Appendix A - ATmega164P, ATmega324P and ATmega644P specification at 105°C

This document contains information specific to devices operating at temperatures up to 105°C. Only deviations are covered in this appendix, all other information can be found in the complete datasheet. The complete datasheet can be found in www.atmel.com.
1. Electrical Characteristics

### Absolute Maximum Ratings*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operating Temperature</strong></td>
<td>-55°C to +125°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Storage Temperature</strong></td>
<td>-65°C to +150°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage on any Pin except RESET with respect to Ground</td>
<td>-0.5V to V&lt;sub&gt;CC&lt;/sub&gt;+0.5V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage on RESET with respect to Ground</td>
<td>-0.5V to +13.0V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Operating Voltage</td>
<td>6.0V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC Current per I/O Pin</td>
<td>40.0 mA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC Current V&lt;sub&gt;CC&lt;/sub&gt; and GND Pins</td>
<td>200.0 mA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*NOTICE: Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

1.1 DC Characteristics

\( T_A = -40°C \) to 105°C, \( V_{CC} = 1.8V \) to 5.5V (unless otherwise noted)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Condition</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{IL} )</td>
<td>Input Low Voltage, Except XTAL1 and Reset pin</td>
<td>( V_{CC} = 1.8V - 2.4V ) ( V_{CC} = 2.4V - 5.5V )</td>
<td>-0.5</td>
<td>-0.5</td>
<td>( 0.2V_{CC}^{(1)} ) ( 0.3V_{CC}^{(1)} )</td>
<td>V</td>
</tr>
<tr>
<td>( V_{IL1} )</td>
<td>Input Low Voltage, XTAL1 pin</td>
<td>( V_{CC} = 1.8V - 5.5V )</td>
<td>-0.5</td>
<td></td>
<td>( 0.1V_{CC}^{(1)} )</td>
<td>V</td>
</tr>
<tr>
<td>( V_{IL2} )</td>
<td>Input Low Voltage, RESET pin</td>
<td>( V_{CC} = 1.8V - 5.5V )</td>
<td>-0.5</td>
<td></td>
<td>( 0.1V_{CC}^{(1)} )</td>
<td>V</td>
</tr>
<tr>
<td>( V_{IH} )</td>
<td>Input High Voltage, Except XTAL1 and RESET pins</td>
<td>( V_{CC} = 1.8V - 2.4V ) ( V_{CC} = 2.4V - 5.5V )</td>
<td>0.7( V_{CC}^{(2)} ) 0.6( V_{CC}^{(2)} )</td>
<td></td>
<td>( V_{CC} + 0.5 ) ( V_{CC} + 0.5 )</td>
<td>V</td>
</tr>
<tr>
<td>( V_{IH1} )</td>
<td>Input High Voltage, XTAL1 pin</td>
<td>( V_{CC} = 1.8V - 2.4V ) ( V_{CC} = 2.4V - 5.5V )</td>
<td>0.8( V_{CC}^{(2)} ) 0.7( V_{CC}^{(2)} )</td>
<td></td>
<td>( V_{CC} + 0.5 ) ( V_{CC} + 0.5 )</td>
<td>V</td>
</tr>
<tr>
<td>( V_{IH2} )</td>
<td>Input High Voltage, RESET pin</td>
<td>( V_{CC} = 1.8V - 5.5V )</td>
<td>0.9( V_{CC}^{(2)} )</td>
<td></td>
<td>( V_{CC} + 0.5 )</td>
<td>V</td>
</tr>
<tr>
<td>( V_{OL} )</td>
<td>Output Low Voltage(^{(3)}), ( I_{OL} = 20 \text{ mA}, V_{CC} = 5V ) ( I_{OL} = 10 \text{ mA}, V_{CC} = 3V )</td>
<td></td>
<td>1.0</td>
<td>0.7</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>( V_{OH} )</td>
<td>Output High Voltage(^{(4)}), ( I_{OH} = -20 \text{ mA}, V_{CC} = 5V ) ( I_{OH} = -10 \text{ mA}, V_{CC} = 3V )</td>
<td></td>
<td>4.0</td>
<td>2.1</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>( I_{IL} )</td>
<td>Input Leakage Current I/O Pin</td>
<td>( V_{CC} = 5.5V ), pin low (absolute value)</td>
<td></td>
<td>1</td>
<td>( \mu A )</td>
<td></td>
</tr>
<tr>
<td>( I_{IH} )</td>
<td>Input Leakage Current I/O Pin</td>
<td>( V_{CC} = 5.5V ), pin high (absolute value)</td>
<td></td>
<td>1</td>
<td>( \mu A )</td>
<td></td>
</tr>
<tr>
<td>( R_{REST} )</td>
<td>Reset Pull-up Resistor</td>
<td></td>
<td>30</td>
<td>60</td>
<td>k( \Omega )</td>
<td></td>
</tr>
<tr>
<td>( R_{PU} )</td>
<td>I/O Pin Pull-up Resistor</td>
<td></td>
<td>20</td>
<td>50</td>
<td>k( \Omega )</td>
<td></td>
</tr>
<tr>
<td>( V_{ACIO} )</td>
<td>Analog Comparator Input Offset Voltage</td>
<td>( V_{CC} = 5V ) ( V_{in} = V_{CC}/2 )</td>
<td></td>
<td>40</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>( I_{ACLK} )</td>
<td>Analog Comparator Input Leakage Current</td>
<td>( V_{CC} = 5V ) ( V_{in} = V_{CC}/2 )</td>
<td>-50</td>
<td>50</td>
<td>nA</td>
<td></td>
</tr>
</tbody>
</table>
Note: 1. Max* means the highest value where the pin is guaranteed to be read as low
2. Min* means the lowest value where the pin is guaranteed to be read as high
3. Although each I/O port can sink more than the test conditions (20mA at VCC = 5V, 10mA at VCC = 3V) under steady state conditions (non-transient), the following must be observed:
   1.) The sum of all IOL, for ports PB0-PB7, XTAL2, PD0-PD7 should not exceed 100 mA.
   2.) The sum of all IOL, for ports PA0-PA3, PC0-PC7 should not exceed 100 mA.
   If IOL exceeds the test condition, VOL may exceed the related specification. Pins are not guaranteed to sink current greater than the listed test condition.
4. Although each I/O port can source more than the test conditions (20mA at VCC = 5V, 10mA at VCC = 3V) under steady state conditions (non-transient), the following must be observed:
   1.) The sum of all IOH, for ports PB0-PB7, XTAL2, PD0-PD7 should not exceed 100 mA.
   2.) The sum of all IOH, for ports PA0-PA3, PC0-PC7 should not exceed 100 mA.
   If IOH exceeds the test condition, VOH may exceed the related specification. Pins are not guaranteed to source current greater than the listed test condition.

