

Study and Simulation of Intelligent Sensor Using the Microchip Dspic30f

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Article Info

Article history:

Received , 25/04/2025
Revised , 15/05/2025
Accepted , 06/06/2025

Keywords:

Intelligent sensors
MEMS
dspic30f
FFT
X-Bee Wireless transmission

ABSTRACT

In this paper, we present the simulation of an accelerometer MEMS (vibration sensor) using a microcontroller dsPIC30F from simulation of a part electronic of the intelligent sensor (simulation of the block of conversion and processing). The signal processing is programmed with the Fast Fourier Transform (FFT) algorithm to perform the frequency calculations. Once the knock calculation is completed by the dsPIC microcontroller, it transmits the data to the X-Bee wireless protocol, and the FFT spectrum is displayed on a Graphic Liquid Crystal Display (GLCD) and hence the possible frequency of interest on which knock occurs.

I. Introduction

Intelligent sensors are composed of four units. The acquisition unit contains an analog/digital converter that converts information (a physical phenomenon) and transmits it to the processing unit, the latter consisting of a processor and an integral memory for a specific operating system. This unit has two interfaces: an interface to the acquisition unit and an interface for the communication unit responsible for all transmission and reception of data via a radio communication medium. It can be of optical type or radio frequency. The last unit is a battery to power all these components. However, because of its small size, the battery before it is limited and usually irreplaceable. To do this, energy is the most precious resource since it influences directly on the life of the sensors. These units will allow us to collect, store, process, and transmit the data collected at a collection center via the wireless channel. We've outlined the three characteristics that most engineers consider to be mandatory for an intelligent sensor (called a smart sensor) [1]: a sensing element that measures one or more parameters (essentially the traditional sensor we've been discussing), a computational element that analyzes the measurements made by the sensing element, and a communication interface to the outside world that allows the device to exchange information with other components in a larger system.

Accelerometric sensors for measuring vibration parameters are divided into the piezoelectric [2] and MEMS (micro electro-mechanical systems) categories. The latter can be piezoresistive [3] or differential capacitive [4]. The choice of sensor depends on the application [5]. In this paper, we focus on the simulation of a vibration sensor for industrial applications within wireless sensor networks. The main objective is to detect faults in rotating machines and similar equipment.

II. Accelerometers Sensor

The MEMS inertial sensor module, which includes accelerometers and gyroscopes, is an essential CMOS-MEMS sensor. An accelerometer senses force according to Newton's second law of motion. It consists of a seismic mass and a circuit that converts the capacitance into voltage. When a force acts on the accelerometer, the seismic mass deforms, changing the capacitance and thus the voltage. Figure 1 illustrates the microstructure of the accelerometer. [6]

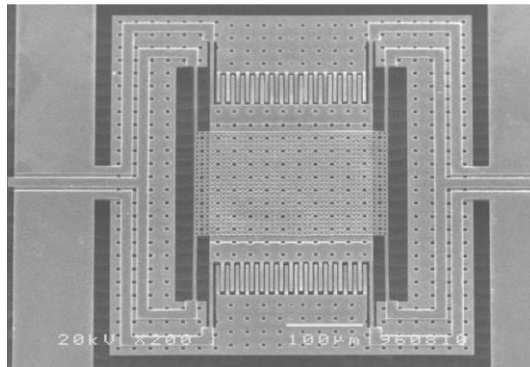


Figure 1. The microstructure of accelerometer.

III. The dsPIC30F

Recently, a new type of processor called a digital signal controller (DSC) has been developed. This innovative class combines the robust mathematical processing capabilities typical of digital signal processors with the predictable, deterministic behavior typically found in standard microcontrollers. An example of this type of DSC is the dsPIC® DSC manufactured by Microchip. [1]

IV. Fast Fourier Transform (FFT)

Fast Fourier Transform (FFT) is a complex algorithm used to calculate the Discrete Fourier Transform (DFT). DFT is essential to generate a frequency spectrum, by converting vibrations from the time domain to the frequency domain. However, the DFT calculation can be slow in some scenarios due to large computations. To address this challenge, the FFT algorithm is implemented to significantly speed up the DFT calculation. In essence, FFT acts as a tool that improves the speed of the DFT calculation process. [7]

IV.1. How the FFT Works ?

