ANALELE UNIVERSITĂȚII
"EFTIMIE MURGU" REȘIȚA
ANUL XXIV, NR. 1, 2017, ISSN 1453 - 7397

High-speed Microcontroller Based System to Real-time Analyzing the Mechanical Waves in Structures

Ion-Cornel Mituletu, Nicoleta Gillich, Emilian Stanciu, Codrin-Nistor Nitescu

Nowadays high-speed microcontrollers are employed to accomplish many applications in different domains, due to their flexible characteristics and structures. In this paper, the microcontroller algorithm performs a fast time-frequency analysis by discrete Fourier transform (DFT) on variable time portions of the vibration signal. System can be easily customized so that a spectrum with variable range and density is achieved. Also, the real-time microcontroller based system (R-TMBS) has been thought as a stand-alone system as well as to be included in a more complex system, which can function in closed-loop, when the system feedback is obtained via R-TMBS.

Keywords*: algorithm, discrete Fourier transform (DFT), microcontroller, real-time operation, vibration analysis*

1. Introduction.

Mechanical structure's damages are mainly detected via vibration signals. Analysis of the vibration signals are divided in two categories: predicting nature, place and severity of damage; or they are limited to damage detection [1]. Vibration-based damage detection is viewed as a non-invasive technique, it not requires access to the place of defect [3] and it can be also performed in the operation state of equipment as well, in particular depending on the specific mode of operation [4]. Considering all the damage types, cracks or damages in early state request high natural frequency identification [2]. Thus, precise frequency identification highlights the damage identification method accuracy [5].

Future researches come to develop new models and devices for precise frequency identification, they including wide approaching areas from analytic methods, grapho-analytichal, and statistical [6], all of them trying to increase the precision in identifying the natural frequency values [7,8].

All these methods being based on time-frequency Fourier transform that provides low accuracy for the short time acquisition signals, and seldom the multiple of natural frequency period exactly appears in that time, the frequency value is more or less close to the right value [4,9,].

We earlier accomplished an iterative windowing method via experimental tests to increase the spectral density, even if only one period of natural frequency occurs. This method has been software implemented in LabView by an iterative algorithm [10].

Due to the effectiveness of the method achieved from many kinds of tests, the idea of hardware simplification and stand-alone device appears as a necessity. Also, a flexibility of future device was aimed, in the direction of possible including in more complex damage detection equipments as feedback. Therefore, a high-speed microcontroller was employed in creation of a system to real-time analyzing the vibration signal, real-time microcontroller based system (R-TMBS).

2. System structure and operation

R-TMBS's structure is based on the STM32 F5 Discovery evaluation kit, having a high-speed microcontroller type STM32F429ZIT6U with high performance 32-bit cortex - M4 MCU on 180 MHz and 2.4" QVGA TFT LCD display, and the ADXL335 a small, low power, complete 3-axis accelerometer, ±3g.

The functional block diagram of the R-TMBS is shown in figure 1.

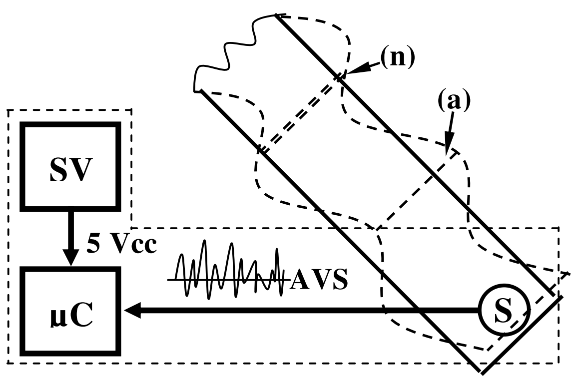


Figure 1. R-TMBS's functional block diagram

R-TMBS is an open-loop simple system with low power consumption from the 5 Vdc SV (5 Volts direct current supply voltage). Microcontroller µC does an analog-to-digital conversion of the analog vibration signal (AVS), at high-speed 7.2 MSPS (mega samples per second) in triple interleaved mode and high-precision of