### 1.1.1 ATmega164P DC Characteristics TBD

Table 1-1. $T_A = -40°C$ to $105°C$, $V_{CC} = 1.8V$ to $5.5V$ (unless otherwise noted)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Condition</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{CC}$</td>
<td>Power Supply Current$^{(1)}$</td>
<td>Active 1 MHz, $V_{CC} = 2V$</td>
<td>mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Active 4 MHz, $V_{CC} = 3V$</td>
<td>mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Active 8 MHz, $V_{CC} = 5V$</td>
<td>mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Idle 1 MHz, $V_{CC} = 2V$</td>
<td>mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Idle 4 MHz, $V_{CC} = 3V$</td>
<td>mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Idle 8 MHz, $V_{CC} = 5V$</td>
<td>mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Power-down mode$^{(2)}$</td>
<td>WDT enabled, $V_{CC} = 3V$</td>
<td>μA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WDT disabled, $V_{CC} = 3V$</td>
<td>μA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: 1. All bits set in the "PRR – Power Reduction Register" on page 48
2. The current consumption values include input leakage current.

### 1.1.2 ATmega324P DC Characteristics

Table 1-2. $T_A = -40°C$ to $105°C$, $V_{CC} = 1.8V$ to $5.5V$ (unless otherwise noted)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Condition</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{CC}$</td>
<td>Power Supply Current$^{(1)}$</td>
<td>Active 1 MHz, $V_{CC} = 2V$</td>
<td>0.7</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Active 4 MHz, $V_{CC} = 3V$</td>
<td>3.0</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Active 8 MHz, $V_{CC} = 5V$</td>
<td>11</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Idle 1 MHz, $V_{CC} = 2V$</td>
<td>0.2</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Idle 4 MHz, $V_{CC} = 3V$</td>
<td>0.85</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Idle 8 MHz, $V_{CC} = 5V$</td>
<td>6</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Power-down mode$^{(2)}$</td>
<td>WDT enabled, $V_{CC} = 3V$</td>
<td>15</td>
<td>μA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WDT disabled, $V_{CC} = 3V$</td>
<td>5</td>
<td>μA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: 1. All bits set in the "PRR – Power Reduction Register" on page 48
2. The current consumption values include input leakage current.
## ATmega644P DC Characteristics

