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(71) Applicant: **MICROCHIP TECHNOLOGY INCORPORATED** [US/US]; 2355 West Chandler Blvd., Chandler, AZ 85224-6199 (US).

(72) Inventors: **STEEDMAN, Sean**; 2622 E. Rockledge Road, Phoenix, AZ 85048 (US). **DUVENHAGE, Fanie**; 16414 South 29th Drive, Phoenix, AZ 85045 (US).

(74) Agent: **SLAYDEN, Bruce, W., II**; King & Spalding LLP, 401 Congress Ave., Suite 3200, Austin, TX 78701 (US).

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

[Continued on next page]

(54) **Title**: MICROCONTROLLER WITH DIGITAL CLOCK SOURCE

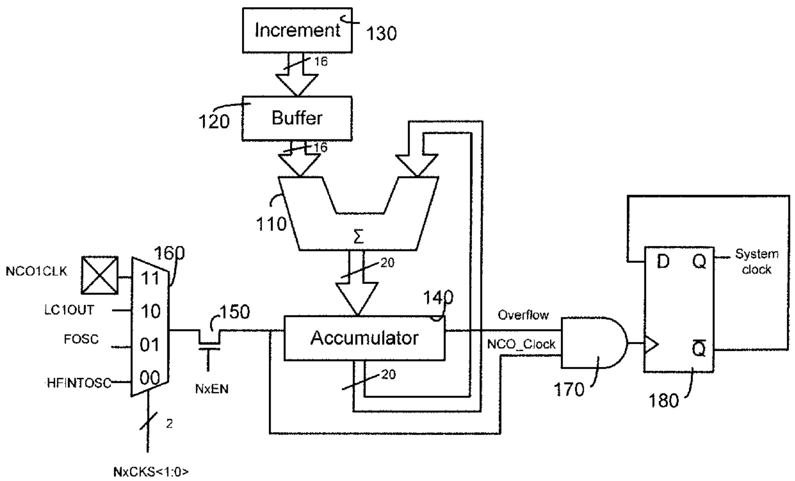

Figure 2

(57) **Abstract**: A microcontroller has a numerical controlled oscillator receiving a primary clock signal and is configured to provide an internal system clock of the microcontroller. A method for operating a microcontroller performs the following steps: Selecting a primary clock signal from a plurality of clock signals; feeding the primary clock signal to a numerical controlled oscillator; configuring the numerical controlled oscillator to generate a numerical controlled clock signal; and providing the numerical controlled clock signal as an internal system clock for the microcontroller.

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MICROCONTROLLER WITH DIGITAL CLOCK SOURCE

Cross-Reference To Related Applications

This application claims the benefit of U.S. Provisional Application No. 61/729,699 filed on November 26, 2012, entitled "MICROCONTROLLER WITH DIGITAL CLOCK SOURCE", which is incorporated herein in its entirety.

Technical Field

The present disclosure relates to microcontrollers, in particular microcontrollers with integrated clock control units.

Background

Most microcontroller clock schemes are based on binary dividers of a standard clock. For instance, on conventional microcontroller products if a16 MHz base clock may be used as the system clock. However, a user may scale down this frequency, in particular for low power applications. Also, peripheral devices may be supplied with clock signals derived from such a system clock by division of 2^n, wherein $n>1$. For example, in the above case the following frequencies may be selected for a system clock or other clock signals derived from the system clock: [8, 4, 2, 1, 0.5, 0.25, .03125] MHz. These selectable output frequencies are based on a divider of [2,4,8, 16,32,64,512], respectively.

Summary

There exists a need for microcontroller with a more flexible configurability of a digital clock source that can be used as a system clock and/or as a clock source for peripheral devices or other uses.

According to an embodiment, a microcontroller may comprise a numerical controlled oscillator receiving a primary clock signal and being configured to provide an internal system clock.

