _{wsck} | t _{bus} – 30 | — | 1024 t _{bus} | ns |
| W5 | D | Data Setup Time (Inputs) | t _{su} | 25 | — | — | ns |
| W6 | D | Data Hold Time (Inputs) | t _{hi} | 0 | — | — | ns |
| W9 | D | Data Valid (after Enable Edge) | t _v | — | — | 25 | ns |
| W10 | D | Data Hold Time (Outputs) | t _{ho} | 0 | — | — | ns |
| W11 | D | Rise Time Inputs and Outputs | t _r | — | — | 25 | ns |
| W12 | D | Fall Time Inputs and Outputs | t _f | — | — | 25 | ns |

¹ The numbers 7, 8 in the column labeled “Num” are missing. This has been done on purpose to be consistent between the Master and the Slave timing shown in Table 34.

3.11.2 Slave Mode

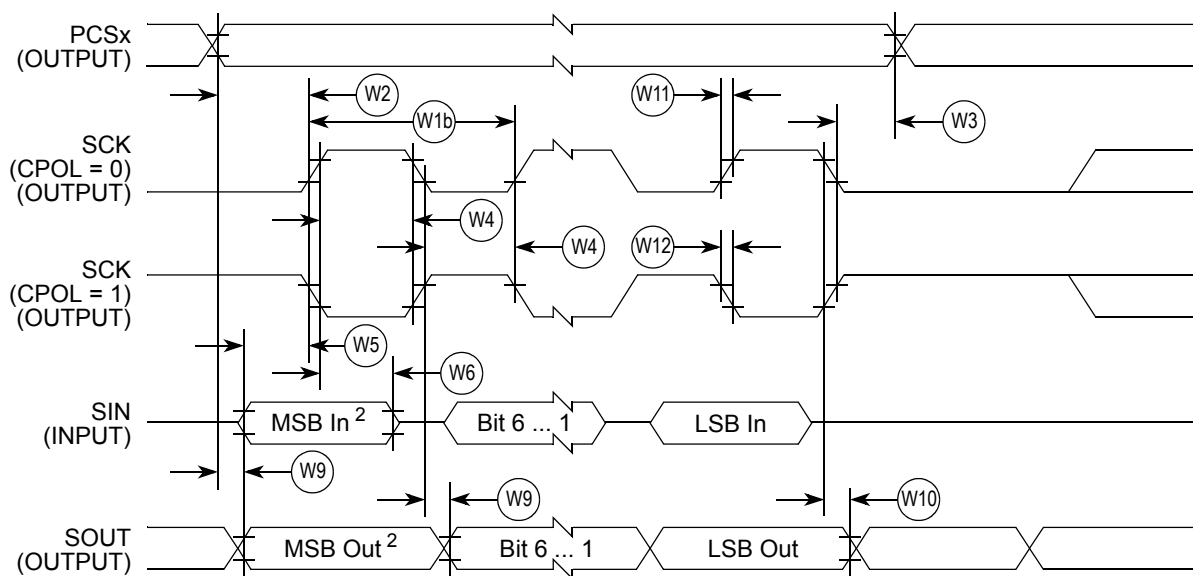
Figure 13 and Figure 14 illustrate the slave mode timing. Timing values are shown in Table 34.

Table 34. SPI Slave Mode Timing Characteristics

| Conditions are shown in Table 6 unless otherwise noted, C _{LOAD} = 200pF on all outputs | | | | | | | |
|--|---|---|-------------------|-----------------------|-----|------|------------------|
| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
| X1a | P | Operating Frequency | f _{op} | DC | — | 1/4 | f _{bus} |
| X1b | P | SCK Period t _{sck} = 1/f _{op} | t _{sck} | 4 | — | 2048 | t _{bus} |
| X2 | D | Enable Lead Time | t _{lead} | 1 | — | — | t _{cyc} |
| X3 | D | Enable Lag Time | t _{lag} | 1 | — | — | t _{cyc} |
| X4 | D | Clock (SCK) High or Low Time | t _{wsck} | t _{cyc} – 30 | — | — | ns |
| X5 | D | Data Setup Time (Inputs) | t _{su} | 25 | — | — | ns |
| X6 | D | Data Hold Time (Inputs) | t _{hi} | 25 | — | — | ns |
| X7 | D | Slave Access Time | t _a | — | — | 1 | t _{cyc} |
| X8 | D | Slave SIN Disable Time | t _{dis} | — | — | 1 | t _{cyc} |
| X9 | D | Data Valid (after SCK Edge) | t _v | — | — | 25 | ns |
| X10 | D | Data Hold Time (Outputs) | t _{ho} | 0 | — | — | ns |
| X11 | D | Rise Time Inputs and Outputs | t _r | — | — | 25 | ns |
| X12 | D | Fall Time Inputs and Outputs | t _f | — | — | 25 | ns |

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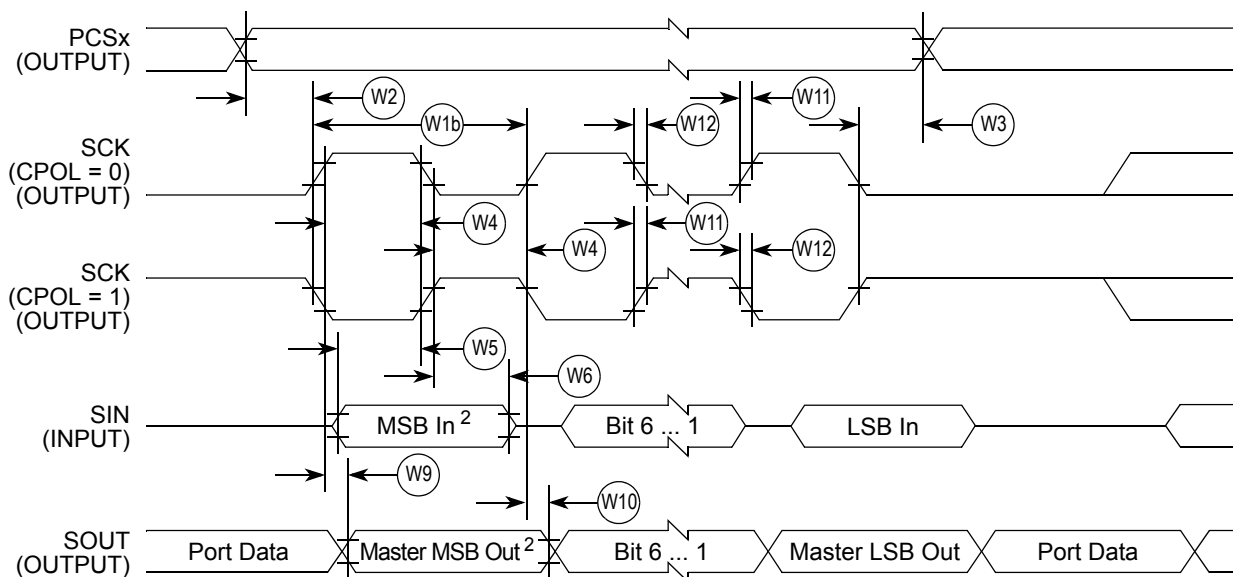
Electrical Characteristics



¹ If configured as output.