Table 1-3. $T_A = -40^\circ$C to 105°C, $V_{CC} = 1.8$V to 5.5V (unless otherwise noted)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Condition</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{CC}$</td>
<td>Power Supply Current$^{(1)}$</td>
<td>Active 1 MHz, $V_{CC} = 2$V</td>
<td>0.7</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Active 4 MHz, $V_{CC} = 3$V</td>
<td>3.0</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Active 8 MHz, $V_{CC} = 5$V</td>
<td>11</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Idle 1 MHz, $V_{CC} = 2$V</td>
<td>0.2</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Idle 4 MHz, $V_{CC} = 3$V</td>
<td>0.85</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Idle 8 MHz, $V_{CC} = 5$V</td>
<td>6</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>Power-down mode$^{(2)}$</td>
<td>WDT enabled, $V_{CC} = 3$V</td>
<td>20</td>
<td></td>
<td></td>
<td>$\mu$A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WDT disabled, $V_{CC} = 3$V</td>
<td>10</td>
<td></td>
<td></td>
<td>$\mu$A</td>
</tr>
</tbody>
</table>

Notes:  
1. All bits set in the "PRR – Power Reduction Register" on page 48  
2. The current consumption values include input leakage current.
2. Typical Characteristics

The following charts show typical behavior. These figures are not tested during manufacturing. All current consumption measurements are performed with all I/O pins configured as inputs and with internal pull-ups enabled. A sine wave generator with rail-to-rail output is used as clock source.

All Active- and Idle current consumption measurements are done with all bits in the PRR registers set and thus, the corresponding I/O modules are turned off. Also the Analog Comparator is disabled during these measurements. The power consumption in Power-down mode is independent of clock selection.

The current consumption is a function of several factors such as: operating voltage, operating frequency, loading of I/O pins, switching rate of I/O pins, code executed and ambient temperature. The dominating factors are operating voltage and frequency.

The current drawn from capacitive loaded pins may be estimated (for one pin) as \( C_L \times V_{CC} \times f \) where \( C_L \) = load capacitance, \( V_{CC} \) = operating voltage and \( f \) = average switching frequency of I/O pin.

The parts are characterized at frequencies higher than test limits. Parts are not guaranteed to function properly at frequencies higher than the ordering code indicates.

The difference between current consumption in Power-down mode with Watchdog Timer enabled and Power-down mode with Watchdog Timer disabled represents the differential current drawn by the Watchdog Timer.

2.1 ATmega164P Typical Characteristics

2.1.1 Active Supply Current

Figure 2-1. ATmega164P: Active Supply Current vs. \( V_{CC} \) (Internal RC Oscillator, 8 MHz)
Figure 2-2. ATmega164P: Active Supply Current vs. $V_{CC}$ (Internal RC Oscillator, 1 MHz)

Figure 2-3. ATmega164P: Active Supply Current vs. $V_{CC}$ (Internal RC Oscillator, 128 kHz)
2.1.2 Idle Supply Current

**Figure 2-4.** ATmega164P: Idle Supply Current vs. $V_{CC}$ (Internal RC Oscillator, 8 MHz)

**Figure 2-5.** ATmega164P: Idle Supply Current vs. $V_{CC}$ (Internal RC Oscillator, 1 MHz)
2.1.3 Power-down Supply Current

Figure 2-7. ATmega164P: Power-down Supply Current vs. $V_{CC}$ (Watchdog Timer Disabled)
**Figure 2-8.** ATmega164P: Power-down Supply Current vs. V<sub>CC</sub> (Watchdog Timer Enabled)

![Graph showing power-down supply current vs. V<sub>CC</sub> at different temperatures](image)