According to a further embodiment, the numerical oscillator may receive a reference clock r(x) and a numerical value q and provides an output clock, wherein the numerical value is provided by a register. According to a further embodiment, the output clock $f(q) = r(x) *$

A; wherein A is a numeric oscillator transfer function. According to a further embodiment, the system clock can be used to operate the central processing core of the microcontroller. According to a further embodiment, at least one other internal clock can be derived from the internal system clock. According to a further embodiment, the microcontroller may further comprise another numerical controlled oscillator to provide for a second internal clock. According to a further embodiment, the microcontroller may comprise a selection unit operable to select the primary clock signal from at least one internal and at least one external clock signal. According to a further embodiment, the numerical controlled oscillator may comprise an adder having a first input coupled with an increment register, and an accumulator being clocked by the primary clock signal having an input coupled with an output of the accumulator and an output coupled with the second input of the accumulator, wherein an overflow output of the accumulator provides said internal system clock signal. According to a further embodiment, the microcontroller may further comprise a multiplexer receiving a plurality of clock signals and being controlled to select one the plurality of clock signals as the primary clock signal. According to a further embodiment, the increment register is buffered. According to a further embodiment, the microcontroller may further comprise an AND gate with a first input coupled with said overflow output and a second input receiving the primary clock signal, wherein an output of the AND gate provides the system clock. According to a further embodiment, the microcontroller may further comprise a multiplexer receiving the output of the numerical controlled oscillator and a plurality of external and internal clock signals, wherein the multiplexer is controlled by a configuration register to select the internal clock. According to a further embodiment, the primary clock can be provided by an internal oscillator of said microcontroller. According to a further embodiment, the internal oscillator can be an RC-oscillator with digital trimming capabilities.

According to another embodiment, a method for operating a microcontroller may comprise: Selecting a primary clock signal from a plurality of clock signals; feeding the primary clock signal to a numerical controlled oscillator; configuring the numerical controlled oscillator to generate a numerical controlled clock signal; and providing the numerical controlled clock signal as an internal system clock for the microcontroller.

According to a further embodiment of the method, the numerical oscillator may receive a reference clock r(x) and a numerical value q and provides an output clock, wherein the numerical value is provided by a register. According to a further embodiment of the method, the output clock f(q) = r(x) * A; wherein A is a numeric oscillator transfer function. According to a further embodiment of the method, the numerical oscillator transfer function may comprise an operation selected from an adding, a multiplying, a dividing, a subtracting, and a logarithmic function. According to a further embodiment of the method, the system clock can be used to operate the central processing core of the microcontroller. According to a further embodiment of the method, at least one other internal clock can be derived from the internal system clock. According to a further embodiment of the method, the numerical controlled oscillator may perform the step of: adding an increment value to an accumulator wherein the accumulator is being clocked by the primary clock signal having an input coupled; and generating an overflow output signal by the accumulator which provides said internal system clock signal. According to a further embodiment of the method, the method may further perform the steps: providing a plurality of external and internal clock signals, and selecting one of the plurality of external and internal clock signals or the output signal of the numerical controlled oscillator as the internal system clock. According to a further embodiment of the method, the primary clock can be provided by an internal oscillator of said microcontroller. According to a further embodiment of the method, the internal oscillator can be an RC-oscillator with digital trimming capabilities.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 shows an exemplary block diagram of a numerical controlled oscillator used as a system clock source;

FIG. 2 a block diagram of a first embodiment of a clock control circuit according to various embodiments;

FIG. 3 a block diagram of another embodiment of a clock control circuit according to various embodiments;

FIG. 4 shows a clock select circuit for a microcontroller;

Detailed Description

According to various embodiments, a different type of on-chip clock peripheral can be used to provide for a programmable clock source. For example a numerically controlled oscillator (NCO) according to various embodiments can be used as a digital source clock provider. According to various embodiments, a numerically controlled oscillator is a module with two inputs, a reference clock r(x) and a numeric value q. Fig. 1 shows such a generic numerical oscillator 20 embedded in a system clock circuit 10 of, for example a microcontroller. The numerical controlled oscillator 20 receives a reference clock r(x) and a numerical value q which may be stored in a configuration register 40, for example a special function register associated with the NCO. The numeric value q entered into the module performs an operation on the reference clock to provide an output frequency f(q). Therefore f(q) = r(x) * A; A is the numeric oscillator transfer function. The transfer function can be as simple as an addition. However other functions can be implemented such as a adding, subtracting, multiplicative, dividing, logarithmic or any other mathematical function. In the following example a simple adder is used to form a numerical controlled oscillator. However, a numerical controlled oscillator as defined above may have other functions to provide for a numerical controlled clock signal as stated above.

