IRACST – International Journal of Computer Networks and Wireless Communications (IJCNWC), ISSN: 2250-3501
Vol.4, No4, August 2014

Adaptive Reference Clock For Frequency Measuring Using Microcontroller

Binish Varghese
M tech. VLSI & Embedded Systems
St. Joseph's College of Engineering & Technology, Palai
Kottayam, Kerala
binish012@gmail.com

Vipin V
Assistant Professor, ECE Department
St. Joseph's College of Engineering & Technology, Palai
Kottayam, Kerala
vipinvenu85@gmail.com

***Abstract*—The frequency measuring devices generally uses either the pulse-counting method or quantify-delay method to characterise the signal. In both cases the signal to be measured compared with a reference frequency. The novel design uses a reference frequency sourced by a timer clock in the microcontroller. The timer frequency is controlled by the microcontroller to provide a reference frequency, which is adaptive to the signal to be measured. The design includes both the pulse counting and delay measuring method to calculate the frequency and other time related parameters of the signal. By controlling the reference frequency the device performance are compared to get the optimum result at the given conditions. The performance of the new design is tested and implemented using MSP430 microcontroller for designing a tachometer. Design aims to measure the AC motor rotation speed, approximately ranges to 1500 RPM. The proposed method can be used for low cost designs and also can accommodate in embedded automation designs.**

Keywords—frequency measuring; pulse counting; MSP430 implementation; TDC-time to digital converter.

I. INTRODUCTION

In high precision measuring devices the TDC (time to digital converter) modules are used for measuring the frequency or time period of signals to be measured [2]. The measuring system requires a reference frequency and a circuitry to compare the signal with the reference signal. These devices always use microcontroller that are programmed for displaying or processing the measured value from the TDC device. In the proposed design the use of TDC avoided by implementing the TDC function in the microcontroller itself. It reduces the product cost and minimises the circuit complexity. The microcontroller must be able to handle the frequency of the input signal and the reference frequency. If the microcontroller satisfies this necessary condition then the TDC can be implemented into microcontroller firmware. The adaptive clock method can only used in microcontrollers with clocks or timers that support clock frequency control at run time. This feature from the microcontroller provides the capability to modulate the reference frequency to a required range.

II. CLOCK CONTROLLING

A. Pulse-counting method

In pulse counting method the reference frequency is very less compared to the frequency of the signal to be measured. Here the number of signal pulse in a specific time delay is counted and using this frequency measured [2]. The reference frequency must be configured to get an optimum delay by considering the number of measurement cycles required and error in result that can neglect in the device requirement. The ratio between the frequency of signal to be measured and the reference delay gives the error in the measurement. In this method the high frequency limitations of the microcontroller specifies the maximum signal frequency that can feed to the system. Microcontroller runs from a clock source, the instruction decoding and the execution are carried according to this clock. The maximum signal frequency that can detect by the microcontroller might be less than the processor clock frequency. The microcontroller with dedicated peripherals, such as pulse counter can be used to measure the signals with frequency higher than the processor running frequency.

Figure 1. Reference clock 50Hz and unknown frequency square wave signal.

B. Quantify-delay method

In quantify delay method the signal frequency that to be measured must be very less than that of reference frequency. Here the reference frequency used in a way that, the frequency are counted to get the pulse width of the signal to be measured [2]. Then these values are used to get the required information from the signal. For low frequency signals this method is suitable. Then the maximum resolution that can achieve depends on the reference frequency. Maximum frequency gives maximum resolution to the measurement value, but takes more processing power to handle these high speed clocks in the circuit. Figure 1 shows the condition in which quantify delay method can be used the reference clock signal have high frequency compared to the signal to be measured.

