Improving Start-up Time at 32kHz for the HA7210 Low Power Crystal Oscillator

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The HA7210 is a very low power crystal-controlled oscillator that can be programmed to operate between 10kHz and 10MHz. In the lowest frequency range setting (FREQ 1 = 1, FREQ 2 = 1), at 32kHz with a 5V supply and a 40pF load, the HA7210 will draw a mere 10µA. In this range (10kHz to 100kHz), the low power consumption may result in extended oscillator start-up time. In higher frequency ranges, power consumption gradually increases and start-up time is not an issue. Several approaches to address low frequency start-up time will be presented.

The first approach is to use the Enable/Disable Mode Pin. This pin, when pulled low, will switch the output to a high impedance state while an internal inverter continues to drive the crystal in normal oscillation. This will result in a power savings because very often a majority of the power dissipation is used to drive the output load. In the disabled mode the HA7210 will draw only 5µA of standby current as compared to 10µA above. This small amount of standby current gives the benefit of instant start-up of a reliable and stable clock. The Enable Time of the HA7210 is typically 800ns.

For applications where the voltage supply is removed from the circuit or standby mode is not desired, the time from power being applied until a stable square wave is generated can be unexpectedly long. It should be noted that 32kHz crystal parameters vary significantly from vendor to vendor and can greatly affect the HA7210 (or any Pierce Oscillator) start-up characteristic. Of particular importance is the Effective Series Resistance (ESR) of the crystal, with lower ESR generally providing faster start-up times (32kHz crystals with ESR greater than 50kΩ should be avoided). Using the circuit in Figure 1 the start-up characteristic of a 32.768kHz crystal, set in the recommended lowest frequency range (FREQ 1 = 1, FREQ 2 = 1) has a delay of 1.9s as shown in Figure 2.

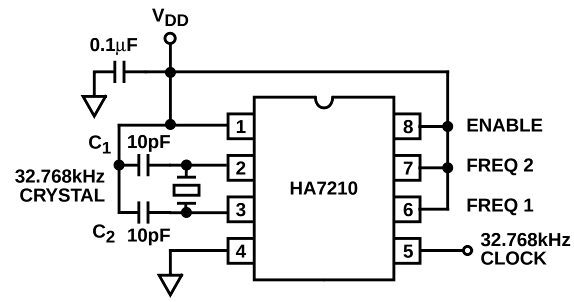
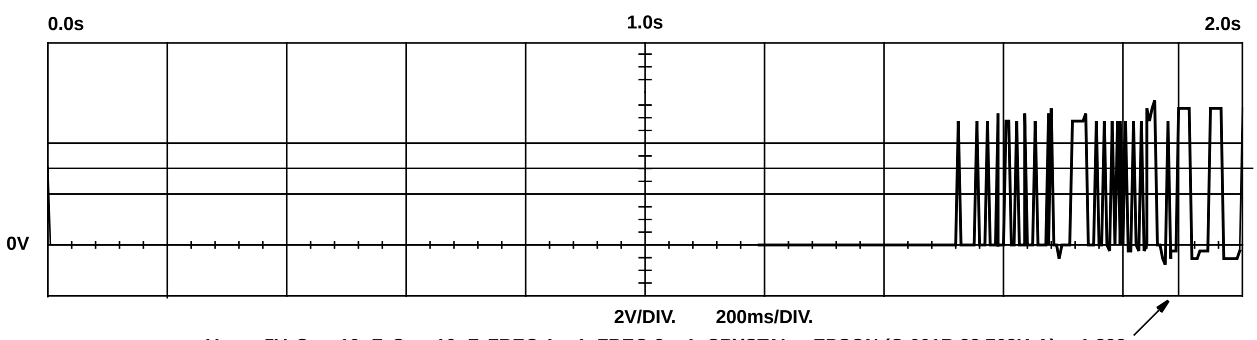


FIGURE 1. TYPICAL APPLICATION CIRCUIT

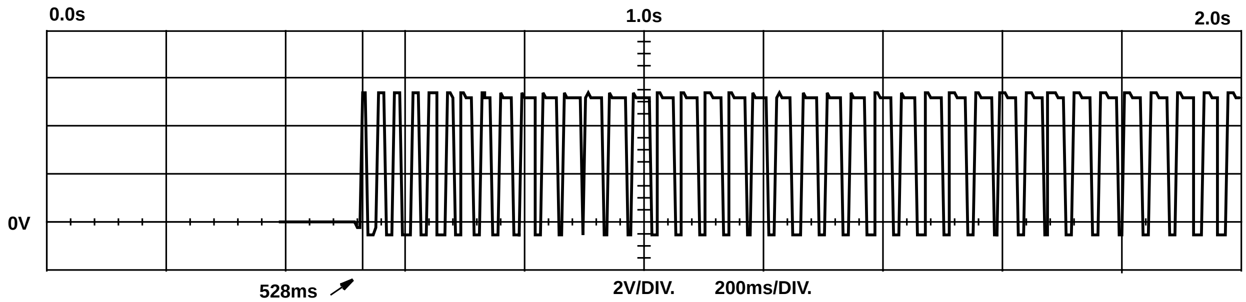
FREQUENCY SELECTION TRUTH TABLE

ENABLE	FREQ 1	FREQ 2	OUTPUT RANGE
1	1	1	10kHz to 100kHz
1	1	0	100kHz to 1MHz
1	0	1	1MHz to 5MHz
1	0	0	5MHz to 10MHz
0	X	X	High-Z



V_{DD} = 5V, C_1 = 10pF, C_2 = 10pF, FREQ 1 = 1, FREQ 2 = 1, CRYSTAL = EPSON (C-001R 32.768K-A) 1.892s

FIGURE 2. START-UP CHARACTERISTIC AT 32kHz WITH FREQ 1 = 1 AND FREQ 2 = 1



V_{DD} = 5V, C_1 = 10pF, C_2 = 10pF, FREQ 1 = 1, FREQ 2 = 0, CRYSTAL = EPSON (C-001R 32.768K-A)