In Fig. 1, the output signal of the numerical controlled oscillator 20 is fed to a multiplexer 30 which may receive one or more other clock signals which can be generated internally or may be fed from an external source. Alternatively, an external component, such as a crystal, may control an internal oscillator circuit to provide one of these additional clock signals. Multiplexer 30 may receive a control signal, for example, from a non-volatile configuration register to select one of the clock sources as the system clock. The reference clock r(x) may be preferably one of the signals Clock 1 or Clock 2 in the above example. Moreover, an additional multiplexer may be provided to select a reference clock form a plurality of internal and/or external clock signals. The NCO 20 can thus be used to provide a system clock for example for a microcontroller.

For example, as a peripheral an NCO is known to provide the user with a fixed duty-cycle, frequency controlled output. For example, microcontroller PIC10F320 comprises an NCO peripheral to generate a signal with a fixed duty cycle or to provide a pulse width control. Such a signal can then be used in an application in which the microcontroller is used.

However, according to various embodiments, such a numerical controlled oscillator can also be used to provide a system clock. Hence a clock signal developed by the NCO can be applied to system clocks of a microcontroller.

The system clock is the clock which drives operation of the microcontroller module. The system clock is typically derived from an analog clock source such as a main oscillator which can be an internal oscillator or external oscillator. According to various embodiments, the primary clock signal of the main microcontroller oscillator is then tied into the NCO, which then drives the system clock from its output.

The NCO is a digital solution to the problem, where clock sources tend to be analog solutions (for example internal RC oscillators, crystal oscillators, etc.). Also, according to various embodiments, there are two needs that are being solved. One is a variable clock source that can be controlled digitally, which is accomplished by the NCO peripheral. The other is that internal clock frequencies of a microcontroller are binary multiples, so the step size between larger frequencies is larger and larger as frequency increases. The NCO can be applied to fill in the gaps between these frequency increases to allow the user to optimize performance issues like: power, specific frequency, etc.

NCO clocks could be applied to different modules individually to allow for programmable timings by the user. Thus, it can be used advantageously as a system clock, watchdog timer frequency source, peripheral clock source, etc. An NCO system clock allows users to optimize performance, choose intermediate frequencies from binary weighted values.

Figure 2 shows a first possible implementation of a numerical controlled oscillator 100 according to various embodiments. A variety of clock inputs can be selected through a multiplexer 160. For example, an external clock through an external pin NCO1CLK or one of several internal clock signals LC1OUT, FOSC, or HFINTOSC can be selected through the multiplexer. For example, LC1OUT is an output signal provided by a programmable logic cell, FOSC and HFINTOSC are internal clock signal from the internal or integrated oscillator. This primary clock is then fed to the numerical controlled oscillator as shown in figure 1. The numerical controlled oscillator comprises an increment register 130 coupled with a buffer 120 that feeds a first input of an adder 110. The adder output is coupled with an accumulator 140 whose output is fed back to the second input of the adder 110. The primary input clock signal is fed through an enable gate 150 to control accumulator 140 and also to a first input of AND gate 170. An overflow from the accumulator is fed to a second input of AND gate 170 to generate the numerical controlled output clock. The output of AND gate 170 is coupled with the clock input of D-Flip-Flop 180 whose inverted output is coupled with its D-input. The non-inverted output of D-Flip-Flop 180 provides for a clock output, which according to various embodiments, can be selected as a system clock. Thus, a wide variety of frequencies can be directly controlled through programming of the control registers associated with the NCO 100. A plurality of such NCOs can be provided to provide multiple internal clocks such as system clocks and/or peripheral clocks. Moreover, standard digital divider may be coupled with the output of an NCO to provided derived internal clock signals.

Fig. 3 shows another embodiment of a numerical controlled oscillator 200. Here increment register 130 is directly coupled with adder 110. However, a buffer could be used as shown in Fig. 2. The primary clock signal is routed again through enable gate 150 and is also passed to a clock input of counter 210. The overflow output of accumulator 140 is coupled with the set input of RS-Flip-Flop220. A multiplexer 250 is operable to select one of the bits of counter 210 to reset Flip-Flop220. Counter 210 is reset by inverted Q output of Flip-Flop 220. Multiplexer 230 is provided to select either the Q output of D-Flip-Flop 180 or the Q output of RS-Flip-Flop 220 as the output signal of the numeric controlled oscillator. According to an embodiment, the overflow output of accumulator 140 may also be fed to an AND gate which receives the primary clock signal similar as in Fig. 1. Before it is fed to Flip-Flop220 and multiplexer 230.