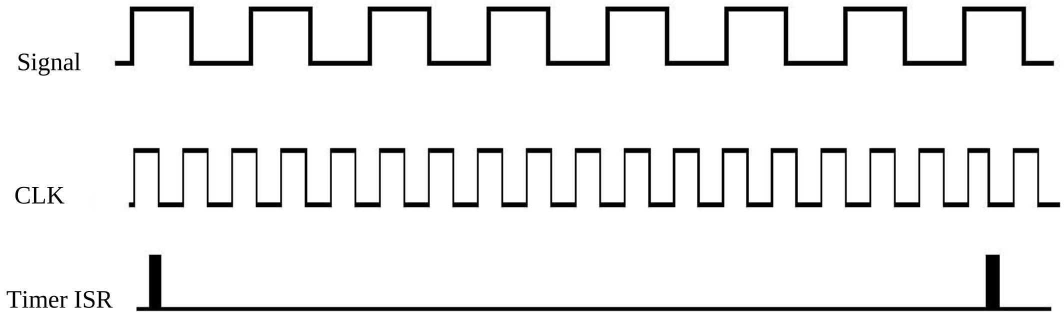

Figure 2. Wave form for pulse counting method.

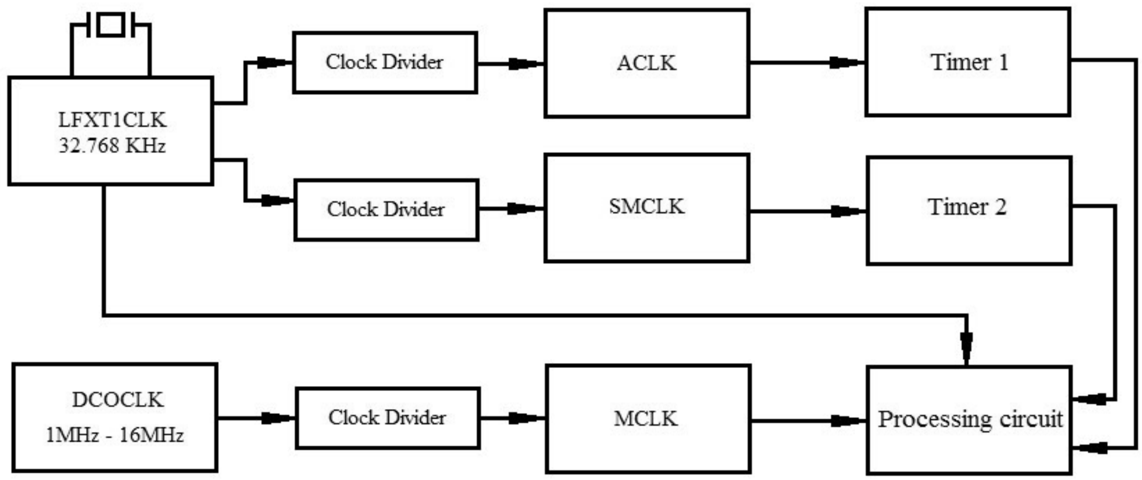

Figure 3. MSP 430 clock configuration

C. Adaptive Clock

The reference clock is used for comparing the signal properties, defines the resolution that can achieve in the measurement. That is the difference between the reference frequency and the signal must be made maximum to get readings with minimum quantization error [5]. If we are feeding a high frequency signal to the microcontroller, it will affect the control circuits inside the microcontroller. The clock must maintain a maximum value to get a maximum resolution and must lie inside the frequency range that the microcontroller can handled. In adaptive clock method the reference clock signal changes its frequency in order to track the signal that should measured. In both the pulse counting method and quantify delay method the adaptive function can be implemented. The adaptive clock is controlled by the microcontroller firmware, to follow a frequency which maintains an affordable balance in error, rate of measuring and processing power.

III. Microcontroller Considerations

The first consideration in choosing the microcontroller is that, it must be capable of getting two signals and compare the signals using the above mentioned methods. The second consideration is the capability of the clock module to handle the frequency variations in runtime. The clock must be programmable for implementing the adaptive clock capabilities. In low cost device designs the microcontroller capabilities are considered just to attain the specified design requirements, and the device should have minimum circuit elements and circuit complexity. Considering these, the frequency measuring devices can be designed to attain better performance.