² LSBFE = 0. For LSBFE = 1, bit order is LSB, bit 1, ..., bit 6, MSB.

Figure 11. SPI Master Timing (CPHA = 0)



¹ If configured as output.

² LSBF = 0. For LSBF = 1, bit order is LSB, bit 1, ..., bit 6, MSB.

Figure 12. SPI Master Timing (CPHA = 1)

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Electrical Characteristics

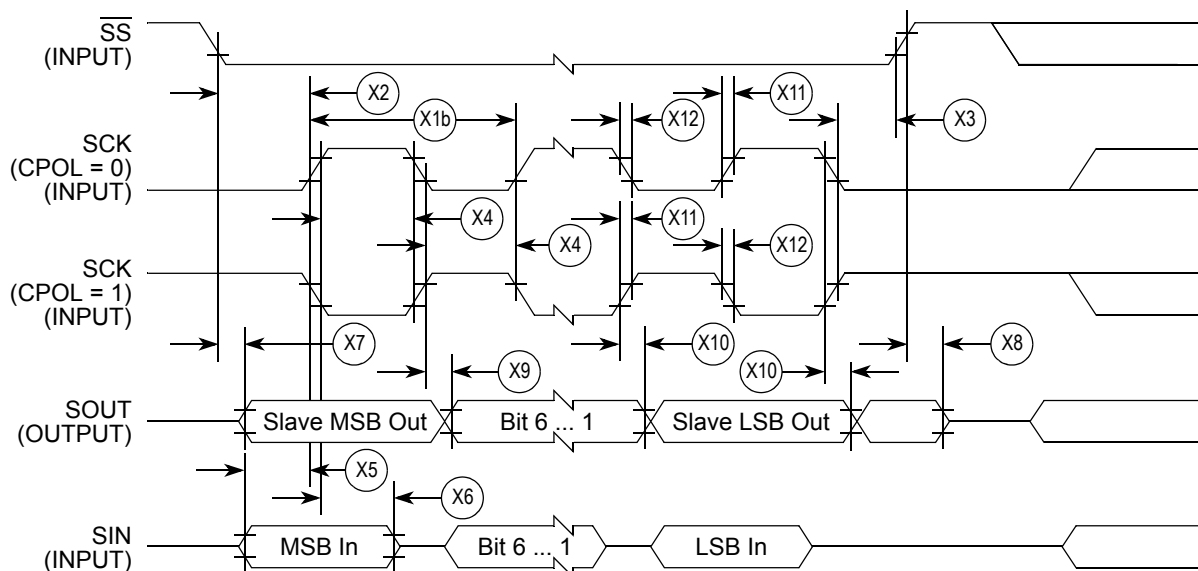


Figure 13. SPI Slave Timing (CPHA = 0)

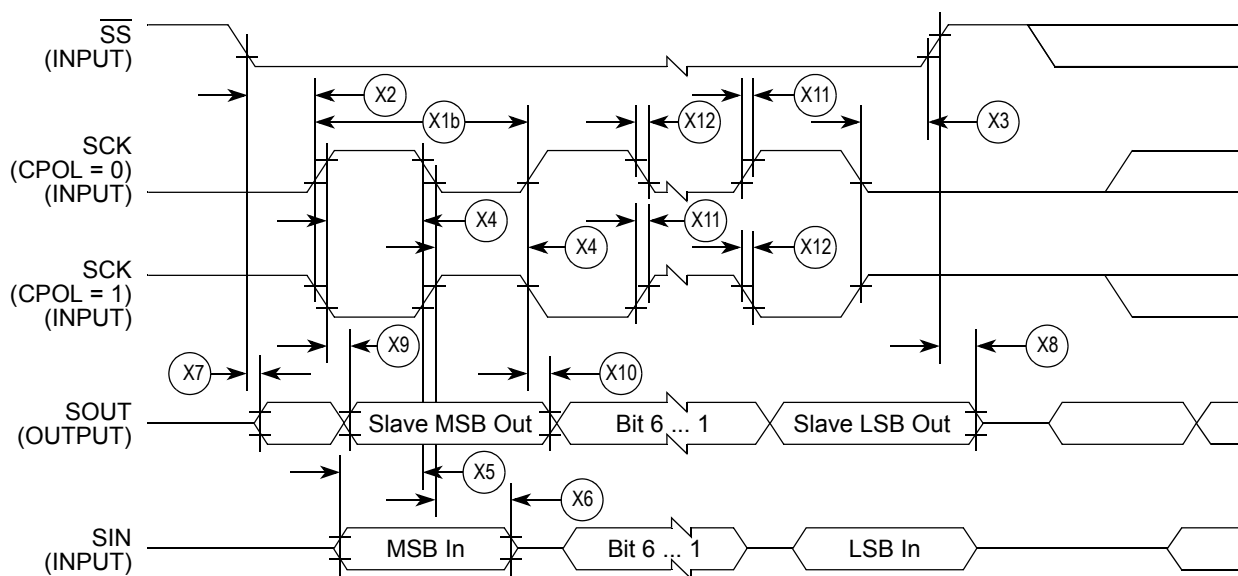


Figure 14. SPI Slave Timing (CPHA = 1)

3.12 FlexCAN Electrical Specifications

Table 35. FlexCAN Wake-up Pulse Characteristics

| Conditions are shown in Table 6 unless otherwise noted | | | | | | | |
|--|---|---|-----------|-----|-----|-----|---------------|
| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
| Y1 | P | FlexCAN Wake-up dominant pulse filtered | t_{WUP} | — | — | 2 | μs |
| Y2 | P | FlexCAN Wake-up dominant pulse passed | t_{WUP} | 5 | — | — | μs |

3.13 Program Flash and Data Flash Timing Characteristics

NOTE

Unless otherwise noted the abbreviation NVM (Non-Volatile Memory) is used for both program Flash and data Flash.