### 2.1.4 Pin Pull-up

**Figure 2-9.** ATmega164P: I/O Pin Pull-up Resistor Current vs. Input Voltage (V<sub>CC</sub> = 1.8V)

![Graph showing I/O pin pull-up resistor current vs. input voltage](image)
**Figure 2-10.** ATmega164P: I/O Pin Pull-up Resistor Current vs. Input Voltage ($V_{CC} = 2.7V$)

**Figure 2-11.** ATmega164P: I/O Pin Pull-up Resistor Current vs. Input Voltage ($V_{CC} = 5V$)
Figure 2-12. ATmega164P: Reset Pull-up Resistor Current vs. Reset Pin Voltage ($V_{CC} = 1.8V$)

Figure 2-13. ATmega164P: Reset Pull-up Resistor Current vs. Reset Pin Voltage ($V_{CC} = 2.7V$)
2.1.5 Pin Driver Strength

Figure 2-15. ATmega164P: I/O Pin Output Voltage vs. Sink Current ($V_{CC} = 3V$)
**Figure 2-16.** ATmega164P: I/O Pin Output Voltage vs. Sink Current ($V_{CC} = 5V$)

**Figure 2-17.** ATmega164P: I/O Pin Output Voltage vs. Source Current ($V_{CC} = 3V$)
2.1.6 Pin Threshold and Hysteresis

Figure 2-19. ATmega164P: I/O Pin Input Threshold vs. $V_{CC}$ ($V_{IH}$, I/O Pin Read as ‘1’)
**Figure 2-20.** ATmega164P: I/O Pin Input Threshold vs. $V_{CC}$ ($V_{IL}$, I/O Pin Read as '0')

![Graph showing I/O Pin Input Threshold vs. $V_{CC}$](image)

**Figure 2-21.** ATmega164P: I/O Pin Input Hysteresis vs. $V_{CC}$

![Graph showing I/O Pin Input Hysteresis vs. $V_{CC}$](image)
**Figure 2-22.** ATmega164P: Reset Pin Input Threshold vs. $V_{CC}$ ($V_{IH}$, I/O Pin Read as ‘1’)

![Graph showing ATmega164P Reset Pin Input Threshold vs. $V_{CC}$ at different temperatures.]

**Figure 2-23.** ATmega164P: Reset Pin Input Threshold vs. $V_{CC}$ ($V_{IL}$, I/O Pin Read as ‘0’)

![Graph showing ATmega164P Reset Pin Input Threshold vs. $V_{CC}$ at different temperatures.]

ATmega164P/324P/644P
2.1.7 BOD Threshold

Figure 2-25. ATmega164P: BOD Threshold vs. Temperature ($V_{CC} = 4.3V$)
**Figure 2-26.** ATmega164P: BOD Threshold vs. Temperature ($V_{CC} = 2.7V$)

**Figure 2-27.** ATmega164P: BOD Threshold vs. Temperature ($V_{CC} = 1.8V$)
2.1.8 Internal Oscillator Speed

**Figure 2-28.** ATmega164P: Watchdog Oscillator Frequency vs. Temperature

![Graph showing the relationship between temperature and watchdog oscillator frequency for different VCC levels.](image)

**Figure 2-29.** ATmega164P: Watchdog Oscillator Frequency vs. VCC

![Graph showing the relationship between VCC and watchdog oscillator frequency for different temperatures.](image)
Figure 2-30. ATmega164P: Calibrated 8 MHz RC Oscillator vs. $V_{CC}$

Figure 2-31. ATmega164P: Calibrated 8 MHz RC Oscillator vs. Temperature
2.1.9 Current Consumption of Peripheral Units

Figure 2-32. ATmega164P: Calibrated 8 MHz RC Oscillator vs. OSCCAL Value

Figure 2-33. ATmega164P: ADC Current vs. VCC (AREF = AVCC)
Figure 2-34. ATmega164P: Analog Comparator Current vs. $V_{CC}$

Figure 2-35. ATmega164P: AREF External Reference Current vs. $V_{CC}$
Figure 2-36. ATmega164P: Brownout Detector Current vs. $V_{CC}$

Figure 2-37. ATmega164P: Programming Current vs. $V_{CC}$
2.1.10 Current Consumption in Reset and Reset Pulsewidth

Figure 2-38. ATmega164P: Watchdog Timer Current vs. $V_{CC}$

Figure 2-39. ATmega164P: Reset Supply Current vs Vcc 0.1-1.0MHz
Figure 2-40. ATmega164P: Reset Supply Current vs Vcc 1-20MHz