The clock control modules of microcontrollers provides the ability to generate timer interrupts, which can be used to implement the pulse counting method to the measuring device[3]. The external pulses in a specific time interval are counted using external port input interrupts, or by using a pulse counter circuit in the microcontroller chip. The clock and timer circuit together gives the reference clock counting circuit, which is used to implement the quantify delay method in measurement.

For getting an adaptive nature to the device the clock signals must be controlled using the software program running in the microcontroller [4]. The clock module is programmed to run from a clock that can accommodate the incoming signal in its measuring range. In case of deviations in the input signal, the clock module changes its frequency so that the signal can be measured using any of the measuring methods.

IV. Implementation And Testing

The proposed method of frequency measurement implemented using 16 bit microcontroller. The TI MSP430 microcontroller is used for implementing and testing the design. Using MSP430 16 bit microcontroller a tachometer is designed. The design meant for measuring the RPM of an AC motor, measure the rotation of a shaft that rotates nearly at a speed of 1500rpm. IR proximity sensor is used to get the pulse signal corresponding to the rotation of the shaft.

Proximity sensor consists of one IR LED light source and an IR sensor. When an object reflects the light from the sensor module, it will give a high voltage to the microcontroller. The sensor should place in a way that it gets the IR light reflected back to the module in pulse form. To measure RPM from rotating shafts IR reflecting markings are provided in it. This arrangement will give one pulse for one rotation of the shaft.

The MSP430 microcontroller support different operating frequencies, and supports runtime changes in the clock frequency. The basic clock module supports different clock sources and can be configured to clock different peripheral modules from different clock sources.

The reference clock for measuring the signal generated from a clock crystal having frequency 32.768 KHz. This clock source is used to run two clock modules, one will perform the display and overall control of the device operation. The second module performs the delay generation which is required to implement the adaptive clocking in pulse counting method. The crystal frequency is considered as a constant frequency source. The timer modules are used to run the clock and to count the clocks to get the reference clock. It is used for implementing the quantify delay method.

Designed circuit performs to measure from 0.5Hz to 50Hz using the quantify delay method and rearranges its clock to track the input signal. In this method the delay counter runs from the 32.768 KHz crystal. To attain the same performance with different reference clock, the adaptive logic can be included. For the values above 50 Hz the adaptive clock provide a constant delay, it uses the adaptive clock control to perform the clock frequency change in the runtime.

The measuring range depends on the microcontroller specifications. The experimental arrangement results an accurate output in the range 1Hz to 400Hz with two digit fractional value. The maximum frequency limitation for the test design, the 400Hz, caused by the limitations of the clock circuit to run from different clock sources. This design requires minimum number of components, namely display, sensor and one integrated circuit element, the microcontroller. This simple implementation provides advantages, while implementing the TDC functions in embedded control systems, or in automation systems, by reducing the dedicated circuits required.

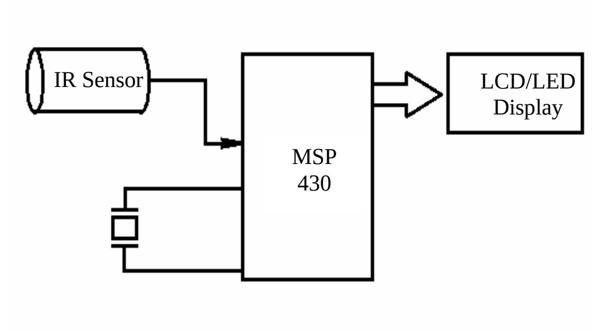

Figure 4. Arrangement for tachometer design

V. Test Results

The timer is configured to refresh the display at regular intervals. The minimum frequency that can measure to display is 1 Hz. When measured using the quantify delay method, the measured value displayed gives an accurate value from 1 Hz to 50 Hz. For the frequencies above 50Hz the measuring method changes to pulse counting method. From 50Hz to 400Hz the clock circuit varies its clock to trace the input signal. Signals above 400 Hz because of the circuit and microcontroller limitations the clock circuit gets affected. The choice of microcontroller and reference clock signal can improve the measuring range. By using the internal oscillator of 1 MHz, the measuring range can be improved in pulse counting mode. The internal oscillator can give a reference clock which is less accurate compared to the crystal clock. Internal oscillator is less stable at different electromagnetic noise environments. The table below shows the timer counter readings and the deviations in successive readings for four to five seconds taken from the test circuit running the quantify delay mode.