3.13.1 NVM timing

The time base for all NVM program or erase operations is derived from the system clock divided by two ($F_{\text{sys}}/2$). A minimum system frequency $f_{\text{NVMf}_{\text{sys}}}$ is required for performing program or erase operations. The NVM modules do not have any means to monitor the frequency and will not prevent program or erase operation at frequencies above or below the specified minimum. Attempting to program or erase the NVM modules at a lower frequency a full program or erase transition is not assured.

The Flash and Data Flash program and erase operations are timed using a clock derived from the system frequency using the CFMCLKD register. The frequency of this clock must be set within the limits specified as f_{NVMOP} . The minimum program and erase times shown in Table 36 are calculated for maximum f_{NVMOP} and maximum f_{bus} . The maximum times are calculated for minimum f_{NVMOP} and a f_{bus} of 2 MHz.

3.13.1.1 Single Word Programming

The programming time for single word programming is dependant on the bus frequency as a well as on the frequency f_{NVMOP} and can be calculated according to the following formula.

$$t_{\text{swpgm}} = 9 \cdot \frac{1}{f_{\text{NVMOP}}} + 25 \cdot \frac{1}{f_{\text{bus}}}$$

3.13.1.2 Burst Programming

This applies only to the Flash where up to 32 words in a row can be programmed consecutively using burst programming by keeping the command pipeline filled. The time to program a consecutive word can be calculated as:

$$t_{\text{bwpgm}} = 4 \cdot \frac{1}{f_{\text{NVMOP}}} + 9 \cdot \frac{1}{f_{\text{bus}}}$$

The time to program a whole row is:

$$t_{\text{brpgm}} = t_{\text{swpgm}} + 31 \cdot t_{\text{bwpgm}}$$

Burst programming is more than 2 times faster than single word programming.

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Electrical Characteristics

3.13.1.3 Sector Erase

Erasing a 4k byte Flash sector takes:

$$t_{\text{era}} \approx 4000 \cdot \frac{1}{f_{\text{NVMOP}}}$$

The setup time can be ignored for this operation.

3.13.1.4 Mass Erase

Erasing a NVM block takes:

$$t_{\text{mass}} \approx 20000 \cdot \frac{1}{f_{\text{NVMOP}}}$$

The setup time can be ignored for this operation.

3.13.1.5 Blank Check

The time it takes to perform a blank check on the Flash or Data Flash is dependant on the location of the first non-blank word starting at relative address zero. It takes one bus cycle per word to verify plus a setup of the command.

$$t_{\text{check}} \approx \text{location} \cdot t_{\text{cyc}} + 10 \cdot t_{\text{cyc}}$$

Table 36. NVM Timing Characteristics ¹

| Num | C | Rating | Symbol | Min | Typ | Max | Unit |
|-----|---|---|----------------------|--------------------|-----|---------------------|------------------|
| Z1 | D | System Clock/2 | f_{NVMfsys} | 0.5 | — | 50 ² | MHz |
| Z2 | D | Bus frequency for Programming or Erase Operations | f_{NVMBUS} | 1 | — | — | MHz |
| Z3 | D | Operating Frequency | f_{NVMOP} | 150 | — | 200 | kHz |
| Z4 | P | Single Word Programming Time | t_{swpgm} | 46 ³ | — | 74.5 ⁴ | μs |
| Z5 | D | Flash Burst Programming consecutive word | t_{bwpgm} | 20.4 ³ | — | 31 ⁴ | μs |
| Z6 | D | Flash Burst Programming Time for 32 Words | t_{brpgm} | 678.4 ³ | — | 1035.5 ⁴ | μs |
| Z7 | P | Sector Erase Time | t_{era} | 20 ⁵ | — | 26.7 ⁴ | ms |
| Z8 | P | Mass Erase Time | t_{mass} | 100 ⁵ | — | 133 ⁴ | ms |
| Z9 | D | Blank Check Time Flash per block | t_{check} | 11 ⁶ | — | 32778 ⁷ | t_{cyc} |
| Z10 | D | Blank Check Time Data Flash per block | t_{check} | 11 ⁶ | — | 2058 ⁷ | t_{cyc} |

¹ Conditions are shown in Table 6 unless otherwise noted

² Restrictions for oscillator in crystal mode apply!

³ Minimum programming times are achieved under maximum NVM operating frequency f_{NVMOP} and maximum bus frequency f_{bus} .

⁴ Maximum erase and programming times are achieved under particular combinations of f_{NVMOP} and bus frequency f_{bus} . Refer to formulae in Section 3.13.1.1, "Single Word Programming," through Section 3.13.1.4, "Mass Erase," for more information.

⁵ Minimum erase times are achieved under maximum NVM operating frequency f_{NVMOP} .

⁶ Minimum time, if first word in the array is not blank

⁷ Maximum time to complete check on an erased block

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3.13.2 NVM Reliability

The reliability of the NVM blocks is guaranteed by stress test during qualification, constant process monitors and burn-in to screen early life failures. The failure rates for data retention and program/erase cycling are specified at the operating conditions noted. The program/erase cycle count on the sector is incremented every time a sector or mass erase event is executed.

Table 37. NVM Reliability Characteristics

| Conditions shown in Table 6 unless otherwise noted. | | | | |
|---|---|--|--------|--------|
| Num | C | Rating | Min | Unit |
| Z10 | C | Program/Data Flash Program/Erase endurance (–40C to +125C) | 10,000 | Cycles |
| Z11 | C | Program/Data Flash Data Retention Lifetime | 15 | Years |

NOTE

All values shown in Table 37 are target values and subject to characterization.

For Flash cycling performance, each Program operation must be preceded by an erase.

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Device Pin Assignments

4 Device Pin Assignments

The MAC7100 Family is available in 208-pin ball grid array (MAP BGA), 144-pin low profile quad flat (LQFP), 112-pin LQFP, and 100-pin LQFP package options. The family of devices offer pin-compatible packaged devices to assist with system development and accommodate a direct application enhancement path. Refer to Table 1 for a comparison of the peripheral sets and package options for each device.