Figure 2-41. ATmega164P: Minimum reset Pulswith vs. Vcc
2.2 ATmega324P Typical Characteristics

2.2.1 Active Supply Current

**Figure 2-42.** ATmega324P: Active Supply Current vs. $V_{CC}$ (Internal RC Oscillator, 8 MHz)

**Figure 2-43.** ATmega324P: Active Supply Current vs. $V_{CC}$ (Internal RC Oscillator, 1 MHz)
Figure 2-44. ATmega324P: Active Supply Current vs. $V_{CC}$ (Internal RC Oscillator, 128 kHz)

2.2.2 Idle Supply Current

Figure 2-45. ATmega324P: Idle Supply Current vs. $V_{CC}$ (Internal RC Oscillator, 8 MHz)
**Figure 2-46.** ATmega324P: Idle Supply Current vs. $V_{CC}$ (Internal RC Oscillator, 1 MHz)

![Graph showing the relationship between $V_{CC}$ and $I_{CC}$ for different temperatures.]

**Figure 2-47.** ATmega324P: Idle Supply Current vs. $V_{CC}$ (Internal RC Oscillator, 128 kHz)

![Graph showing the relationship between $V_{CC}$ and $I_{CC}$ for different temperatures.]

ATmega164P/324P/644P
2.2.3 Power-down Supply Current

**Figure 2-48.** ATmega324P: Power-down Supply Current vs. $V_{CC}$ (Watchdog Timer Disabled)

**Figure 2-49.** ATmega324P: Power-down Supply Current vs. $V_{CC}$ (Watchdog Timer Enabled)
2.2.4 Pin Pull-up

**Figure 2-50.** ATmega324P: I/O Pin Pull-up Resistor Current vs. Input Voltage ($V_{CC} = 1.8V$)

**Figure 2-51.** ATmega324P: I/O Pin Pull-up Resistor Current vs. Input Voltage ($V_{CC} = 2.7V$)
Figure 2-52. ATmega324P: I/O Pin Pull-up Resistor Current vs. Input Voltage ($V_{CC} = 5V$)

Figure 2-53. ATmega324P: Reset Pull-up Resistor Current vs. Reset Pin Voltage ($V_{CC} = 1.8V$)
Figure 2-54. ATmega324P: Reset Pull-up Resistor Current vs. Reset Pin Voltage ($V_{CC} = 2.7V$)

Figure 2-55. ATmega324P: Reset Pull-up Resistor Current vs. Reset Pin Voltage ($V_{CC} = 5V$)
2.2.5 Pin Driver Strength

**Figure 2-56.** ATmega324P: I/O Pin Output Voltage vs. Sink Current ($V_{CC} = 3V$)

**Figure 2-57.** ATmega324P: I/O Pin Output Voltage vs. Sink Current ($V_{CC} = 5V$)
Figure 2-58. ATmega324P: I/O Pin Output Voltage vs. Source Current ($V_{CC} = 3V$)

Figure 2-59. ATmega324P: I/O Pin Output Voltage vs. Source Current ($V_{CC} = 5V$)
2.2.6 Pin Threshold and Hysteresis

Figure 2-60. ATmega324P: I/O Pin Input Threshold vs. $V_{CC}$ ($V_{IH}$, I/O Pin Read as ‘1’)

Figure 2-61. ATmega324P: I/O Pin Input Threshold vs. $V_{CC}$ ($V_{IL}$, I/O Pin Read as ‘0’)

Figure 2-62. ATmega324P: I/O Pin Input Hysteresis vs. V\textsubscript{CC}

Figure 2-63. ATmega324P: Reset Pin Input Threshold vs. V\textsubscript{CC} (V\textsubscript{IH}, I/O Pin Read as ‘1’)
Figure 2-64. ATmega324P: Reset Pin Input Threshold vs. $V_{CC}$ ($V_{IL}$, I/O Pin Read as ‘0’)

Figure 2-65. ATmega324P: Reset Pin Input Hysteresis vs. $V_{CC}$
2.2.7 BOD Threshold

**Figure 2-66.** ATmega324P: BOD Threshold vs. Temperature ($V_{CC} = 4.3\, \text{V}$)

**Figure 2-67.** ATmega324P: BOD Threshold vs. Temperature ($V_{CC} = 2.7\, \text{V}$)
### Figure 2-68. ATmega324P: BOD Threshold vs. Temperature ($V_{CC} = 1.8V$)

![Graph showing BOD Threshold vs. Temperature](image)

#### 2.2.8 Internal Oscillator Speed

### Figure 2-69. ATmega324P: Watchdog Oscillator Frequency vs. Temperature

![Graph showing Watchdog Oscillator Frequency vs. Temperature](image)
Figure 2-70. ATmega324P: Watchdog Oscillator Frequency vs. \( V_{CC} \)

![Graph showing Watchdog Oscillator Frequency vs. \( V_{CC} \) at different temperatures.]