Figure 4 shows an embodiment of how an NCO can be integrated within a microcontroller to provide a selectable system clock. A high frequency internal oscillator 320 may be provided on chip. In addition, an external high speed oscillator 330 and an external low speed oscillator 340 may be provided. Other internal and external clock sources may be available. According to embodiments, the NCO 310 is fed directly from the internal high frequency oscillator 320 which can be for example an RC oscillator with digital trimming capabilities 390. Here a system clock selection multiplexer 350 is provided that can be controlled for example by a configuration register 380 or any other special function register. Thus, a user can program a configuration register to select any of the four clock sources wherein upon selection of the NCO 310 a wide range of additional frequencies can be programmed by means of a respective associated control register. In addition, another multiplexer 360 may be provided to select a second internal clock signal, for example for one or more peripheral devices such as timers, pulse width modulators, etc. The selected system clock may then either be directly used as the system clock or fed to a divider 370 for dividing the clock by 2^n, wherein n>=1.

CLAIMS

1. A microcontroller comprising:

a numerical controlled oscillator receiving a primary clock signal and being configured to provide an internal system clock.

2. The microcontroller according to claim 1, wherein the numerical oscillator receives a reference clock r(x) and a numerical value q and provides an output clock, wherein the numerical value is provided by a register.

3. The microcontroller according to claim 1, wherein the output clock f(q) = r(x) * A; wherein A is a numeric oscillator transfer function.

4. The microcontroller according to claim 1, wherein the system clock is used to operate the central processing core of the microcontroller.

5. The microcontroller according to claim 4, wherein at least one other internal clock is derived from the internal system clock.

6. The microcontroller according to claim 1, further comprising another numerical controlled oscillator to provide for a second internal clock.

7. The microcontroller according to claim 1, comprising a selection unit operable to select the primary clock signal from at least one internal and at least one external clock signal.

8. The microcontroller according to claim 1, wherein the numerical controlled oscillator comprises

an adder having a first input coupled with an increment register, and

an accumulator being clocked by the primary clock signal having an input coupled with an output of the accumulator and an output coupled with the second input of the accumulator, wherein an overflow output of the accumulator provides said internal system clock signal.

9. The microcontroller according to claim 8, further comprising a multiplexer receiving a plurality of clock signals and being controlled to select one the plurality of clock signals as the primary clock signal.

10. The microcontroller according to claim 8, wherein the increment register is buffered.

11. The microcontroller according to claim 8, further comprising an AND gate with a first input coupled with said overflow output and a second input receiving the primary clock signal, wherein an output of the AND gate provides the system clock.

12. The microcontroller according to claim 8, further comprising:

a multiplexer receiving the output of the numerical controlled oscillator and a plurality of external and internal clock signals, wherein the multiplexer is controlled by a configuration register to select the internal clock.

13. The microcontroller according to claim 12, wherein the primary clock is provided by an internal oscillator of said microcontroller.

14. The microcontroller according to claim 13, wherein the internal oscillator is an RC-oscillator with digital trimming capabilities.

15. A method for operating a microcontroller comprising:

Selecting a primary clock signal from a plurality of clock signals;

feeding the primary clock signal to a numerical controlled oscillator;

configuring the numerical controlled oscillator to generate a numerical controlled clock signal;

providing the numerical controlled clock signal as an internal system clock for the microcontroller.

16. The method according to claim 15, wherein the numerical oscillator receives a reference clock r(x) and a numerical value q and provides an output clock, wherein the numerical value is provided by a register.

17. The method according to claim 16, wherein the output clock f(q) = r(x) * A; wherein A is a numeric oscillator transfer function.

18. The method according to claim 17, wherein the numerical oscillator transfer function comprises an operation selected from an adding, a multiplying, a dividing, a subtracting, and a logarithmic function.