Most pins perform two or more functions, which is described in more detail in the *MAC7100 Microcontroller Family Reference Manual* (MAC7100RM/D). Figure 15, Figure 16, Figure 17, Figure 18, and Figure 19 show the pin assignments for the various packages.

4.1 MAC7141PV Pin Assignments

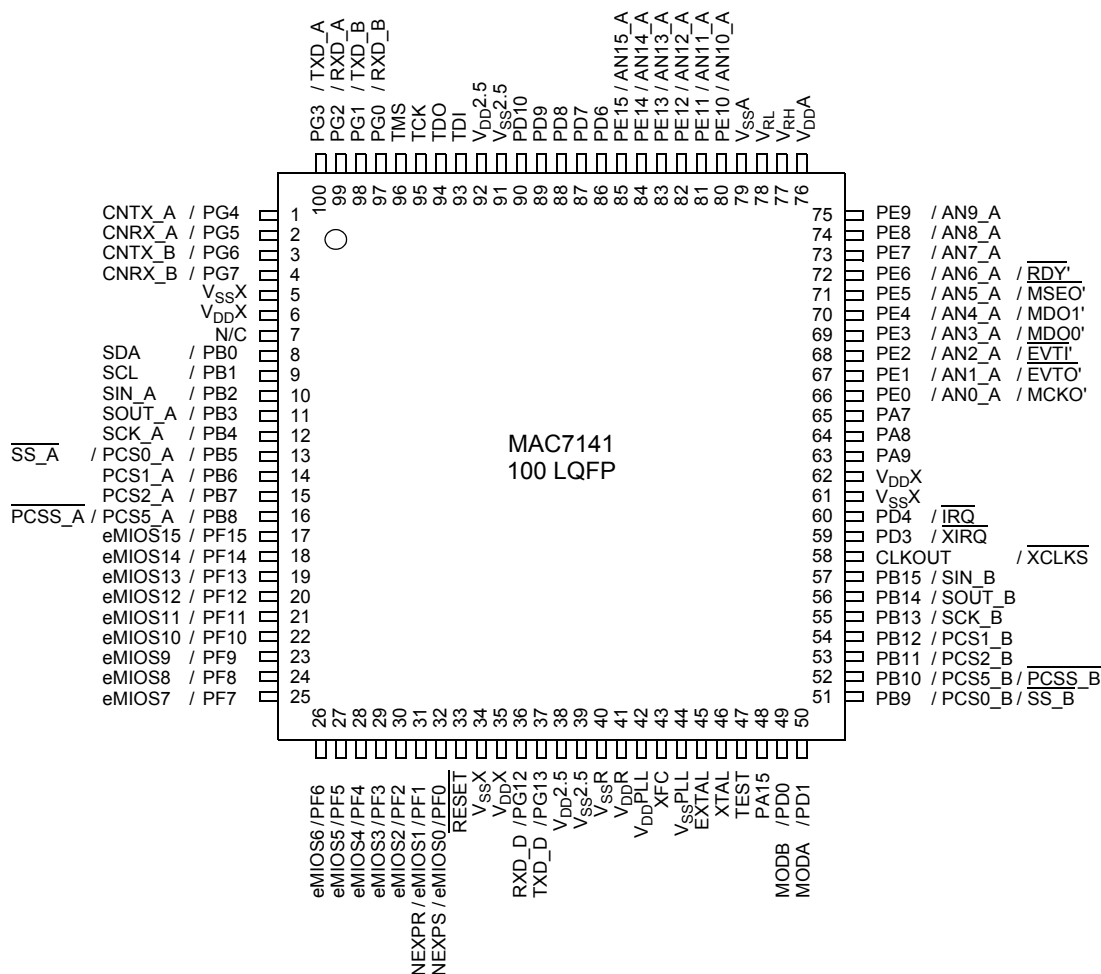


Figure 15. Pin Assignments for MAC7141 in 100-pin LQFP

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Device Pin Assignments

4.2 MAC7121PV Pin Assignments

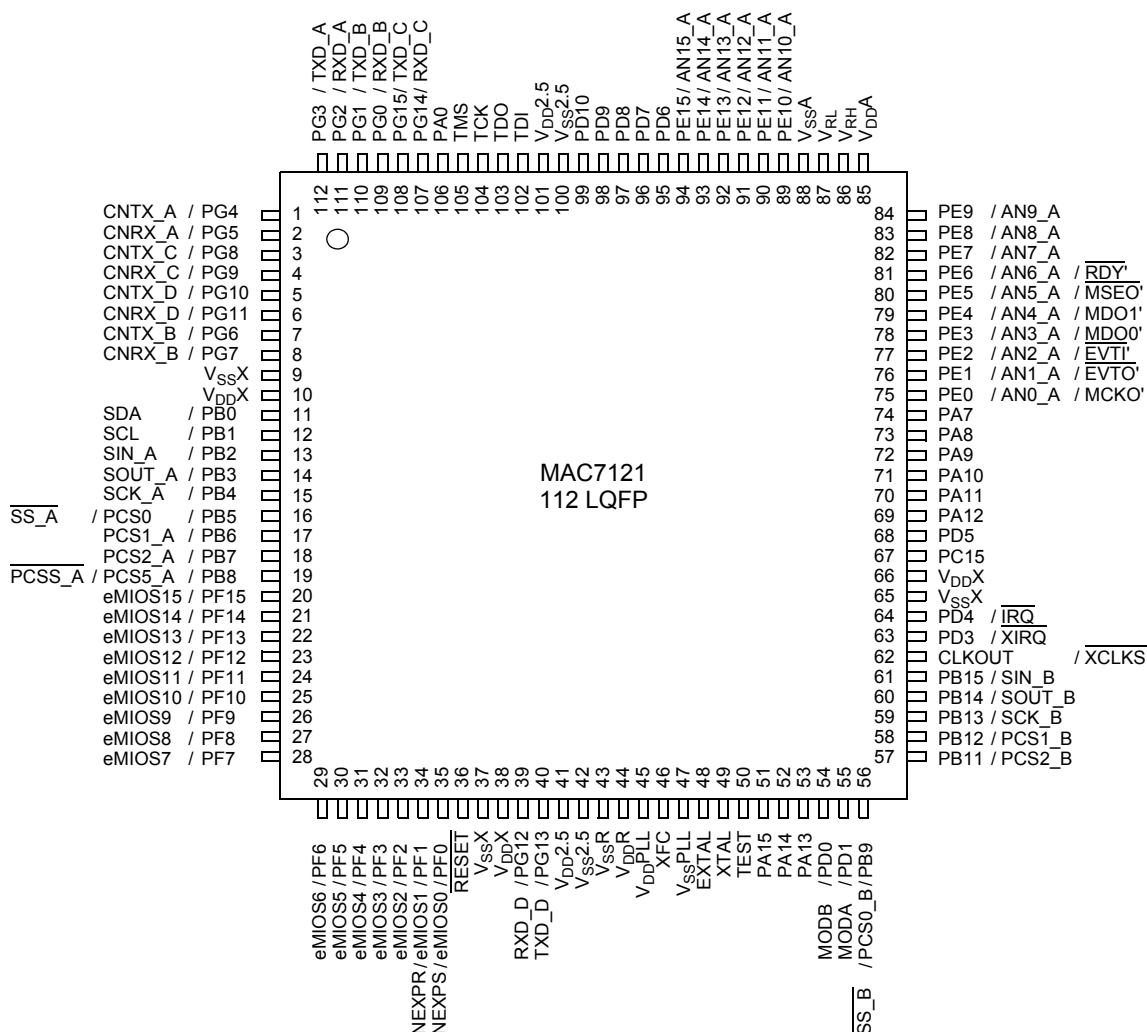


Figure 16. Pin Assignments for MAC7121 in 112-pin LQFP

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Device Pin Assignments

4.4 MAC7111PV Pin Assignments

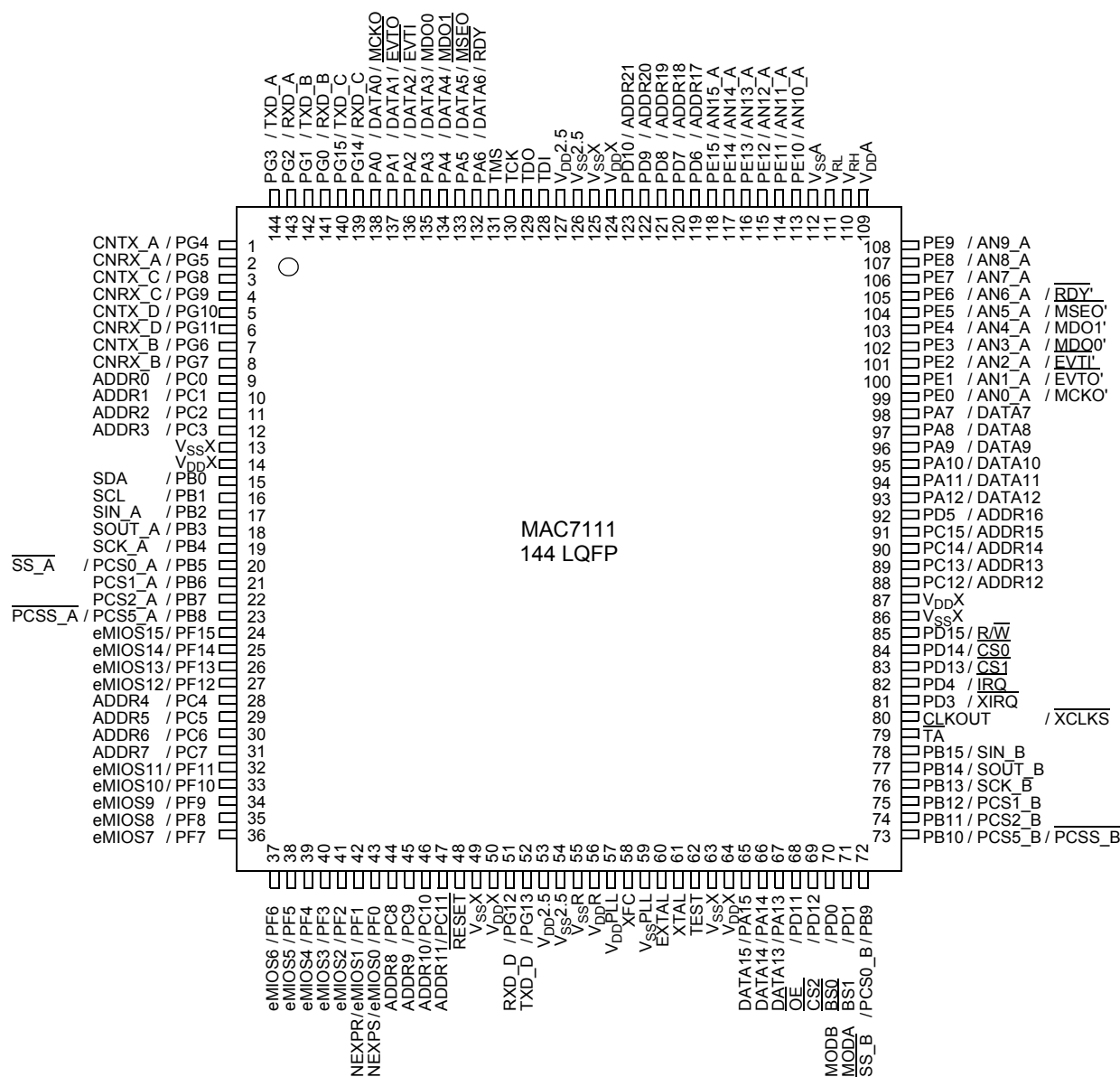


Figure 18. Pin Assignments for MAC7111 in 144-pin LQFP

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Device Pin Assignments

4.5 MAC7131VF Pin Assignments

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|-------------------|-------------------|-------------------|-------------------|-------------------|---------------------|---------------------------|---------------------|---------------------|---------------------|-------------------|-------------------|-------------------|------------------------|-------------------|-------------------|