Figure 2-71. ATmega324P: Calibrated 8 MHz RC Oscillator vs. \( V_{CC} \)

![Graph showing Calibrated 8 MHz RC Oscillator vs. \( V_{CC} \) at different temperatures.]

105 °C
85 °C
25 °C
-40 °C

VCC (V)
FRC (kHz)

125
120
115
110

1.5 2 2.5 3 3.5 4 4.5 5 5.5

VCC (V)
FRC (MHz)

8.5
8.3
8.1
7.9
7.7
7.5

1.5 2 2.5 3 3.5 4 4.5 5 5.5
Figure 2-72. ATmega324P: Calibrated 8 MHz RC Oscillator vs. Temperature

Figure 2-73. ATmega324P: Calibrated 8 MHz RC Oscillator vs. OSCCAL Value
2.2.9 Current Consumption of Peripheral Units

**Figure 2-74.** ATmega324P: ADC Current vs. $V_{CC}$ (AREF = $AV_{CC}$)

**Figure 2-75.** ATmega324P: Analog Comparator Current vs. $V_{CC}$
Figure 2-76. ATmega324P: AREF External Reference Current vs. $V_{CC}$

Figure 2-77. ATmega324P: Brownout Detector Current vs. $V_{CC}$
Figure 2-78. ATmega324P: Programming Current vs. V<sub>CC</sub>

Figure 2-79. ATmega324P: Watchdog Timer Current vs. V<sub>CC</sub>
2.2.10 Current Consumption in Reset and Reset Pulsewidth

**Figure 2-80.** ATmega324P: Minimum reset Pulsewidth vs. Vcc

**Figure 2-81.** ATmega324P: Reset Supply Current vs Vcc 0.1-1.0MHz
Figure 2-82. ATmega324P: Reset Supply Current vs Vcc 1-20MHz

![Graph showing the relationship between reset supply current (I_{CC}) in mA and frequency (MHz) for different VCC voltages (1.8 V, 2.7 V, 3.3 V, 4.0 V, 4.5 V, 5.0 V, 5.5 V).]
2.3 ATmega644P Typical Characteristics

2.3.1 Active Supply Current

Figure 2-83. ATmega644P: Active Supply Current vs. $V_{CC}$ (Internal RC Oscillator, 8 MHz).

Figure 2-84. ATmega644P: Active Supply Current vs. $V_{CC}$ (Internal RC Oscillator, 1 MHz).
2.3.2 Idle Supply Current

Figure 2-86. ATmega644P: Idle Supply Current vs. $V_{CC}$ (Internal RC Oscillator, 8 MHz).
**Figure 2-87.**  ATmega644P: Idle Supply Current vs. V\(_{CC}\) (Internal RC Oscillator, 1 MHz).

![Graph showing Idle Supply Current vs. V\(_{CC}\) for ATmega644P at different temperatures.](image)

**Figure 2-88.**  ATmega644P: Idle Supply Current vs. V\(_{CC}\) (Internal RC Oscillator, 128 kHz).

![Graph showing Idle Supply Current vs. V\(_{CC}\) for ATmega644P at different temperatures.](image)
2.3.3 Power-down Supply Current

**Figure 2-89.** ATmega644P: Power-down Supply Current vs. $V_{CC}$ (Watchdog Timer Disabled).

**Figure 2-90.** ATmega644P: Power-down Supply Current vs. $V_{CC}$ (Watchdog Timer Enabled).
2.3.4 Pin Pull-up

Figure 2-91. ATmega644P: I/O Pin Pull-up Resistor Current vs. Input Voltage ($V_{CC} = 1.8V$).