FIGURE 3. START-UP CHARACTERISTIC AT 32kHz WITH FREQ 1 = 1 AND FREQ 2 = 0

The start-up time can be improved by switching to the next higher frequency range setting, where FREQ 1 = 1 and FREQ 2 = 0. In this setting the voltage that is internally applied to the oscillating inverter increases from 1.4V to 2.2V providing more power and higher transconductance. This increased power comes at the expense of increased supply current. For a 32kHz crystal, with V_{DD} = 5V and a 40pF load the FREQ 1 = 1, FREQ 2 = 0 setting will draw 30MA as compared to 10MA for the FREQ 1 = 1, FREQ 2 = 1 range setting. Another concern when using the next higher range is that the internal 15pF crystal loading capacitors are disconnected. This means that the user must provide external crystal loading capacitors for the crystal to start properly in the higher range. The minimum values for C_1 and C_2 to provide reliable start-up was found to be 10pF each. The start-up time in the FREQ 1 = 1, FREQ 2 = 0 mode is shown in Figure 3 at 528ms, significantly faster than the FREQ 1 = 1, FREQ 2 = 1 setting.

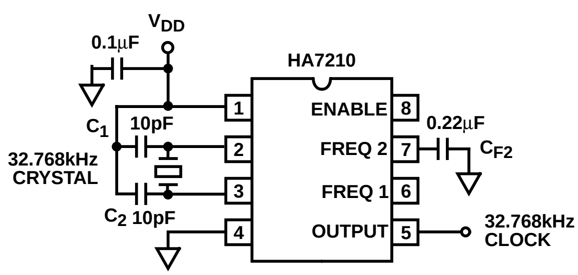


FIGURE 4. FAST START-UP AT 32kHz WITH NO SUPPLY CURRENT PENALTY

How can the benefits of faster start-up be gained without the penalty of increased supply current? A solution to this problem is provided with the addition of a single capacitor C_{F2} as shown in Figure 4.

The digital inputs (ENABLE, FREQ 1, FREQ 2) provide internal pull-up devices. These P-Channel devices provide 0.4µA of current to insure that an input will go to the "1" state if left open. This pull-up current is used to charge a 0.22µF capacitor (C_{F2}) connected to the FREQ 2 pin. At power-up C_{F2} has zero charge and holds FREQ 2 "low", (FREQ 1 = 1, FREQ 2 = 0) so that the HA7210 will give a fast start-up. Then the 0.4µA pull-up current will slowly charge C_{F2} until it reaches a "high" state (FREQ 1 = 1, FREQ 2 = 1) and the part draws lower supply current. The FREQ 2 pin must be held low until the oscillation has fully started to insure a start-up time improvement. The digital input threshold is about 1.5V, providing a delay determined by:

$$i = C\frac{dv}{dt} \qquad dt = \frac{(0.22\mu F)(1.5V)}{0.4\mu A} = 0.825s$$

The results are shown in Figure 5. Notice that CH 2 doesn't go all the way to 5V as expected. This is due to the 10MΩ scope probe loading the 0.4µA current source. This probe loading also causes CH 2 (FREQ 2 pin) to have an RC shape rather that the expected linear trace.

In summary, start-up time is an important consideration in the design and crystal selection for low frequency crystal oscillators. This Application Note describes several alternatives to improve start-up time utilizing unique features of the HA7210 while taking advantage of its extremely low supply current.

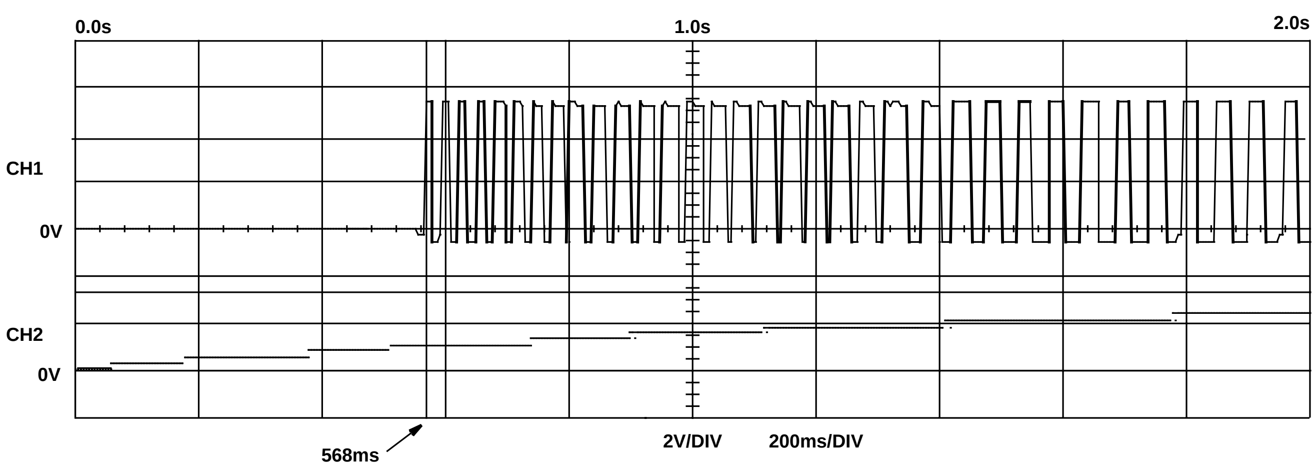


FIGURE 5. START-UP CHARACTERISTIC AT 32kHz WITH SPEED-UP CIRCUIT

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