| A | V _{SS} X | V _{SS} X | PG0 | PG14 | PA2 | PA5 | TCLK | TDI | PE15 | PE14 | PH14 | PE12 | PH11 | V _{RL} | V _{RH} | V _{DD} A |
| B | V _{SS} X | V _{SS} X | PG2 | PG15 | PA0 | PA4 | TMS | TDO | PD9 | PH15 | PE13 | PH12 | PE10 | PH9 | V _{DD} A | PH8 |
| C | PG5 | PG3 | V _{SS} X | PG1 | PA1 | PA3 | PA6 | V _{SS} 2.5 | V _{DD} X | PD6 | PH13 | PE11 | V _{DD} A | PE8 | PE7 | PH7 |
| D | PG9 | PG8 | PG4 | V _{SS} X | V _{SS} X | V _{SS} 2.5 | V _{SS} 2.5 | PD10 | PD8 | PD7 | V _{SS} A | V _{SS} A | PH10 | PE9 | PE6 | PH6 |
| E | PG6 | PG11 | PG10 | V _{SS} X | | | | | | | | | PE4 | PE5 | PH5 | PH4 |
| F | PC0 | PG7 | PC1 | V _{SS} X | | | | | | | | | PE2 | PE3 | PH3 | PH2 |
| G | PB0 | PC2 | PC3 | V _{SS} X | | | | | | | | | PH0 | PH1 | PE1 | PE0 |
| H | PB3 | PB2 | PB1 | V _{DD} X | | | | | | | | | PA8 | PA9 | PA7 | PA10 |
| J | PB5 | PB6 | PB4 | V _{SS} X | | | | | | | | | PD5 | PA12 | PA11 | PC15 |
| K | PB7 | PB8 | PF15 | V _{SS} X | | | | | | | | | PC13 | PC12 | PC14 | V _{DD} X |