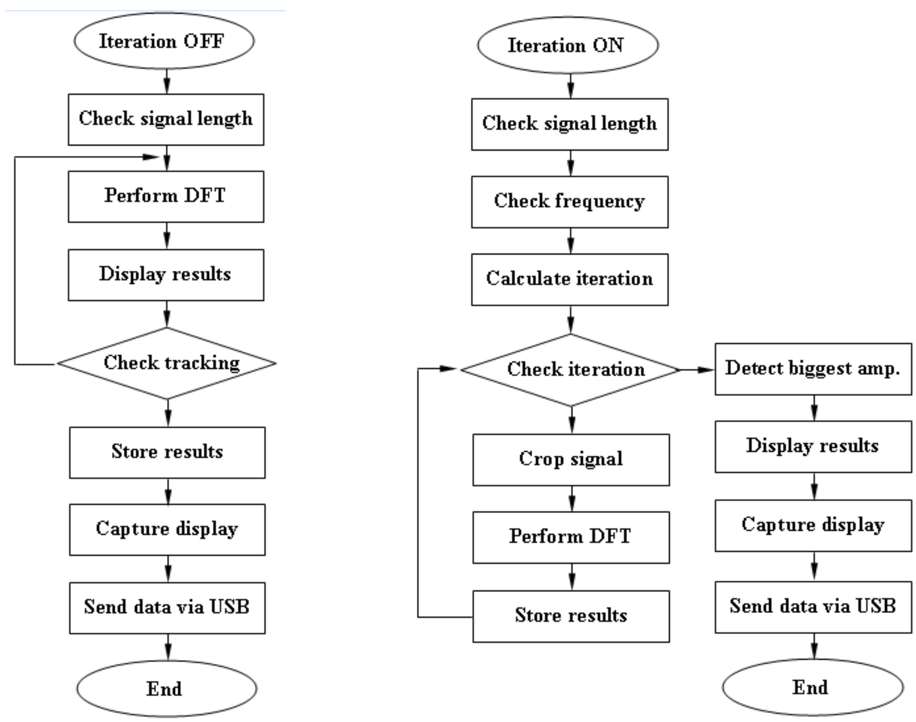
12-bit. The AVS is generated by the ADXL335 three-axial accelerometer sensor (S) in relation to the structure vibration.

The system aim is to perform simple DFT or iterative windowing on different short time vibration signals, graphical signal display, send display captures and values to the USB flash memory stick (MS) or to a personal computer (PC) for future analysis.

3. Algorithm description

R-TMBS works in two modes: it can perform a simple DFT on a certain vibration signal length, maintaining on display the last result until the new one is ready, in this way the image is continuous; or iteratively windowing and analyzing also by DFT a portion of the vibration signal, detecting from all results the biggest amplitude, where the natural frequency best fits, and display only that result. The selection between modes is made by the Iteration button from the Menu, choosing Iteration OFF for the first mode, or ON for the second one.

Depending of iteration mode state, OFF or ON, both routines are given in figure 2.



a) b)

Figure 2. Iteration routines flowchart: a) for state OFF and b) in state ON

The logic of the routines was limited to minimum necessary steps, in order to fast up the work time and simplify the setting way.

When the iteration is off, the amplitude of the vibration signal is checked after the first DFT analysis. If the actual amplitude is less than the old one, then the last result is displayed and prompt to be sent to MS.

If iteration is on, due to the more time taken by the iterative analysis, the results are displayed and send at the end of each entire analysis.

4. Tests and results

Tests were accomplished on a cantilever beam fixed at one end and having 1000 mm length, 50 mm wide and 5 mm thick, and the results are given below.

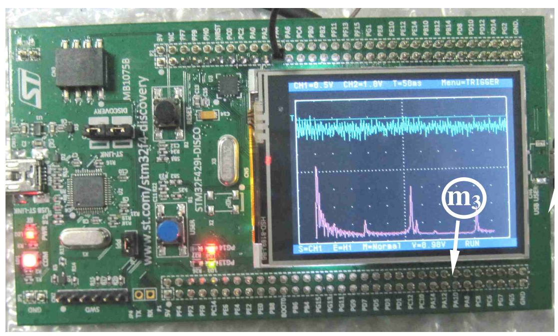


Figure 3.a.

