

selectable delays are shown in [Table 6-2](#). The frequency of the Watchdog Oscillator is voltage dependent as shown in ["Typical Characteristics" on page 328](#).

**Table 6-2.** Number of Watchdog Oscillator Cycles

| Typ Time-out ( $V_{CC} = 5.0V$ ) | Typ Time-out ( $V_{CC} = 3.0V$ ) | Number of Cycles |
|----------------------------------|----------------------------------|------------------|
| 0 ms                             | 0 ms                             | 0                |
| 4.1 ms                           | 4.3 ms                           | 512              |
| 65 ms                            | 69 ms                            | 8K (8,192)       |

Main purpose of the delay is to keep the AVR in reset until it is supplied with minimum  $V_{CC}$ . The delay will not monitor the actual voltage and it will be required to select a delay longer than the  $V_{CC}$  rise time. If this is not possible, an internal or external Brown-Out Detection circuit should be used. A BOD circuit will ensure sufficient  $V_{CC}$  before it releases the reset, and the time-out delay can be disabled. Disabling the time-out delay without utilizing a Brown-Out Detection circuit is not recommended.

The oscillator is required to oscillate for a minimum number of cycles before the clock is considered stable. An internal ripple counter monitors the oscillator output clock, and keeps the internal reset active for a given number of clock cycles. The reset is then released and the device will start to execute. The recommended oscillator start-up time is dependent on the clock type, and varies from 6 cycles for an externally applied clock to 32K cycles for a low frequency crystal.

The start-up sequence for the clock includes both the time-out delay and the start-up time when the device starts up from reset. When starting up from Power-save or Power-down mode,  $V_{CC}$  is assumed to be at a sufficient level and only the start-up time is included.

## 6.3 Low Power Crystal Oscillator

Pins XTAL1 and XTAL2 are input and output, respectively, of an inverting amplifier which can be configured for use as an On-chip Oscillator, as shown in [Figure 6-2 on page 29](#). Either a quartz crystal or a ceramic resonator may be used.

This Crystal Oscillator is a low power oscillator, with reduced voltage swing on the XTAL2 output. It gives the lowest power consumption, but is not capable of driving other clock inputs, and may be more susceptible to noise in noisy environments. In these cases, refer to the ["Full Swing Crystal Oscillator" on page 30](#).

C1 and C2 should always be equal for both crystals and resonators. The optimal value of the capacitors depends on the crystal or resonator in use, the amount of stray capacitance, and the electromagnetic noise of the environment. Some initial guidelines for choosing capacitors for use with crystals are given in [Table 6-3 on page 29](#). For ceramic resonators, the capacitor values given by the manufacturer should be used.