| L | PF14 | PF13 | PC4 | V _{SS} X | | | | | | | | | PD13 | PD14 | PD15 | PD4 |
| M | PF12 | PC5 | PC6 | V _{SS} X | | | | | | | | | V _{SS} X | $\overline{\text{TA}}$ | PD3 | CLKOUT |
| N | PF11 | PF10 | PC7 | V _{SS} X | V _{SS} R | V _{SS} R | V _{SS} 2.5 | V _{SS} 2.5 | V _{SS} PLL | V _{SS} PLL | V _{SS} X | V _{SS} X | V _{SS} X | PB11 | PB14 | PB15 |
| P | PF9 | PF8 | V _{SS} X | PF5 | PC8 | PC10 | V _{DD} X | V _{SS} 2.5 | V _{DD} R | V _{DD} X | PA15 | PD11 | PD12 | V _{SS} X | PB12 | PB13 |
| R | PF7 | V _{SS} X | PF6 | PF3 | PF1 | PC9 | PG12 | PG13 | V _{SS} X | V _{SS} X | TEST | PA13 | PD1 | PB10 | V _{SS} X | V _{SS} X |
| T | V _{SS} X | V _{SS} X | PF4 | PF2 | PF0 | PC11 | $\overline{\text{RESET}}$ | V _{SS} PLL | XFC | EXTAL | XTAL | PA14 | PD0 | PB9 | V _{SS} X | V _{SS} X |

Figure 19. Pin Assignments for MAC7131 in 208-pin MAP BGA

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Mechanical Information

5 Mechanical Information

5.1 100-Pin LQFP Package

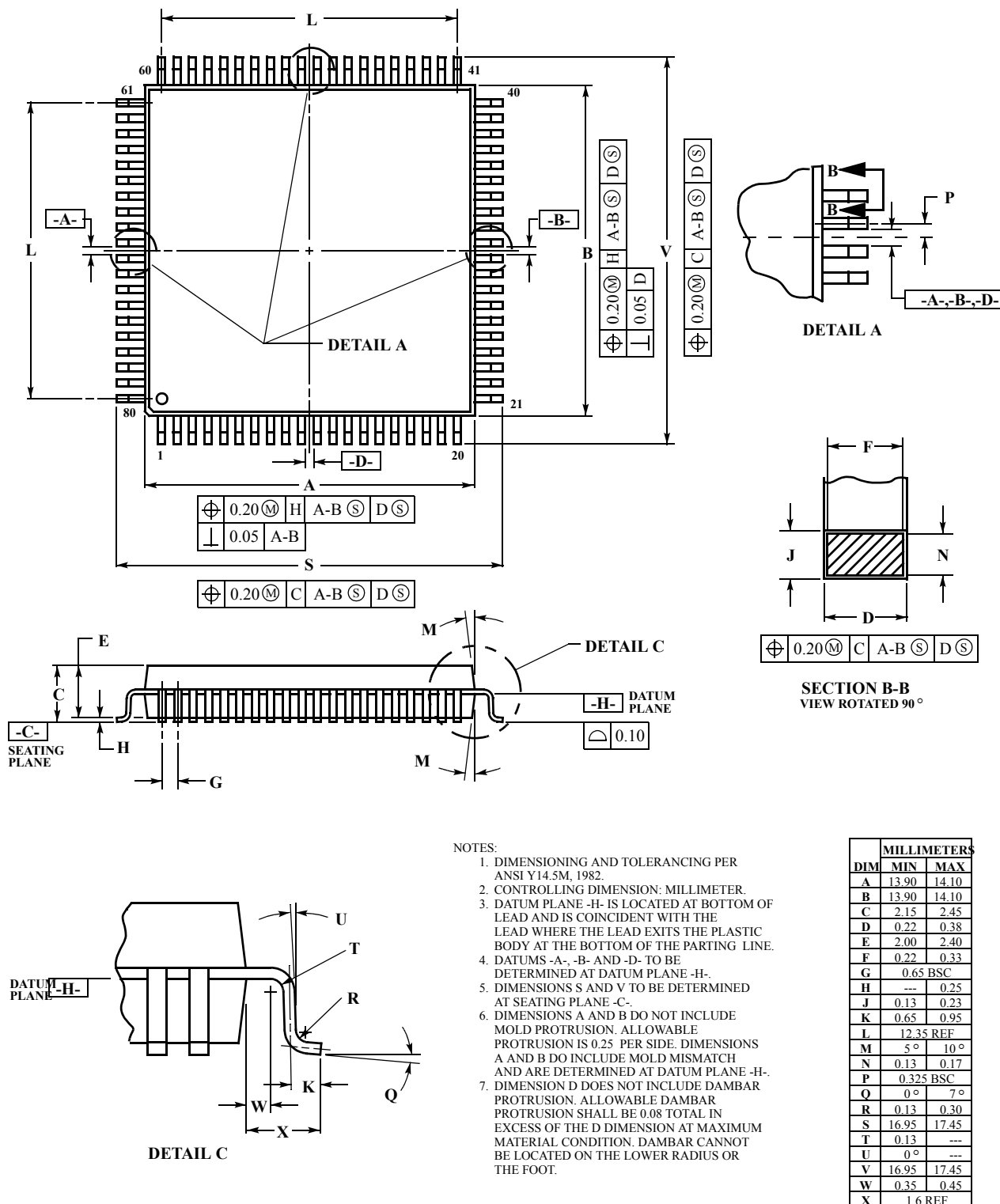


Figure 20. 100-Pin LQFP Mechanical Dimensions (Case No. 983)