VI. Conclusion

In comparison with other frequency measuring methods this method uses both the quantify-delay measurement and pulse counting method. The reference clock source changes its frequency so that the error due to comparison methods reduces to required levels. The microcontrollers that can support clock signal modifications during runtime can be used for these applications. Software controlled clock modules which provide flexibility to control the reference clock to the reference signal. These clock control features are more common to 16 bit microcontrollers. For measuring low frequency signals the microcontroller provide enough hardware support to implement the measuring device. Using the clock adaptation method the measuring capability can be enhanced. Implementing the pulse counting method and the quantify delay method together will provide a measuring device that runs to maintain a minimum error and maximum measuring range. Microcontrollers like MSP 430 are designed for low power devices, which are required to be programmed in a way to minimise the power conception while running. The implementation gives very little external hardware complexity and produces an efficient performance result.

TABLE I. RESULT FROM THE TEST CIRCUIT.

Input(Hz)	TAR/count	TAR/count fluctuation
1	32772	0
1.2	27310	1
1.5	21857	0
1.8	18206	1
1.9	17247	1
2	16385	0
3	10923	1
4	8192	1
5	6553	1
6	5461	1
7	4680	1
8	4095	1
9	3640	1
10	3276	1
12	2730	1
14	2340	1
16	2047	1
17	1926	1
18	1819	1
19	1723	1
20	1637	1
22	1488	1
24	1364	1
26	1259	1
28	1168	1
30	1091	1
35	935	1
40	818	1
45	727	1
50	654	1

REFERENCES

[1] Baoqiang Du, Shaofeng Dong, Yanfeng Wang, Shuting Guo, Lingzhi Cao,Wei Zhou, Yandi Zuo, and Dan Liu, " High-Resolution Frequency Measurement Method With a Wide-Frequency Range Based on a Quantized Phase Step Law" IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 60, no. 11, November 2013

[2] Chunlin Yi, Chunhao Ma, Deren Kong, "Development of High Precision Time-measuring Instrument Based on TDC-GP2," Second International Conference on Instrumentation & Measurement, Computer, Communication and Control (ICCECT) 2012

[3] LIN Hai-bo. " A Kind of Multipurpose Digital Measurement Instrument Based on Microcontroller," International Conference on Control Engineering and Communication Technology (ICCECT) 2012.

[4] Hong Qunhuan, Song Shile and Xiao Zhihong, " Design of Digital Frequency Meter Based on Synchronous Frequency Measurement Method," Second International Conference on Instrumentation & Measurement, Computer, Communication and Control (ICCECT) 2010.

[5] Daniel Hernandez B, Oleg Sergiyenko, Vera Tyrsa, Larisa Burtseva. " Frequency measurement method for Mechatronic and Telecommunication applications," ISIE 2008. IEEE International Symposium, July 2008.

[6] John N. Lygouras, Theodore P. Pachidis,Kostas N. Tarchanidis, and Vassilis S. Kodogiannis. "Adaptive High-Performance Velocity Evaluation Based on a High-Resolution Time-to-Digital Converter," IEEE Transactions on Instrumentation and Measurement, Vol. 57, No. 9, September 2008

AUTHORS PROFILE

Mr. Binish Varghese: received the Bachelors degree in Electronics and Communication from Cochin University of Science and Technology. He is having two years of industrial experience as hardware service engineer, and he is doing his Masters degree in VLSI and Embedded Systems from Mahatma Gandhi University, Kerala.

Mr. Vipin V: received his Bachelors degree in Electronics and Communication from Mahatma Gandhi University Kerala. He received his Masters degree in Remote Sensing and Wireless Sensor Network from Amrita Scholl of Engineering, Coimbatore, Tamilnadu. He is having four years of experience in lectureship. And he is working as Assistant professor in the Department of Electronics and communication at St: Joseph College of Engineering and Technology, Palai, Kerala.