![Graph showing ATmega644P I/O Pin Pull-up Resistor Current vs. Input Voltage (VCC = 1.8V).](image1)

Figure 2-92. ATmega644P: I/O Pin Pull-up Resistor Current vs. Input Voltage ($V_{CC} = 2.7V$).

![Graph showing ATmega644P I/O Pin Pull-up Resistor Current vs. Input Voltage (VCC = 2.7V).](image2)
Figure 2-93. ATmega644P: I/O Pin Pull-up Resistor Current vs. Input Voltage ($V_{CC} = 5V$).

Figure 2-94. ATmega644P: Reset Pull-up Resistor Current vs. Reset Pin Voltage ($V_{CC} = 1.8V$).
Figure 2-95. ATmega644P: Reset Pull-up Resistor Current vs. Reset Pin Voltage ($V_{CC} = 2.7V$).

Figure 2-96. ATmega644P: Reset Pull-up Resistor Current vs. Reset Pin Voltage ($V_{CC} = 5V$).
2.3.5 Pin Driver Strength

**Figure 2-97.** ATmega644P: I/O Pin Output Voltage vs. Sink Current ($V_{CC} = 3V$).

**Figure 2-98.** ATmega644P: I/O Pin Output Voltage vs. Sink Current ($V_{CC} = 5V$).
Figure 2-99. ATmega644P: I/O Pin Output Voltage vs. Source Current ($V_{CC} = 3\text{V}$).

Figure 2-100. ATmega644P: I/O Pin Output Voltage vs. Source Current ($V_{CC} = 5\text{V}$).
2.3.6 Pin Threshold and Hysteresis

Figure 2-101. ATmega644P: I/O Pin Input Threshold vs. $V_{CC}$ ($V_{IH}$, I/O Pin Read as ‘1’).

Figure 2-102. ATmega644P: I/O Pin Input Threshold vs. $V_{CC}$ ($V_{IL}$, I/O Pin Read as ‘0’).
**Figure 2-103.** ATmega644P: I/O Pin Input Hysteresis vs. $V_{CC}$

![Graph showing I/O Pin Input Hysteresis vs. $V_{CC}$](image)

**Figure 2-104.** ATmega644P: Reset Pin Input Threshold vs. $V_{CC}$ ($V_{IH}$, I/O Pin Read as ‘1’).

![Graph showing Reset Pin Input Threshold vs. $V_{CC}$](image)
Figure 2-105. ATmega644P: Reset Pin Input Threshold vs. $V_{CC}$ ($V_{IL}$, I/O Pin Read as ‘0’).

Figure 2-106. ATmega644P: Reset Pin Input Hysteresis vs. $V_{CC}$
2.3.7 BOD Threshold

**Figure 2-107.** ATmega644P: BOD Threshold vs. Temperature (\( V_{CC} = 4.3\text{V} \))

**Figure 2-108.** ATmega644P: BOD Threshold vs. Temperature (\( V_{CC} = 2.7\text{V} \))
2.3.8 Internal Oscillator Speed

Figure 2-109. ATmega644P: BOD Threshold vs. Temperature ($V_{CC} = 1.8V$)

Figure 2-110. ATmega644P: Watchdog Oscillator Frequency vs. Temperature
Figure 2-111. ATmega644P: Watchdog Oscillator Frequency vs. $V_{CC}$

Figure 2-112. ATmega644P: Calibrated 8 MHz RC Oscillator vs. $V_{CC}$
Figure 2-113. ATmega644P: Calibrated 8 MHz RC Oscillator vs. Temperature

Figure 2-114. ATmega644P: Calibrated 8 MHz RC Oscillator vs. OSCCAL Value
2.3.9 Current Consumption of Peripheral Units

**Figure 2-115.** ATmega644P: ADC Current vs. $V_{CC}$ (AREF = $AV_{CC}$)

**Figure 2-116.** ATmega644P: Analog Comparator Current vs. $V_{CC}$
Figure 2-117. ATmega644P: AREF External Reference Current vs. $V_{CC}$

Figure 2-118. ATmega644P: Brownout Detector Current vs. $V_{CC}$
**Figure 2-119. ATmega644P: Programming Current vs. V<sub>CC</sub>**

![Programming Current vs. V<sub>CC</sub> graph for ATmega644P at various temperatures (-40°C, 25°C, 85°C, 105°C).](image)

