

Motorola Semiconductor Engineering Bulletin

EB371

Considerations in Programming the System Clock Frequency of MC68HC16 and MC68300 Devices

By Charles Melear
Microcontroller Division
Austin, Texas

Introduction

The MC68HC16 and MC68300 Families of microcontrollers (MCU) derive the internal system clock from either an external clock source or the output of an internal PLL/VCO (phase-locked loop/voltage-controlled oscillator).

If the MODCK pin is held low at the release of reset, the clock signal applied to the EXTAL pin will be the system clock frequency. If the MODCK pin is held high at the release of reset, the system clock frequency will be the output of the PLL/VCO.

VCO Frequency

The frequency of the VCO is controlled by the programming of the SYNCR (clock synthesizer control register).

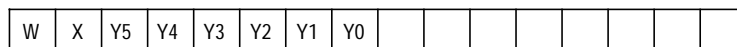


Figure 1. SYNCR Register at \$FF FA04

The VCO maximum frequency must be limited to no greater than two times the maximum rated clock speed for any device in the MC68HC16 and MC68300 Families.

For instance, the MC68332ACFT16 is rated at a maximum speed of 16.7 MHz. Therefore, the maximum speed of the VCO is 33.4 MHz. Likewise, a device rated to run at 20.97 MHz would allow for a maximum VCO speed of 41.94 MHz, and a device rated to run at 25.16 MHz would allow for a maximum VCO speed of 50.32 MHz.

When a low-frequency crystal is used, the EXTAL input feeds the input into the PLL/VCO. Nominally, a 32.768-kHz crystal or external clock source is used. When a high-frequency crystal or external clock source is applied to the EXTAL pin, this input is divided by 128 and then applied to the PLL/VCO.

When a 4.194304-MHz crystal is used, the internal divide-by-128 on the EXTAL pin produces 32.768-kHz which is then applied to the PLL/VCO.

For a low-frequency crystal (approximately 25 to 50 kHz), these two equations apply:

1. $F_{\text{System}} = F_{\text{Crystal}}[4(Y+1)(2^{2W} + X)]$
2. $F_{\text{VCO}} = 2 * F_{\text{System}}(2 - X)$

For a high-frequency crystal (approximately 4 to 6 MHz), these two equations apply:

1. $F_{\text{System}} = (F_{\text{Crystal}}/128)[4(Y+1)(2^{2W} + X)]$
2. $F_{\text{VCO}} = 2 * F_{\text{System}}(2 - X)$

X, W, and Y Bits in SYNCR

The X, W, and Y bits control the frequency of the system clock. The W and Y bits control the feedback prescaler in the VCO. The output of the VCO is fed to a divide-by-2 circuit whose output drives the internal system clock bus.

- If X bit = 1, the divide-by-2 circuit is bypassed so that the full frequency of the VCO is applied to the internal system clock bus.

- If X bit = 0, the internal system clock bus is driven at one-half the speed of the VCO. In other words, if X bit = 0, the VCO has to operate at two times the frequency to generate a particular system clock frequency than if X bit = 1.

The W bit and the Y bits control the feedback divider in the VCO. The W bit controls a divide-by-4 in the feedback chain. If W = 1, the frequency of the VCO will be multiplied by four. As an example, a system clock frequency of 2.097 MHz will be obtained if X = 0, W = 0, and Y = 001111 or for the combination of X = 0, W = 1, and Y = 000011.

It is possible to program any combination of X, W, and Y in the SYNCR register. However, some of the possible combinations will cause specification violations.

For instance:

- If X = 0 and W = 1, the Y bits cannot exceed the binary value of %001111.
- If X = 0, W = 0, and Y = 111111 or X = 0, W = 1, and Y = 001111, a system clock frequency of 8.389 MHz will be obtained.

In both cases, the frequency of the VCO will be four times the system clock frequency or 33.554 MHz. This is the maximum allowable frequency for the VCO on a device rated to run with a system clock speed of 16.777 MHz.

- If X = 0, W = 1, and the Y bits exceed the binary value of %001111, the VCO will run at a speed that exceeds its maximum rating.

Permissible Values Tables in this document show all permissible values for W, X, and Y for 16-, 20- and 25-MHz devices.

NOTE: *Any value that is not in the table will cause the frequency of the VCO to be above the maximum allowable specification.*

Using the numbers in [Table 1](#), [Table 2](#), and [Table 3](#) to obtain clock frequency, find the counter modulus in the leftmost column, then look in the appropriate prescaler cell. Empty cells represent values that exceed maximum system frequency specifications or cause the internal PLL/VCO to exceed maximum frequency specifications for all MC68300 and all MC68HC16 devices that use a SIM (system integration module) or SCIM (single-chip integration module).