19. The method according to claim 15, wherein the system clock is used to operate the central processing core of the microcontroller.

20. The method according to claim 19, wherein at least one other internal clock is derived from the internal system clock.

21. The method according to claim 15, wherein the numerical controlled oscillator performs the step of

adding an increment value to an accumulator wherein the accumulator is being clocked by the primary clock signal having an input coupled;

generating an overflow output signal by the accumulator which provides said internal system clock signal.

22. The method according to claim 21, comprising
providing a plurality of external and internal clock signals, and
selecting one of the plurality of external and internal clock signals or the output signal of the numerical controlled oscillator as the internal system clock.

23. The method according to claim 22, wherein the primary clock is provided by an internal oscillator of said microcontroller.

24. The method according to claim 24, wherein the internal oscillator is an RC-oscillator with digital trimming capabilities.

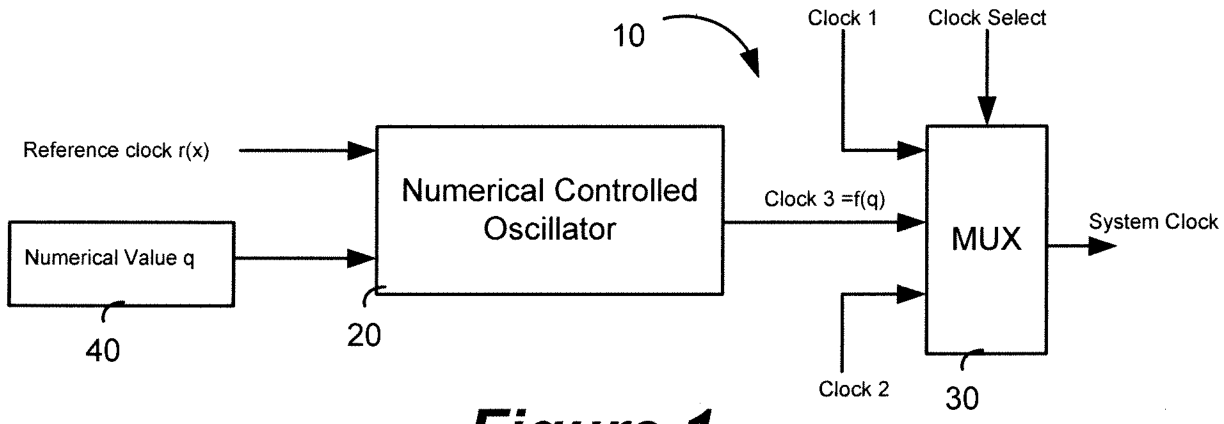