FFT involves decomposing an N-point time domain signal into smaller segments, recursively decomposing the signal until each segment represents a single point. For example, consider a signal consisting of 16 points. Initially, this signal is decomposed into two signals, each containing 8 points. This decomposition process continues recursively, halving the number of points in each segment, until it finally results in 16 signals, each containing a single point. [8]

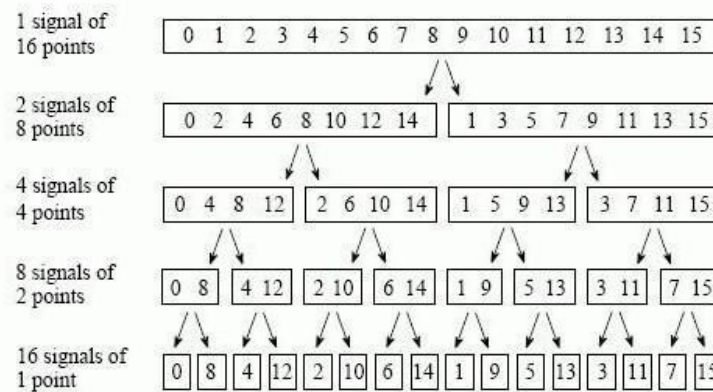


Figure 1. FFT involves decomposing

V. The Basic Concept of FFT Working in the Knock System

A buffer is used to store the input signal, which is sampled at regular intervals. Subsequently, the buffer interprets the complex array of samples. In this representation, the imaginary part of each sample is set to zero, leaving only the real part, which contains the even frequencies. Therefore, the GLCD displays only these even frequency data. The samples stored in the buffer are then transferred to the FFT algorithm. After processing by the discrete Fourier transform, the algorithm returns the processed samples to the buffer. The amplitude of the FFT spectrum is displayed on GLCD and calculated as:

$$F[k] = \sqrt{\text{Re}[k]^2 + \text{Im}[k]^2} \quad (1)$$

V.1. Basic concept as

The input signal is sampled at regular intervals, with each sample stored in a buffer. This buffer is structured as a complex array, where the real part represents the actual sample and the imaginary part is always zero. Once the buffer has accumulated the required number of samples, it is then passed to the FFT subroutine for processing. The FFT subroutine computes the fast Fourier transform (FFT) of the input signal and then stores the FFT samples in the input buffer. The FFT samples are also given in format Re,Im,Re,Im..., where the Imaginary part is nonzero. Since the FFT spectrum is symmetric, only the first half of the input buffer is utilized.

The amplitude spectrum is then displayed GLCD. The whole process repeats infinitely, giving impression that the spectrum is drawn in real-time. Signal power can be calculated as a sum of all FFT samples as:

$$Pw = \sum_{k=0}^{N-1} F[k] \quad (2)$$

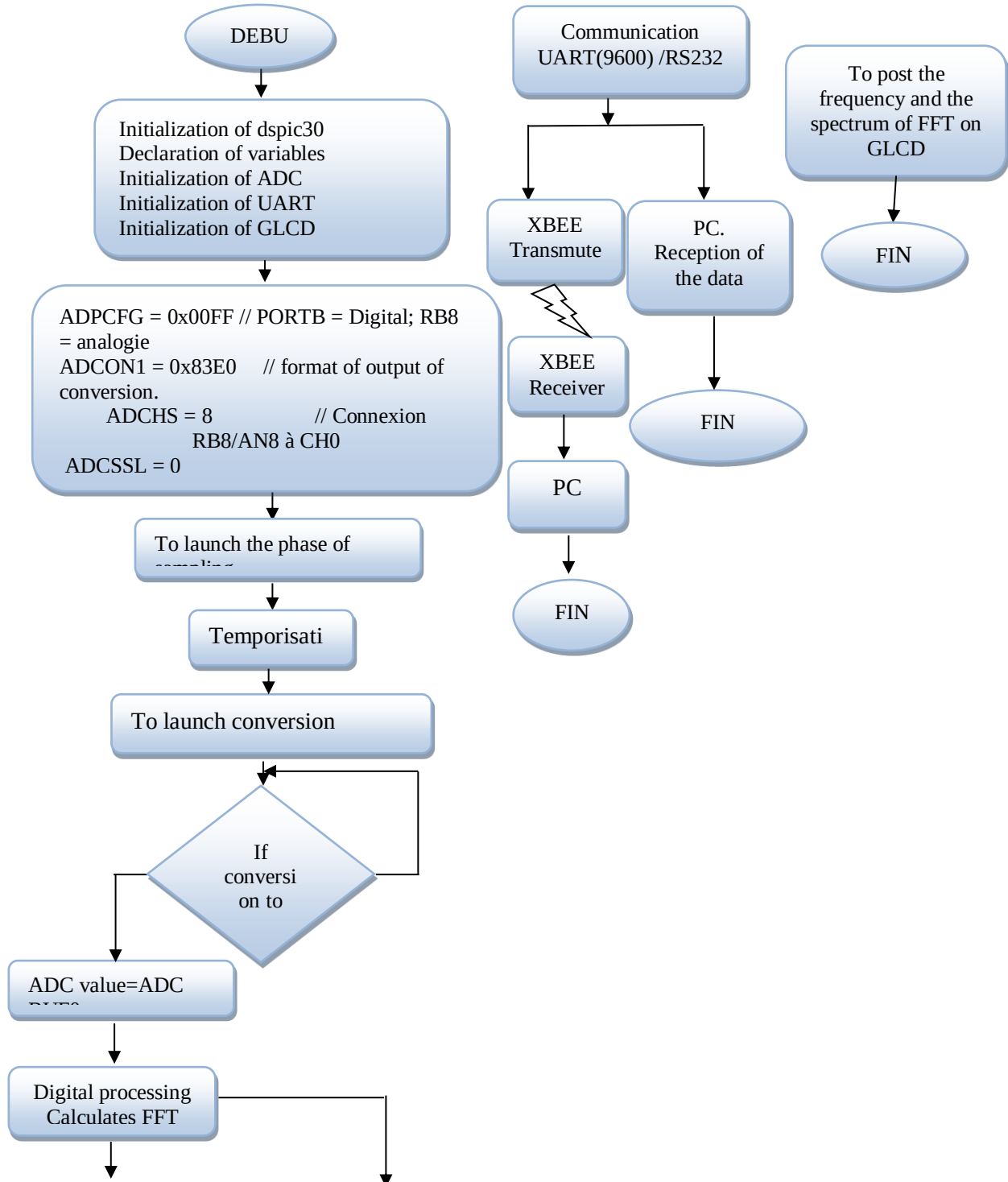
For the input signal, it must meet specific requirements to avoid distortion and ensure accurate analysis:

Frequency range: The maximum frequency of the analog signal must not exceed 6 kHz.

Amplitude: The amplitude of the signal must not exceed 1 V. DC offset: The DC value of the signal must be approximately 1 V. Saturation and distortion: Values exceeding these limits may cause saturation and result in distortion of the output signal. Adjustments: If unusual or unstable displays occur on the GLCD, adjusting the input signal levels within the specified limits can stabilize the image. Buffer size: To analyze signals faster than 6 kHz, ensure that the buffer size of the input matrix is increased appropriately to support the higher sampling rate required to capture higher frequencies.

VI. Result and Discussion

VI.1 Principal Organigram



The GLCD only displays the first half of the FFT spectrum due to its symmetrical nature on both sides. This displayed spectrum represents the frequency amplitudes. This entire process runs continuously. The system is designed to detect frequencies ranging from 100 Hz to 6000 Hz, with the displayed frequencies being multiples of 100 Hz compared with other work [9] that the system detected frequencies ranging from 200 Hz to 6000 Hz. If a frequency greater than 6000 Hz is detected, it will be displayed as 6200 Hz, indicating that the vibration is beyond the frequency range of the system.

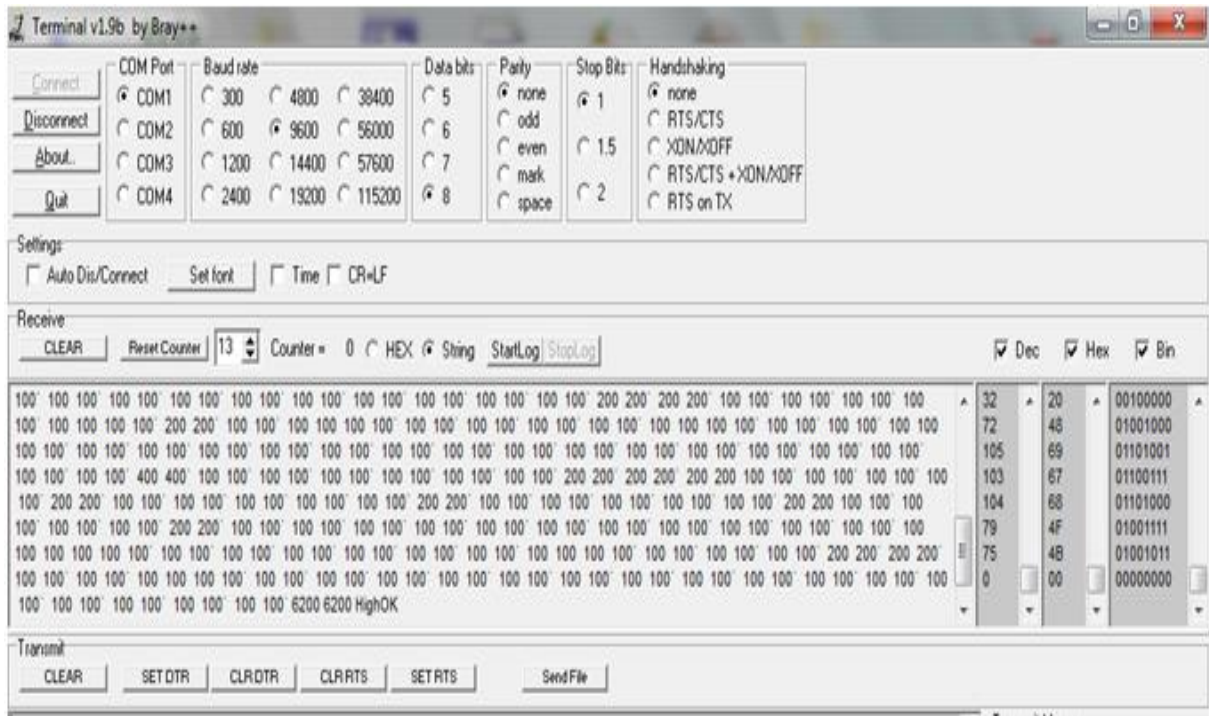


Figure 2. Resption of the values frequency on terminal

We propose a 100mv/g accelerometer and an amplifier ($\times 10$):

1g at the accelerometer output: $100\text{mv} \times 10 = 1\text{v}$

2 g at the accelerometer output: $200\text{mv} \times 10 = 2\text{v}$

2.5 g at the accelerometer output: $250\text{mv} \times 10 = 2.5\text{v}$

3 g at the accelerometer output: $300\text{mv} \times 10 = 3\text{v}$

4 g at the accelerometer output: $400\text{mv} \times 10 = 4\text{v}$

Figure 3 illustrates the case of a spectrum of a harmonic vibration of frequency 100Hz.

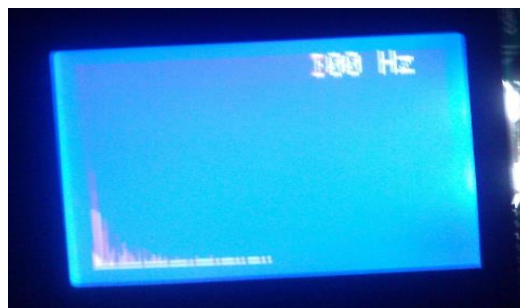


Figure 3. The spectre of FFT on GLCD.

VII. Conclusion

We have integrated an FFT algorithm for calculating the vibration spectrum locally for fault diagnosis and detection; this algorithm has been validated by practical tests on a hardware platform based on the dsPIC30F6014A. We devoted the first time to simulating the block of conversion and the treatment from calculating the FFT and posting the spectrum on GLCD.