Table 1. System Frequencies from 32.768-kHz Low-Frequency Reference or 4.194-MHz High Frequency References for 16-MHz Devices

Modulus Y	Prescaler			
	[W:X] = 00	[W:X] = 01	[W:X] = 10	[W:X] = 11
000000	131	262	524	1049
000001	262	524	1049	2097
000010	393	786	1573	3146
000011	524	1049	2097	4194
000100	655	1311	2621	5243
000101	786	1573	3146	6291
000110	918	1835	3670	7340
000111	1049	2097	4194	8389
001000	1180	2359	4719	9437
001001	1311	2621	5243	10486
001010	1442	2884	5767	11534
001011	1573	3146	6291	12583
001100	1704	3408	6816	13631
001101	1835	3670	7340	14680
001110	1966	3932	7864	15729
001111	2097	4194	8389	16777
010000	2228	4456		
010001	2359	4719		
010010	2490	4981		
010011	2621	5243		
010100	2753	5505		
010101	2884	5767		
010110	3015	6029		
010111	3146	6291		
011000	3277	6554		
011001	3408	6816		
011010	3539	7078		
011011	3670	7340		

Table 1. System Frequencies from 32.768-kHz Low-Frequency Reference or 4.194-MHz High Frequency References for 16-MHz Devices (Continued)

Modulus Y	Prescaler			
	[W:X] = 00	[W:X] = 01	[W:X] = 10	[W:X] = 11
011100	3801	7602		
011101	3932	7864		
011110	4063	8126		
011111	4194	8389		
100000	4325	8651		
100001	4456	8913		
100010	4588	9175		
100011	4719	9437		
100100	4850	9699		
100101	4981	9961		
100110	5112	10224		
100111	5243	10486		
101000	5374	10748		
101001	5505	11010		
101010	5636	11272		
101011	5767	11534		
101100	5898	11796		
101101	6029	12059		
101110	6160	12321		
101111	6291	12583		
110000	6423	12845		
110001	6554	13107		
110010	6685	13369		
110011	6816	13631		
110100	6947	13894		
110101	7078	14156		
110110	7209	14418		
110111	7340	14680		
111000	7471	14942		
111001	7602	15204		

Table 1. System Frequencies from 32.768-kHz Low-Frequency Reference or 4.194-MHz High Frequency References for 16-MHz Devices (Continued)

Modulus	Prescaler			
	[W:X] = 00	[W:X] = 01	[W:X] = 10	[W:X] = 11
Y				
111010	7733	15466		
111011	7864	15729		
111100	7995	15991		
111101	8126	16253		
111110	8258	16515		
111111	8389	16777		

Table 2. System Frequencies from 32.768-kHz Low-Frequency Reference or 4.194-MHz High-Frequency Reference for 20-MHz Devices

Modulus	Prescaler			
	[W:X] = 00	[W:X] = 01	[W:X] = 10	[W:X] = 11
Y				
000000	131	262	524	1049
000001	262	524	1049	2097
000010	393	786	1573	3146
000011	524	1049	2097	4194
000100	655	1311	2621	5243
000101	786	1573	3146	6291
000110	918	1835	3670	7340
000111	1049	2097	4194	8389
001000	1180	2359	4719	9437
001001	1311	2621	5243	10486
001010	1442	2884	5767	11534
001011	1573	3146	6291	12583
001100	1704	3408	6816	13631
001101	1835	3670	7340	14680
001110	1966	3932	7864	15729
001111	2097	4194	8389	16777
010000	2228	4456	8913	17826
010001	2359	4719	9437	18874

Table 2. System Frequencies from 32.768-kHz Low-Frequency Reference or 4.194-MHz High-Frequency Reference for 20-MHz Devices (Continued)

Modulus Y	Prescaler			
	[W:X] = 00	[W:X] = 01	[W:X] = 10	[W:X] = 11
010010	2490	4981	9961	19923
010011	2621	5243	10486	20972
010100	2753	5505		
010101	2884	5767		
010110	3015	6029		
010111	3146	6291		
011000	3277	6554		
011001	3408	6816		
011010	3539	7078		
011011	3670	7340		
011100	3801	7602		
011101	3932	7864		
011110	4063	8126		
011111	4194	8389		
100000	4325	8651		
100001	4456	8913		
100010	4588	9175		
100011	4719	9437		
100100	4850	9699		
100101	4981	9961		
100110	5112	10224		
100111	5243	10486		
101000	5374	10748		
101001	5505	11010		
101010	5636	11272		
101011	5767	11534		
101100	5898	11796		
101101	6029	12059		
101110	6160	12321		
101111	6291	12583		

Table 2. System Frequencies from 32.768-kHz Low-Frequency Reference or 4.194-MHz High-Frequency Reference for 20-MHz Devices (Continued)

