Engineering 67(1) 2022 DOI: 10.24193/subbeng.2022.1.10

Sine Wave Electromagnetic Generation Using H-Bridge and Microcontroller

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Abstract. *The paper presents a way of accomplishing a non-contact excitation by electromagnetic waves generated from a system that includes WiFi microcontroller, H-Bridge and coil. The ESP 32 microcontroller software achieves PWM signal, which follows' a sinusoidal shape of variable frequency. The PWM signal drives the H-bridge resulting in a more powerful electric signal that also drives the coil, accomplishing in this way the pseudo-sine electromagnetic wave. The source code from microcontroller provides variable frequency and working period as well. The main features of the system are 0.5 to 3000 Hz, working periods between 0.1 and 10 seconds, the possibility to achieve more than one working period with standby periods in between.*

Keywords*: sine electromagnetic wave, WiFi microcontroller, H-bridge, software PWM, vibration based modal analysis.*

1. Introduction

Structural Integrity Monitoring (SIM) is a multidisciplinary field that represents the development and implementation of techniques that are used in monitoring and maintenance of structures [1,2,3].

One of the most used techniques is Vibration Based Detection (VBD). Method used to obtain the vibration that is applied to the analyzed structure can vary from methods of contact (e.g. using vibration or impact hammers) to non-contact methods (by using an electromagnetic system) [4,5].

To obtain information about the general condition of structures and to detect and locate hidden defects, VBD SIM systems are made using accelerometers with micro electromechanical system (ASME). These accelerometers are used to measure linear acceleration, vibrations and orientation of an object in space [6].

This system is based on platforms and applications from the Internet of Things sphere (IoT). The data obtained by the sensors is sent via wireless communication.

The main feature of the system is to produce a sine electromagnetic wave and by testing to determine if the impact of s smooth wave has better results on the cantilever beam than the square pulses.

2. Mathematical background

Electromagnetic excitation scenario gives the mathematical structure of the resulted source code, establishing the limit conditions and experimental evaluation structure. Excitation scenario supposes excitation periods, assumed as working periods, and no-excitation periods, in order for the cantilever to slow down/in order to slow down the cantilever beam. Also, the working period can be at a constant frequency value, or the frequency can be swept between a small and a big value and reversal. Sweep scenario supposes an average value of the frequency in the sweeping interval, which is the same with the constant value of the frequency. In both cases, that frequency is performed by a carrier-frequency, or switching frequency, which is 20 times bigger.

Figure 1 shows the main parameters that contribute to the achieving of the desired signal at a certain frequency. For the source code analysis more important is the period than the frequency, therefor both will be provided from now on. At a certain moment, the sweeping frequency (SF) corresponds to a period (SP). The period includes 20 or more switching periods (SWP), each one having a duty cycle (DC) that follows a sinusoidal evolution.

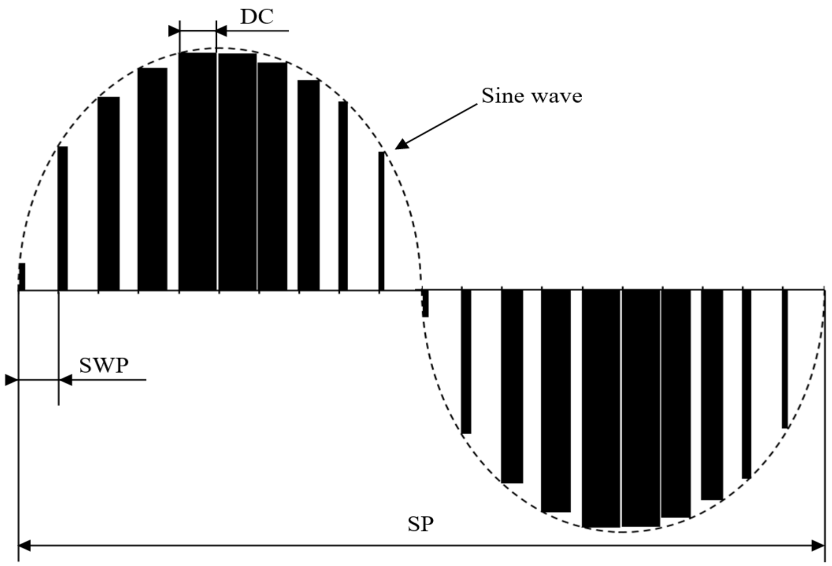


Figure 1. A certain period sempled by the switching period and the evolution of the duty cycle to achieve a sine evolution.

The first thing is to establish the limits of the excitation/working period. Working time:

$$WT \in [0;\ 10]\ \text{(s)} \tag{1}$$

Stopping / standby time:

$$ST \in [0, 180]\ \text{(s)} \tag{2}$$

Sweeping frequency and period:

$$SF \in [0.5, 3000]\ \text{(Hz)} \tag{3}$$

$$SP \in [2, 0.3 \cdot 10^{-3}]\ \text{(s)} \tag{4}$$

If the end frequency and period are bigger than the star ones, the sweeping will be performed in the reverse direction.