Figure 1

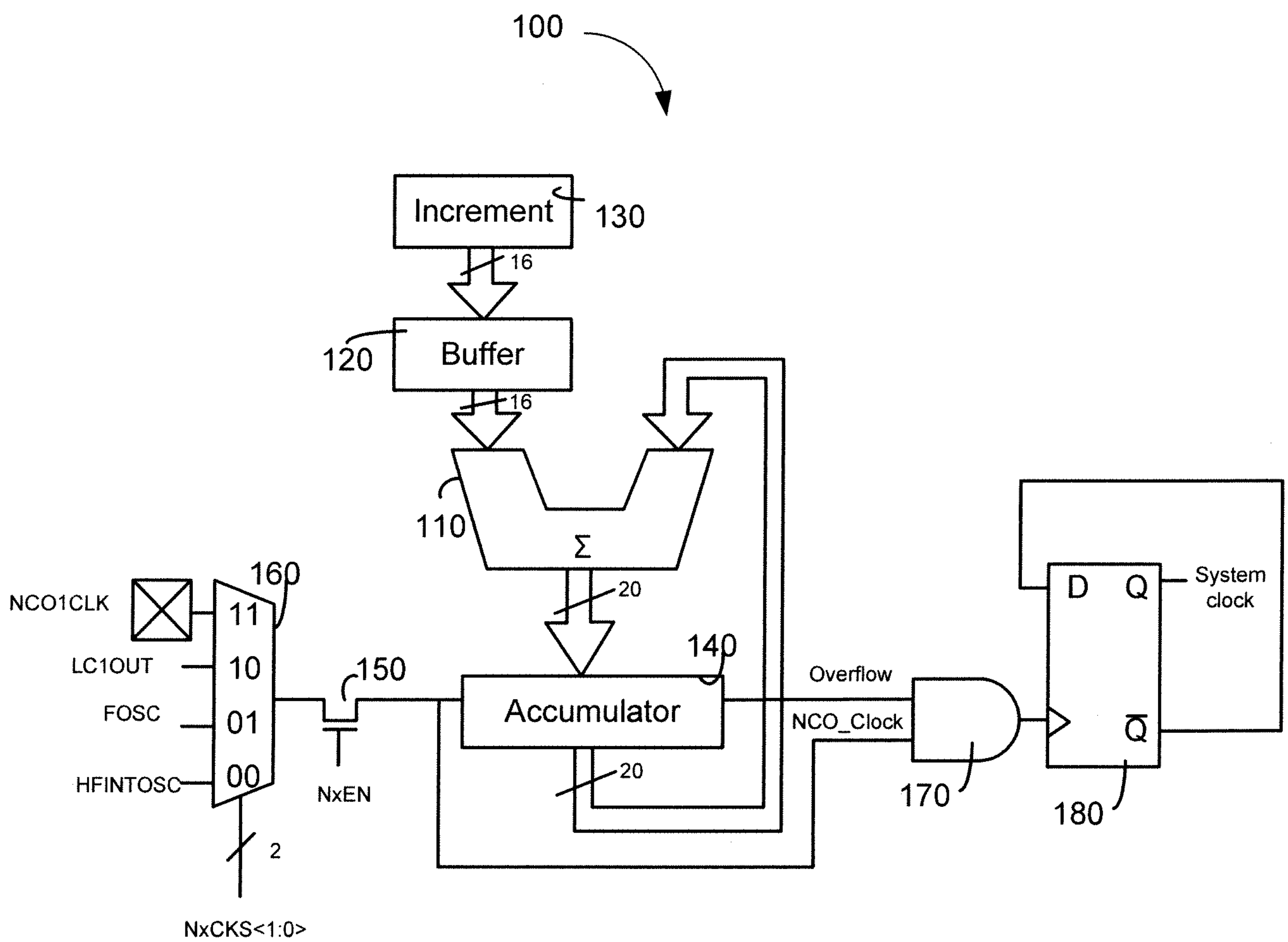

Figure 2

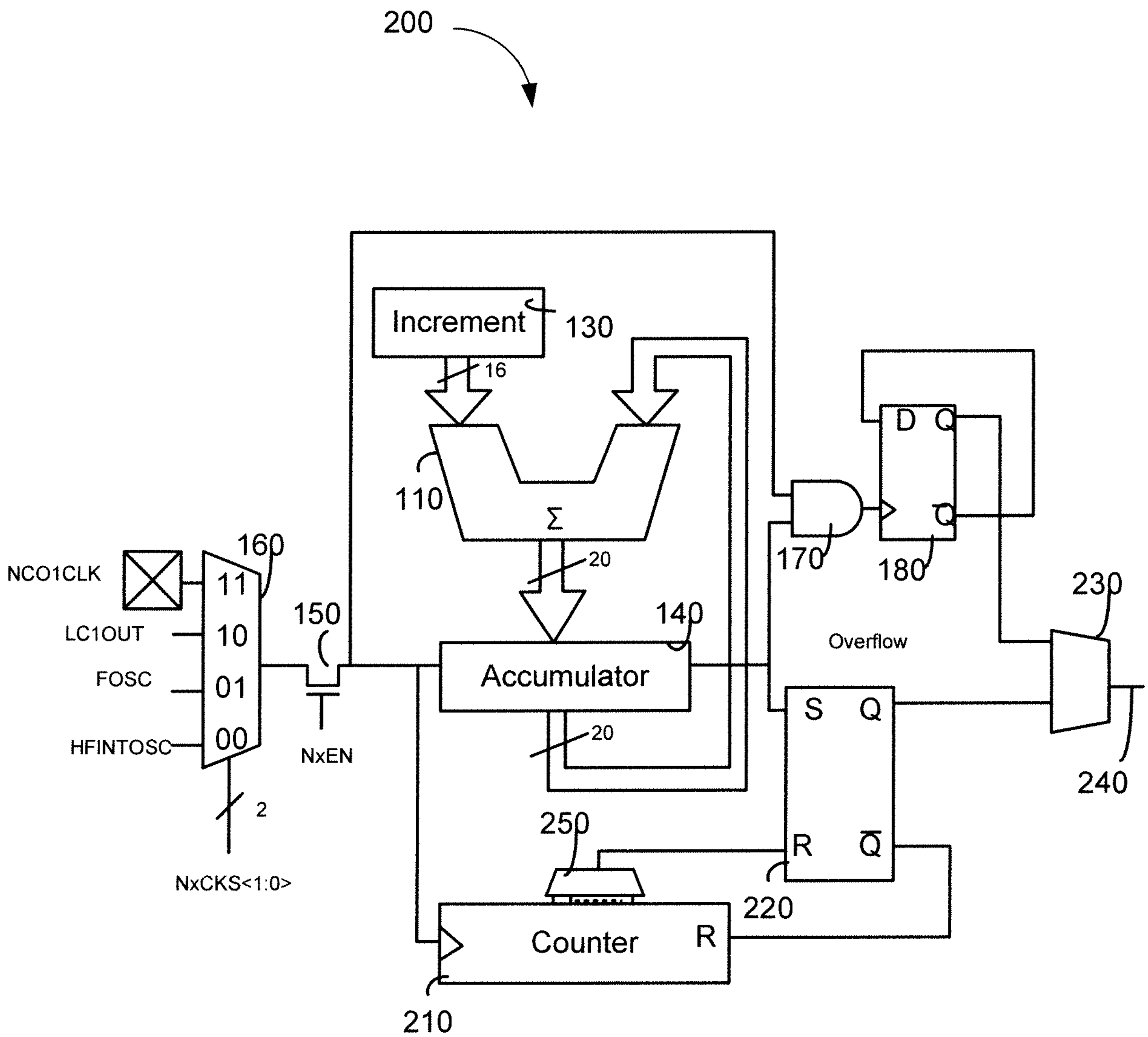
200
Increment
130
16
110
Σ
20
140
Accumulator
20
NCO1CLK
LC1OUT
FOSC
HFINTOSC
160
11
10
01
00
2
NxCKS<1:0>
150
NxEN
170
180
D
Q
Q̄
230
240
Overflow
S
Q
R
Q̄
220
250
Counter
R
210

Figure 3

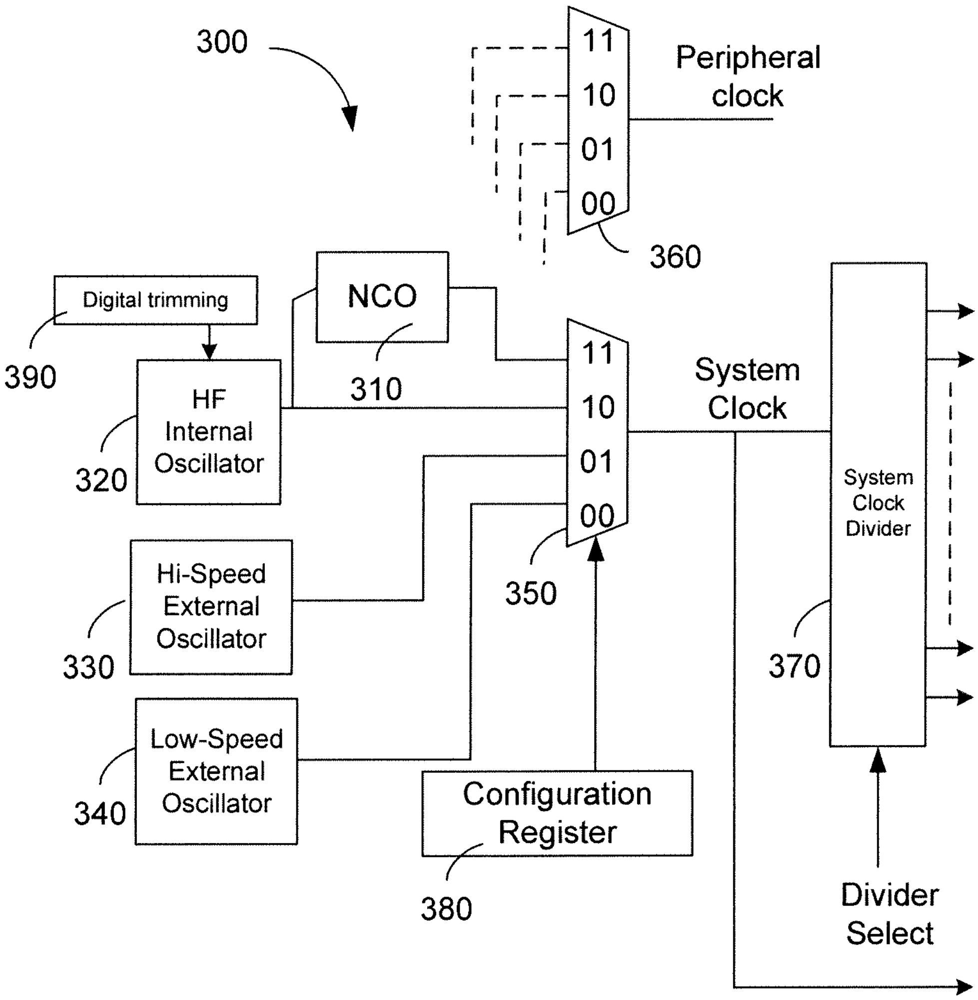
300
11
10
01
00
Peripheral clock
360
Digital trimming
390
NCO
310
HF Internal Oscillator
320
11
10
01
00
System Clock
350
System Clock Divider
370
Hi-Speed External Oscillator
330
Low-Speed External Oscillator
340
Configuration Register
380
Divider Select