The developed system serves as an FFT analyzer integrated into a single unit. This unit combines an accelerometer and a microprocessor (such as a dsPIC) to process and analyze the signals using a specialized program. The accelerometer captures vibration data, while the microprocessor executes FFT (Fast Fourier Transform) algorithms to diagnose machine faults.

This system can be implemented using micro-electromechanical systems (MEMS) technology, which allows the miniaturization and integration of these components in a compact package. This integration allows real-time analysis of vibration signals, facilitating early detection and diagnosis of faults in rotating machines and other industrial equipment.

Acknowledgements

This study is supported by Microsystems and Embedded Systems Laboratory, University of Sciences & Technology of Oran, Algeria.

References

- [1] Creed Huddleston. "Intelligent sensor design using the microchip dspic", Amsterdam: Boston, 2007, pp. 283.
- [2] B. Yaghootkar, S. Azimi, B. Bahreyni, "Wideband piezoelectric mems vibration sensor". In Proceedings of the 2016 IEEE Sensors, Orlando, FL, USA, 30 October–2 November 2016.
- [3] P. Negrea, "An Overview of Acceleration Detection in Inertial Navigation Systems". In Proceedings of the 2021 International Conference on Applied and Theoretical Electricity (ICATE), Craiova, Romania, 27–29 May 2021.
- [4] X. Liu, K. Peng, Z. Chen, H. Pu, Z. Yu, "A New Capacitive Displacement Sensor with Nanometer Accuracy and Long Range". IEEE Sens. J. vol. 8, pp. 2306–2316, 2016
- [5] A. Mystkowski, R. Kociszewski, A. Kotowski, M. Ciężkowski, W. Wojtkowski, M. Ostaszewski, Z. Kulesza, A. Wolniakowski, G. Kraszewski And A. Idzkowski, "Design and Evaluation of Low-Cost Vibration-Based Machine Monitoring System for Hay Rotary Tedder", *Sensors*, vol. 22, pp. 4072, 2022.
- [6] S-C Shen, C-J Chen, and H-J Huang, "a new calibration method for low cost mems inertial sensor module", *J. mar. sci. eng.*, vol. 18, pp. 819-824, 2010.
- [7] Johan Walthert, "*Gestion des stores électriques en fonction de la lumière et de la présence*", *Haute Ecole spécialisée de Suisse occidentale*, 2010.
- [8] Steven W. Smith. "Digital signal processing", 2nd ed, San Diego, California, 1999.
- [9] P. Padmanathan, Development of an on-board visual display for early knock detection in si engines, University of Technology Malaysia, 2012.