For the sweeping case, firstly a medium frequency/period value is determined:

$$MP = \left|\frac{SP+EP}{2}\right|\ \text{(s)} \tag{5}$$

Afterwards, the number of cycles:

$$NC = \frac{WT^{(\underline{R})}}{MP}\ \text{(s)} \tag{6}$$

($\underline{R}$) - round down;

After that, the exact working time is calculated:

$$EWT = 9 \cdot NC + NC \cdot MP = NC(MP + 9) \tag{7}$$

9 – microcontroller’s clock cycles need to setup the timer.

Added value to each frequency and period shift:

$$AP = \left|\frac{SP+EP}{NC}\right| + 9 \cdot NC \tag{8}$$

Switching frequency and period:

$$SWF = 60\ \text{(kHz)} \tag{9}$$

$$SWP = 1.67 \cdot 10^{-5}\ \text{(s)} \tag{10}$$

For a certain frequency:

$$f_k \in [SF; EF] \tag{11}$$

$$P_k \in [SP; EP] \tag{12}$$

The number of switches:

$$NS = \frac{P_k}{SWP} \text{ (s)} \tag{13}$$

Added period value to shift the duty cycle (DC):

$$DCP = \frac{P_k}{NS} \text{ (s)} \tag{14}$$

DC value is:

$$DC = sin(2 \cdot \pi \cdot f_k \cdot n) \tag{15}$$

where:

$$n \in [1, NS] \tag{16}$$

The source code was written in order to meet these mathematical structure. The hardware main condition was to choose a development board able to generate PWM at least 60 kHz.

3. System design and testing

Figure 2 presents the functional block structure of the sine wave electromagnetic generator, which consists of two subsystems: excitation subsystem and data acquisition subsystem.

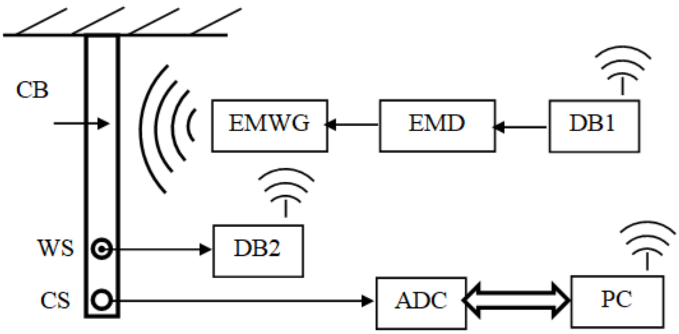
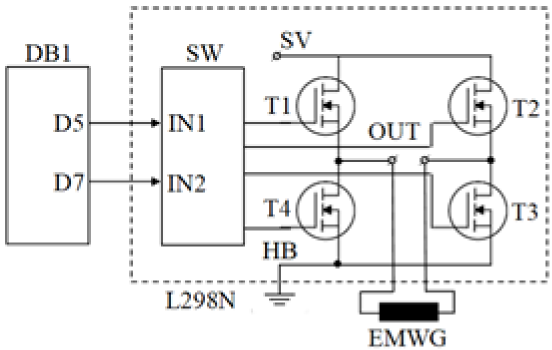


Figure 2. Functional block structure of the sine wave electromagnetic generator.

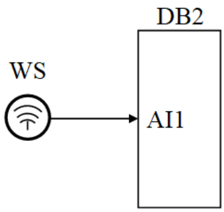
The non-contact excitation subsystem consists of the Development Board 1 (ESP 32), the Electromagnetic Driver (EMD) and the Electromagnetic Wave Generator (EMWG).

The data acquisition subsystem is made using an accelerometer wireless sensor and the Development Board 2 (ESP 32). This subsystem detects the vibrations of the excited cantilever beam and sends the data wirelessly to the P.C.

Figure 3. a) depicts the connection diagram of the sine wave electromagnetic generator in two image. The first image details the electronic links between the DB1 and the H-bridge (HB), which is based on the IC L298N. H-bridge includes the sine wave driver (SW) and the force bridge based on the T1 – T4 MOSFET transistors. Development board DB1 drives the H-bridge by two digital outputs (D5 and D7). Image b) simply shows the connection strategy between the wireless vibration sensor (SW) and the second development board (DB2).



a)



b)

Figure 3. Connection diagram of the sine wave electromagnetic generator a), and vibration acquisition b).

The ESP-WROOM-32 module has the following features [6]:

- Xtensa processor with frequency between 160 and 240 MHz;
- RAM memory 320 kB;
- ROM memory 448 kB;
- Wi-Fi: 802.11 b/g/n;

- 34 programmable general purpose ports;
- 18 12-bit analog-to-digital converters;
- 2 8-bit digital-to-analog converters;
- 4 SPI interfaces;
- 2 I2C interfaces;
- 3 UART interfaces;

L298N is a high voltage, high current dual full-bridge driver. It has the following features [7]:

- Operating supply voltage up to 46 V;
- Over temperature protection;
- Current up to 4A.

The experimental setup is presented in figure 4.

