AVR051: Set-up and Use the External RC Oscillator

8-bit AVR® RISC Microcontroller

Application Note

Features

- Low Power Consumption.
- Wide Frequency Range 100 kHz - 12 MHz
- Programmable Frequency Range to Minimize Current Consumption for a desired Frequency

Applicability

This application note applies to all AVRs with External RC Oscillator except ATtiny11, ATtiny12, ATtiny28, ATmega163, and ATmega323. For these devices, please refer to the device datasheets.

Introduction

This application note describes how to use the external RC oscillator for the AVR® Microcontroller. The AVR external RC oscillator is designed for use with an off-chip resistor and capacitor. The oscillator has a programmable bias current so the on-chip active modules can be biased at a lower current for low frequency operation, and at a higher current for high frequency operation. The Bias Current is controlled by the clock fuse settings as described in Table 3.

The advantages of an RC oscillator are that the AVR user can easily, and at a low cost, get a desired frequency of operation by adding an external R and C to the AVR. Another desirable feature of the RC oscillator is short start-up time (max. 4 µs + 10 clock cycles) compared to a crystal oscillator. The drawbacks of an RC oscillator compared to a crystal oscillator are the frequency stability and power consumption (especially at high frequencies).

For some AVR parts the oscillator pins are shared by several oscillators as well as I/O pins. See the individual AVR data sheets for more information.

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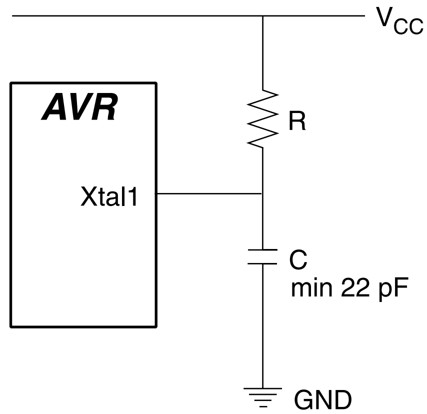
Using the External Oscillator

To use an external RC oscillator with the AVR, connect the R and C as shown in Figure 1.

Figure 1. Connection of R and C



Choosing R and C Values

The frequency of operation should be given entirely by R and C, but it can be influenced by the delay in the internal comparators unless proper bias-currents are selected. The frequency can be estimated by using this equation:

$$f \approx \frac{1}{3 \cdot R \cdot C}$$

Note that for low frequencies (below 1 MHz), the equation will indicate a lower value than the actual frequency of operation. Also note that different package and PCB layouts will give different stray capacitances that will alter the frequency.

Due to noise issues, the lowest suggested value of the capacitor is 22 pF. Always use 22 pF if power consumption is important or if the design requires frequencies above 8 MHz. Otherwise, use a larger value, for example 47 pF. It is not recommended to use a value larger than 100 pF due to the increase in power consumption.

Table 1 and Table 2 show the frequency and power consumption for some standard resistor values using C = 22 pF (low power consumption) and C = 100 pF (high noise immunity). By choosing a higher capacitor (compared to the minimum 22 pF), the impedance for high frequencies is reduced and hence the tolerance for high frequency noise is increased. However, the penalty is increased current consumption as can be seen in the tables. The bias programming current is shown in Table 3.

Table 1. Frequency and Power Consumption for C = 22 pF[1]

Resistor Value (KΩ)	Frequency (MHz)	Typical Internal Current Consumption, Oscillator Only (mA)	Typical External Current Consumption, Oscillator Only (mA)
1.2	11.9	1.0	2.2
2.2	7.36	1.0	1.2
3.9	4.40	0.57	0.68
8.2	1.98	0.18	0.34
18.0	0.99	0.18	0.15

Note: 1. C = 22 pF, and 12 pF stray capacitance (package, pad, pin, and PCB), simulated values.

Table 2. Frequency and Power Consumption for C = 100 pF[1]

Resistor Value (KΩ)	Frequency (MHz)	Typical Internal Current Consumption, Oscillator Only (mA)	Typical External Current Consumption, Oscillator Only (mA)
1.2	4.54	0.57	2.2
2.2	2.32	0.18	1.2
3.9	1.41	0.18	0.68

Note: 1. C = 100 pF, and 12 pF stray capacitance (package, pad, pin, and PCB), 5V, simulated values

Current Consumption

The current consumption can be divided into two parts: External and internal current consumption. The internal current consumption is the current used by the on-chip comparators and the bias module. The AVR user can program this consumption. Table 3 shows suggested bias settings for various frequency ranges.

The external current consumption is the off-chip current consumption. This can be estimated as $V_{CC}/(2R)$, since the capacitor is charged for half the time through the resistor. As can be seen from the simple expression, increasing the resistance can minimize the external current consumption. The problem is then that the frequency of operation will decrease unless the capacitor is changed as well. Remember that the lowest suggested capacitor value is 22 pF. If the internal bias current is lowered too much by selecting a too high frequency range, then the delay through the comparators will contribute to the period and the external resistor would have to be decreased to obtain the same frequency. This would not lower the total current consumption (it might even increase), but will degrade the oscillator by making the frequency more process dependant.

Note that for 12 MHz, the total current consumption for the oscillator is around 3 mA, which is about 20 times the current consumption of the AVR crystal oscillator for the same frequency.

The Right Bias Current for the Right Frequency

The internal bias current sets the delay through the comparators, lower current gives a longer delay. The idea is that the comparator delay should be negligible compared to the RC time constant (the RC time constant should decide the frequency, not the internal comparators). For low frequencies, one can allow a relatively high delay through the comparator without affecting the frequency of operation, while for high frequencies fast comparators are needed.

The bias setting is determined by the clock fuse settings and may vary from device to device. See the device specific datasheet for details. Table 3 shows which frequency ranges can be used with which bias currents.

Table 3. Bias Programming vs. Frequency

Bias Current	Frequency Range (MHz)
Very low	< 0.9
Low	0.9 - 3
Medium	3 - 8
High	8 - 12

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