6.5 Low Frequency Crystal Oscillator

The Low-frequency Crystal Oscillator is optimized for use with a 32.768 kHz watch crystal. When selecting crystals, load capasitance and crystal's Equivalent Series Resistance, ESR must be taken into consideration. Both values are specified by the crystal vendor. ATmega48P/88P/168P/328P oscillator is optimized for very low power consumption, and thus when selecting crystals, see Table 6-7 on page 32 for maximum ESR recommendations on 6.5 pF, 9.0 pF and 12.5 pF crystals

Table 6-7. Maximum ESR Recommendation for 32.768 kHz Crystal

Crystal CL (pF)	Max ESR [kΩ](1)
6.5	75
9.0	65
12.5	30

Note: 1. Maximum ESR is typical value based on characterization

The Low-frequency Crystal Oscillator provides an internal load capacitance of typical 6 pF at each TOSC pin. The external capacitance (C) needed at each TOSC pin can be calculated by using:

$$C = 2 \cdot CL - C_s$$

where CL is the load capacitance for a 32.768 kHz crystal specified by the crystal vendor and C_S is the total stray capacitance for one TOSC pin.

Crystals specifying load capacitance (CL) higher than 6 pF, require external capacitors applied as described in Figure 6-2 on page 29.

The Low-frequency Crystal Oscillator must be selected by setting the CKSEL Fuses to "0110" or "0111", as shown in Table 6-9. Start-up times are determined by the SUT Fuses as shown in Table 6-8.

Table 6-8. Start-up Times for the Low-frequency Crystal Oscillator Clock Selection

SUT1..0	Additional Delay from Reset (V_{CC} = 5.0V)	Recommended Usage
00	4 CK	Fast rising power or BOD enabled
01	4 CK + 4.1 ms	Slowly rising power
10	4 CK + 65 ms	Stable frequency at start-up
11	Reserved	

Table 6-9. Start-up Times for the Low-frequency Crystal Oscillator Clock Selection

CKSEL3..0	Start-up Time from Power-down and Power-save	Recommended Usage
0100(1)	1K CK	
0101	32K CK	Stable frequency at start-up

Note: 1. This option should only be used if frequency stability at start-up is not important for the application