Modulus	Prescaler			
	Y	[W:X] = 00	[W:X] = 01	[W:X] = 10
110000	6423	12845		
110001	6554	13107		
110010	6685	13369		
110011	6816	13631		
110100	6947	13894		
110101	7078	14156		
110110	7209	14418		
110111	7340	14680		
111000	7471	14942		
111001	7602	15204		
111010	7733	15466		
111011	7864	15729		
111100	7995	15991		
111101	8126	16253		
111110	8258	16515		
111111	8389	16777		

Table 3. System Frequencies from 32.768-kHz Low-Frequency Reference or 4.194-MHz High-Frequency Reference for 25-MHz Devices


Modulus	Prescaler			
	Y	[W:X] = 00	[W:X] = 01	[W:X] = 10
000000	131	262	524	1049
000001	262	524	1049	2097
000010	393	786	1573	3146
000011	524	1049	2097	4194
000100	655	1311	2621	5243
000101	786	1573	3146	6291
000110	918	1835	3670	7340
000111	1049	2097	4194	8389

Table 3. System Frequencies from 32.768-kHz Low-Frequency Reference or 4.194-MHz High-Frequency Reference for 25-MHz Devices (Continued)

Modulus Y	Prescaler			
	[W:X] = 00	[W:X] = 01	[W:X] = 10	[W:X] = 11
001000	1180	2359	4719	9437
001001	1311	2621	5243	10486
001010	1442	2884	5767	11534
001011	1573	3146	6291	12583
001100	1704	3408	6816	13631
001101	1835	3670	7340	14680
001110	1966	3932	7864	15729
001111	2097	4194	8389	16777
010000	2228	4456	8913	17826
010001	2359	4719	9437	18874
010010	2490	4981	9961	19923
010011	2621	5243	10486	20972
010100	2753	5505	11010	22020
010101	2884	5767	11534	23069
010110	3015	6029	12059	24117
010111	3146	6291	12583	25166
011000	3277	6554		
011001	3408	6816		
011010	3539	7078		
011011	3670	7340		
011100	3801	7602		
011101	3932	7864		
011110	4063	8126		
011111	4194	8389		
100000	4325	8651		
100001	4456	8913		
100010	4588	9175		
100011	4719	9437		
100100	4850	9699		
100101	4981	9961		

Table 3. System Frequencies from 32.768-kHz Low-Frequency Reference or 4.194-MHz High-Frequency Reference for 25-MHz Devices (Continued)

Modulus Y	Prescaler			
	[W:X] = 00	[W:X] = 01	[W:X] = 10	[W:X] = 11
100110	5112	10224		
100111	5243	10486		
101000	5374	10748		
101001	5505	11010		
101010	5636	11272		
101011	5767	11534		
101100	5898	11796		
101101	6029	12059		
101110	6160	12321		
101111	6291	12583		
110000	6423	12845		
110001	6554	13107		
110010	6685	13369		
110011	6816	13631		
110100	6947	13894		
110101	7078	14156		
110110	7209	14418		
110111	7340	14680		
111000	7471	14942		
111001	7602	15204		
111010	7733	15466		
111011	7864	15729		
111100	7995	15991		
111101	8126	16253		
111110	8258	16515		
111111	8389	16777		

Motorola reserves the right to make changes without further notice to any products herein. Motorola makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does Motorola assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. "Typical" parameters which may be provided in Motorola data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. Motorola does not convey any license under its patent rights nor the rights of others. Motorola products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the Motorola product could create a situation where personal injury or death may occur. Should Buyer purchase or use Motorola products for any such unintended or unauthorized application, Buyer shall indemnify and hold Motorola and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that Motorola was negligent regarding the design or manufacture of the part. Motorola and  are registered trademarks of Motorola, Inc. Motorola, Inc. is an Equal Opportunity/Affirmative Action Employer.

How to reach us:

USA/EUROPE/Locations Not Listed: Motorola Literature Distribution; P.O. Box 5405, Denver, Colorado 80217. 1-303-675-2140 or 1-800-441-2447

JAPAN: Motorola Japan Ltd.; SPS, Technical Information Center, 3-20-1, Minami-Azabu, Minato-ku, Tokyo 106-8573 Japan. 81-3-3440-3569

ASIA/PACIFIC: Motorola Semiconductors H.K. Ltd.; Silicon Harbour Centre, 2 Dai King Street, Tai Po Industrial Estate, Tai Po, N.T., Hong Kong.
852-26668334

Technical Information Center: 1-800-521-6274

HOME PAGE: <http://www.motorola.com/semiconductors/>



MOTOROLA

© Motorola, Inc., 2000

EB371/D