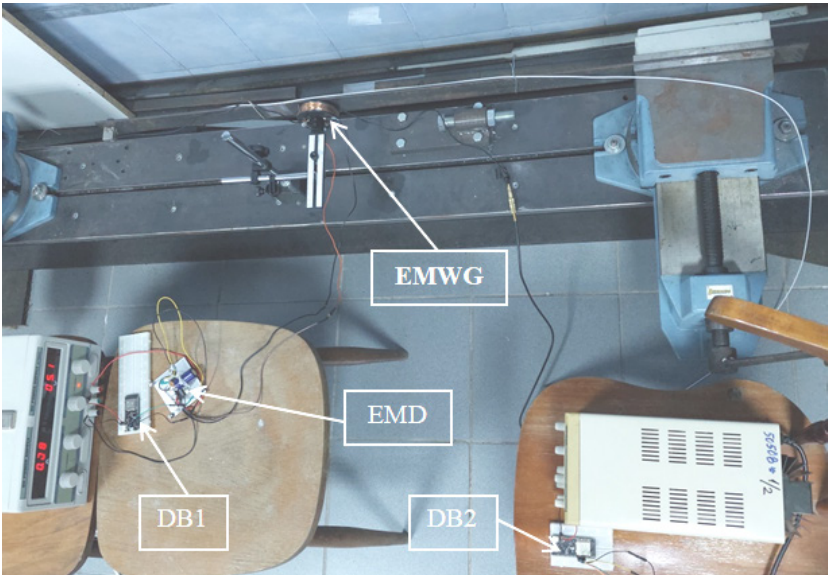


Figure 4. Experimental setup

A number of five parameters are required to achieve the excitation:
- working time (WT);
- stopping time (ST);
- excitation period (PE);
- Start frequency and period: SF and SP;
- Number of cycles: NC.

These parameters are transmitted from an Internet browser interface configured by the first development module when the mobile device is first connected to it.

After the excitation cycle is executed and the acquired data is sent from DB2 to P.C. in the form of a *.csv* format file, the data is processed using the Lab View program and the obtained signal indicates that the frequency for any mode of vibration can be easily achieved. An example of the excitation process in time is shown in figure 5 for the first vibration mode in the up-side image.

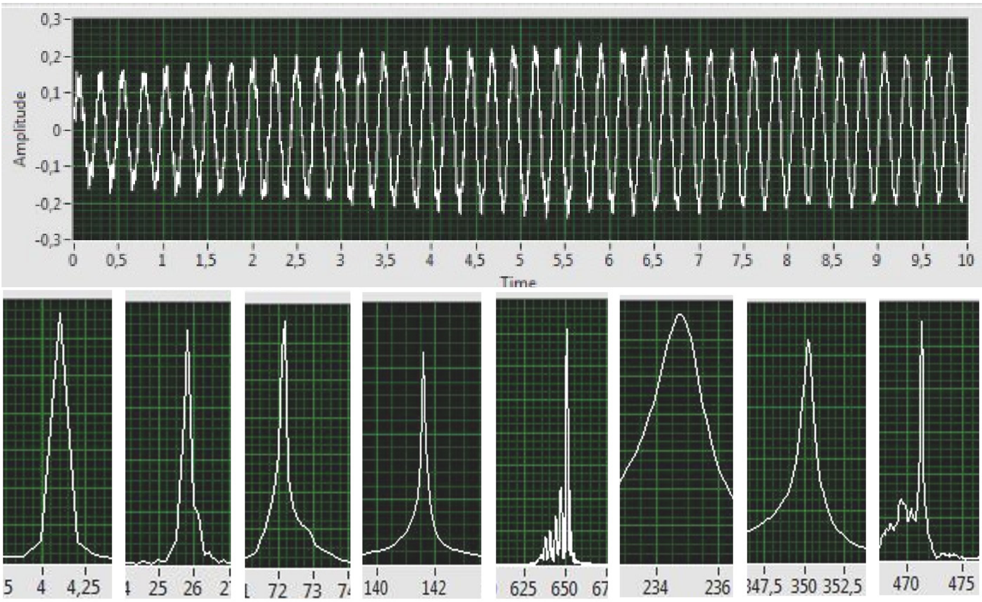


Figure 4. Time vibration for the first vibration mode, and the resulted frequency values for the first 8 vibration modes.

Down-side image of figure 5 presents the resulted values of the frequency for the first 8 vibration modes after the sweep excitation. As can be seen, the amplitude of the frequencies at the modes values is very high and easy to read.

4. Conclusion

Pseudo-sine electromagnetic wave generation system based on microcontroller, H-bridge and coil produces a well-shaped sinusoidal wave at a variable frequency 0.5 to 300 hertz on a certain working time period and sweep feature. Thus, this system can excite magnetic and ferromagnetic mechanical structures with a constant or variable frequency.

The sine electromagnetic waves are preferred to simple square pulses because of smooth evolution in time, which achieve light impact to the mechanical structures.

Also, it should be specified that ferromagnetic mechanical structures oscillates at double of the excitation frequency and the magnetic structures at the excitation value. That is due to the phenomenological behavior of these structures, ferromagnetic materials forms no magnetic pols, but the magnetic materials have already formed pols that interact with the direction of the electromagnetic field.

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