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Mechanical Information

5.2 112-Pin LQFP Package

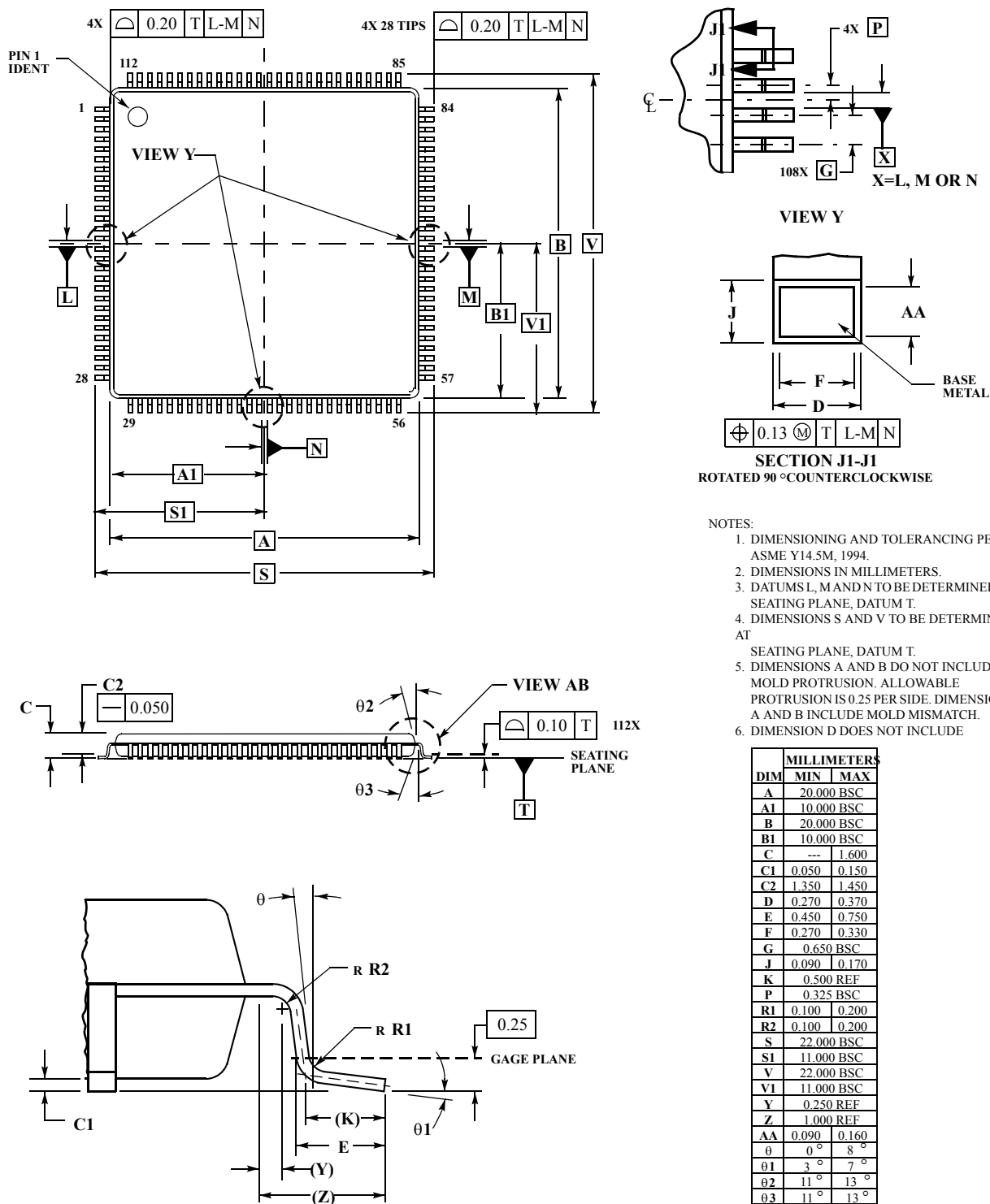


Figure 21. 112-Pin LQFP Mechanical Dimensions (Case No. 987)