Figure 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/071631

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06F1/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06F H03L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MICROCHIP TECHNOLOGY INC: "PIC10(L)F320/322 Data Sheet 6/8-Pin, High-Performance, Flash Microcontrollers", PIC10(L)F320/322 DATA SHEET 6/8-PIN, HIGH-PERFORMANCE, FLASH MICROCONTROLLERS, 11 July 2011 (2011-07-11), pages 1-210, XP055096949, figures 1,2,4-1,19-1,19-2,19-3,20-1,20-2 tables 2-3,20-1 page 3 - page 4 page 27, column 1, line 1, paragraph 4.0 - page 28, column 2, line 27, paragraph 4.3.2 page 113, column 1, line 1, paragraph 19.0 - page 116, column 1, line 24, paragraph 19.2 page 129, column 1, line 1, paragraph 20.0 - page 134, column 1, line 10, paragraph 20.5 -/--	1-24

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search	Date of mailing of the international search report
20 January 2014	28/01/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Rousset, Antoine

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microchip Technology Inc: "Manchester Decoder Using the CLC and NCO", Microchip Technology Inc, 17 October 2012 (2012-10-17), pages 1-16, XP055096981, Retrieved from the Internet: URL:http://ww1.microchip.com/downloads/en/AppNotes/01470A.pdf [retrieved on 2014-01-17] the whole document	1-24
A	US 2011/208329 A1 (CASTOR-PERRY KENDALL [US]) 25 August 2011 (2011-08-25) abstract; figures 9,10,11,12A,12B,18 paragraph [0083] - paragraph [0110] paragraph [0135]	1-24
A	SHUHUAN YU ET AL: "A digital-trim controlled on-chip RC oscillator", PROCEEDINGS OF THE 44TH. IEEE 2001 MIDWEST SYMPOSIUM ON CIRCUITS AND SYSTEMS. MWSCAS 2001. DAYTON, OH, AUG. 14 - 17, 2001; [MIDWEST SYMPOSIUM ON CIRCUITS AND SYSTEMS], NEW YORK, NY : IEEE, US, vol. 2, 14 August 2001 (2001-08-14), pages 882-885, XP010579336, DOI: 10.1109/MWSCAS.2001.986328 ISBN: 978-0-7803-7150-7 abstract; figures 1,2,5 page 882, column 1, line 13 - column 2, line 11	14,24

3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2013/071631

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US 2011208329 A1	25-08-2011	CN 102754348 A	24-10-2012
		US 2011208329 A1	25-08-2011
		WO 2011103602 A2	25-08-2011