**Figure 2-120. ATmega644P: Watchdog Timer Current vs. V<sub>CC</sub>**

![Watchdog Timer Current vs. V<sub>CC</sub> graph for ATmega644P at various temperatures (-40°C, 25°C, 85°C, 105°C).](image)
2.3.10 Current Consumption in Reset and Reset Pulsewidth

**Figure 2-121. ATmega644P: Minimum Reset Pulse Width vs. Vcc**

- **Vcc (V)**
  - 1.5
  - 2
  - 2.5
  - 3
  - 3.5
  - 4
  - 4.5
  - 5
  - 5.5

- **Pulsewidth (ns)**
  - 0
  - 450
  - 900
  - 1350
  - 1800

**Temperature Conditions:**
- 105 °C
- 85 °C
- 25 °C
- -40 °C

**Figure 2-122. ATmega644P: Reset Supply Current vs Vcc 0.1-1.0MHz**

- **Frequency (MHz)**
  - 0
  - 0.1
  - 0.2
  - 0.3
  - 0.4
  - 0.5
  - 0.6
  - 0.7
  - 0.8
  - 0.9
  - 1

- **I_{CC} (mA)**
  - 0
  - 0.02
  - 0.04
  - 0.06
  - 0.08
  - 0.1
  - 0.12
  - 0.14
  - 0.16

**Voltage Conditions:**
- 5.5 V
- 5.0 V
- 4.5 V
- 4.0 V
- 3.3 V
- 2.7 V
- 1.8 V
Figure 2-123. ATmega644P: Reset Supply Current vs Vcc 1-20MHz
3. Ordering Information

3.1 ATmega164P

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<th>Speed(^{(1)}) (MHz)</th>
<th>Power Supply</th>
<th>Ordering Code(^{(2)})</th>
<th>Package</th>
<th>Operational Range</th>
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<td></td>
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<td>ATmega164PV-10PQ</td>
<td>40P6</td>
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<td>ATmega164P-20AQR(^{(3)})</td>
<td>44A</td>
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<tr>
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Notes:
1. For Speed Grades, see complete datasheets.
2. Pb-free packaging, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
3. Tape & Reel

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<th>Package Type</th>
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3.2 ATmega324P

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<th>Ordering Code(^{(2)})</th>
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<th>Operational Range</th>
</tr>
</thead>
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<tr>
<td>10</td>
<td>1.8 - 5.5V</td>
<td>ATmega324PV-10AQ</td>
<td>44A</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>ATmega324PV-10AQR(^{(3)})</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>ATmega324PV-10PQ</td>
<td>40P6</td>
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<tr>
<td></td>
<td></td>
<td>ATmega324PV-10MQR(^{(3)})</td>
<td>44M1</td>
<td>Extended (-40^\circ C) to (105^\circ C)</td>
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<tr>
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<td>ATmega324P-20AQ</td>
<td>44A</td>
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<td>44-lead, Thin (1.0 mm) Plastic Gull Wing Quad Flat Package (TQFP)</td>
</tr>
<tr>
<td>40P6</td>
<td>40-pin, 0.600&quot; Wide, Plastic Dual Inline Package (PDIP)</td>
</tr>
<tr>
<td>44M1</td>
<td>44-pad, 7 x 7 x 1.0 mm body, lead pitch 0.50 mm, Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)</td>
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</table>
### 3.3 ATmega644P

<table>
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<tr>
<th>Speed (MHz)</th>
<th>Power Supply</th>
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<th>Package</th>
<th>Operational Range</th>
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</thead>
<tbody>
<tr>
<td>10</td>
<td>1.8 - 5.5V</td>
<td>ATmega644PV-10AQ, ATmega644PV-10AQR, ATmega644PV-10PQ, ATmega644PV-10MQR</td>
<td>44A, 44A, 40P6, 44M1</td>
<td>10°C to 105°C Extended (-40°C to 105°C)</td>
</tr>
<tr>
<td>20</td>
<td>2.7 - 5.5V</td>
<td>ATmega644P-20AQ, ATmega644P-20AQR, ATmega644P-20PQ, ATmega644P-20MQ, ATmega644P-20MQR</td>
<td>44A, 44A, 40P6, 44M1</td>
<td>10°C to 105°C Extended (-40°C to 105°C)</td>
</tr>
</tbody>
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**Notes:**
1. For Speed Grades, see complete datasheets.
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