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Mechanical Information

5.3 144-Pin LQFP Package

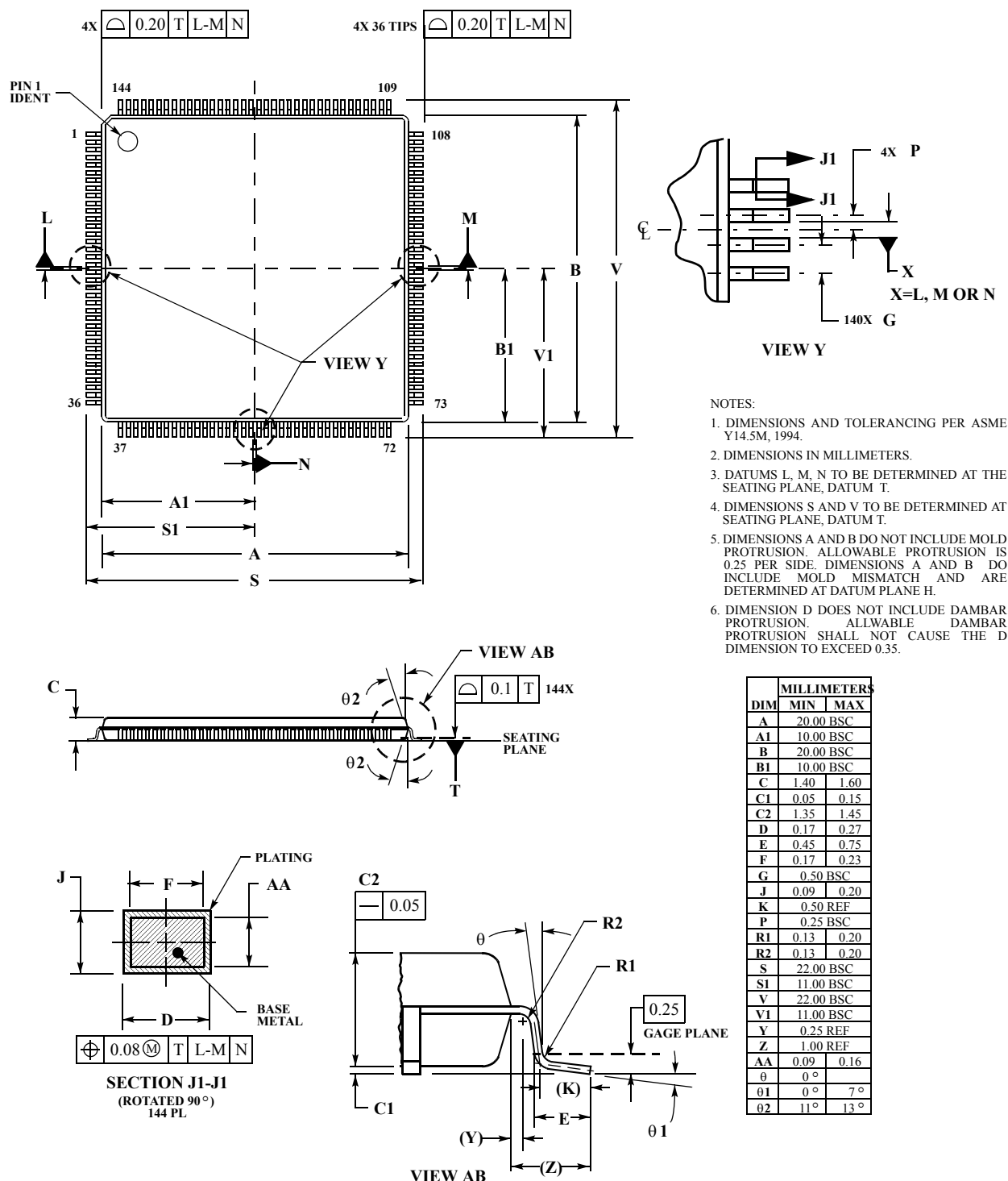


Figure 22. 144-Pin LQFP Mechanical Dimensions (Case No. 918)

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Mechanical Information

5.4 208-Pin MAP BGA Package

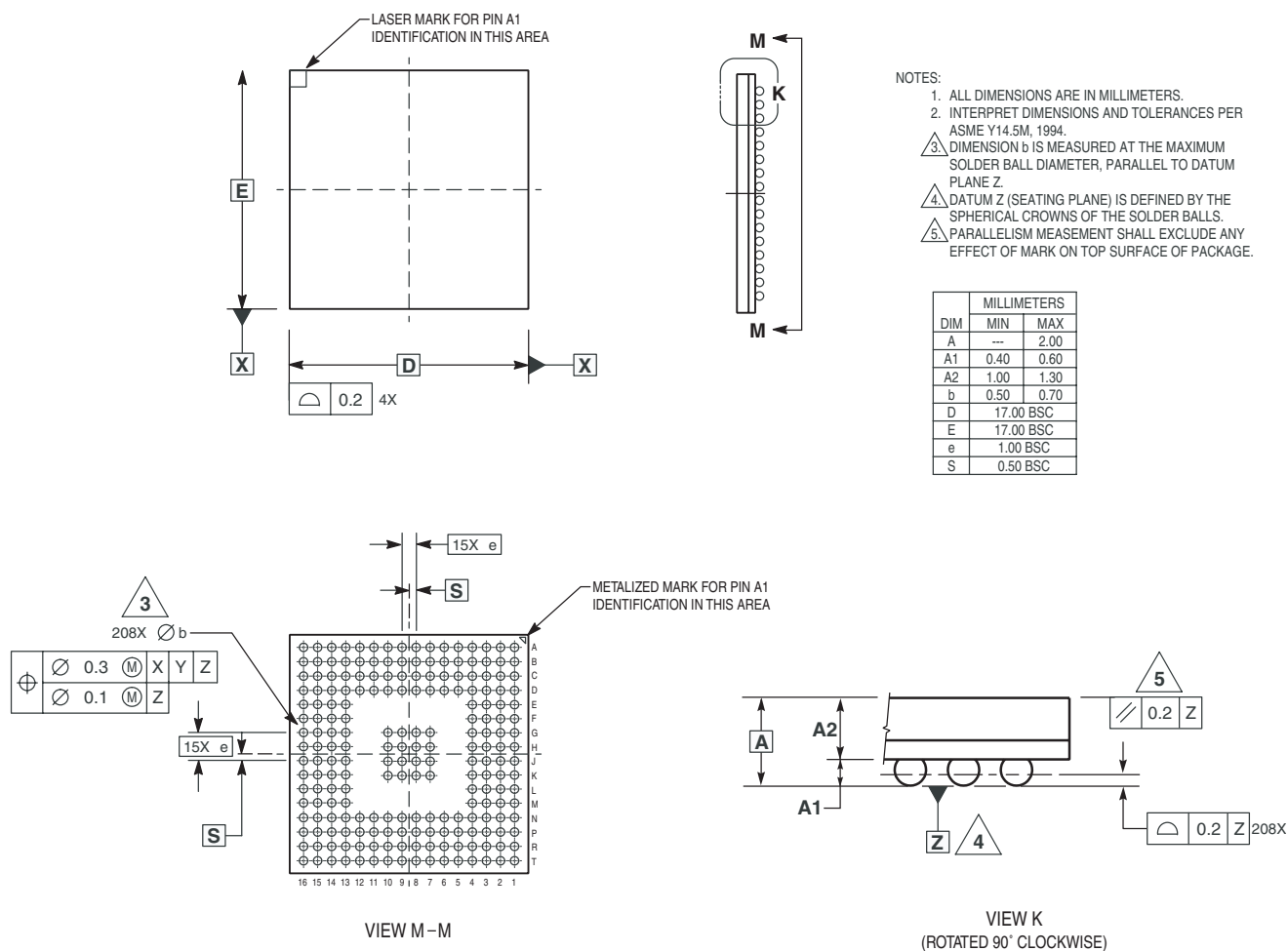


Figure 23. 208-Pin MAP BGA Mechanical Dimensions (Case No. 1159A-01)

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