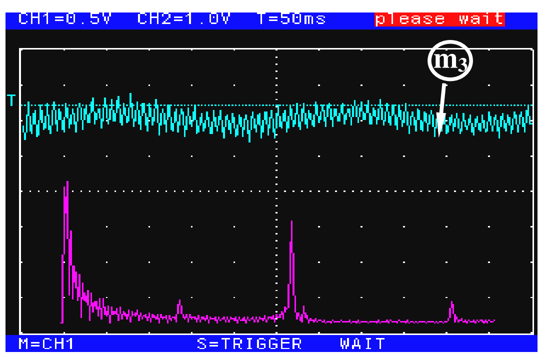
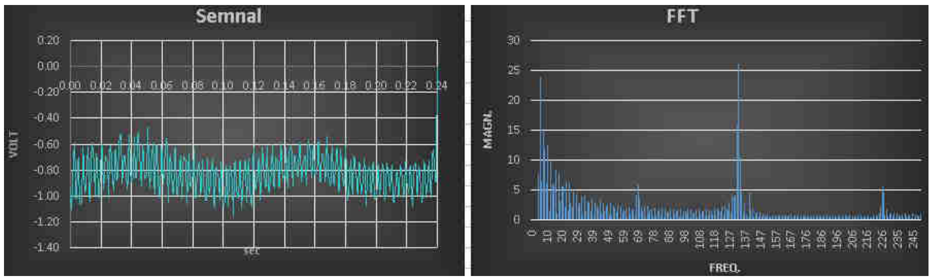


Figure 3.b.



c) d)

Figure 3. Resulted images after tests performed by R-TMBS, where m3, m4 and m5 are the vibration modes

4. Conclusion

Tested R-TMBS shows as suitable in flexible application, real-time classic DFT analysis or iterative analysis for more precision. In the same time, it can operate as stand-alone device or as a feedback included in other complex damage detection equipments.

References

[1] Afshari M., Inman D.J., *Continuous crack modeling in piezoelectrically driven vibrations of an Euler–Bernoulli beam*, Journal of Vibration and Control, 19(3), 2013, 341–355.

[2] Praisach Z.I., Gillich G.R., Protocsil C., Muntean F., *Evaluation of Crack Depth in Beams for known Damage Location based on Vibration Modes Analysis*, Applied Mechanics and Materials, Vol. 430, 2013, 90-94.

[3] Friswell M.I., *Damage identification using inverse methods*, Phil. Trans. R. Soc., A 365, 2007, 393-410.

[4] Morassi A., Vestroni F., *Dynamic Methods for Damage Detection in Structures*, CISM Courses and Lectures, Vol. 499, Springer Wien New York, 2008.

[5] Eiras J.N., Monzo J., Paya J., Kundu T., Popovics J.S., *Non-classical nonlinear feature extraction from standard resonance vibration data for damage detection*, J. Acoust. Soc. Am. 135, 2014, 82–87.

[6] Chen C.C., Yeh M.K., *Parametric Instability of a Beam Under Electro-magnetic Excitation*, Journal of Sound and Vibration, 240(4) , 2001, 747-764.

[7] Campobello G., Cannata G., Donato N., Famulari A., Serrano S., *A novel low-complex and low-memory method for accurate single-tone frequency estimation*, IEEE Proc. "the 4th International Symposium on Communications, Control and Signal Processing", Cyprus, March 3-5, 2010.
[8] Djurovic I., *Estimation of the Sinusoidal Signal Frequency Based on the Marginal Median DFT*, IEEE Transactions on Signal Processing, 55(5), 2007, 1032-1042.
[9] Böhm M., Tasche M., Seifert B. Mitschke F., *Trim-to-Coherence Fourier Transform*, Elsevier, ScienceDirect, Journal of Computational Physics 228, 2009, 2906-2917.
[10] Brown T., Wang M.M., *An Iterative Algorithm for Single-Frequency Estimation*, IEEE Trans. Signal Process, 50(11), 2002.

Addresses:

- Lect. PhD. Eng. Ion-Cornel Mituletu, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, mituic@yahoo.com
- Prof. Dr. Eng. Nicoleta Gillich, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, n.gillich@uem.ro
- PhD. Stud. Emilian Stanciu, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, stanciu_emilian@hotmail.com
- PhD. Stud., Eng. Codrin-Nistor Nitescu, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa codnit@yahoo.de