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Geoscientific Instrumentation Methods and Data Systems Discussions
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Interactive comment on "A geophone-based and low-cost data acquisition and analysis system designed to microtremor measurements" *by* Ozkan Kafadar

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I would like to thank the Editor and the anonymous reviewers for their constructive comments which helped me improve the quality of my work. To address these comments, I have carefully revised the paper. In the following, I provide a point-by-point response to the comments and detail the actions that I have taken to address those issues. For ease of cross referencing, the performed changes are highlighted in red color.

Comment 1: There is a word error in line 4 and line 169.

Reply 1: Thank you very much for your suggestion. The typing errors were

corrected as follows:

Page 1, line 4: It is also an integrated system developed to interpret the microtremor data using the horizontal-to-vertical spectral ratio (H/V) method without any external software.

Page 11, line 179: The channel consistency, internal noise measurement and comparison tests were performed to demonstrate the accuracy and precision performances of the proposed system.

Comment 2: Lines 12 and 13 should be expressed more meaningfully.

Reply 2: Thank you very much for your suggestion. The sentence was revised as follows:

Page 1, line 12: The channel consistency and internal noise measurement tests were performed to demonstrate the accuracy and precision of the proposed system.

Comment 3: Figures 3a, 3b, 5a, 5b,6 and 8b are not framed.

Reply 3: Thank you very much for your suggestion. All figures were framed.

Comment 4: The author should emphasize the importance of this manuscript, its contribution to science in the summary and introduction sections.

Reply 4: Thank you very much for your suggestion. The abstract and introduction sections were rewritten according to your suggestions. The sentences emphasizing the contribution of the study to science were highlighted red color.

Page 1, line 1-16:

Abstract

The commercial data acquisition instruments designed for three-component microtremor measurements are usually very expensive devices. In this paper, a low-cost, computer-aided and geophone-based system designed to record, monitor and analyze the three-component microtremor data, is presented. This proposed system is not a simple data acquisition system. It is also an integrated system developed to interpret the microtremor data using the horizontal-to-vertical spectral ratio (H/V) method without any external software. Therefore, the H/V peak frequency and amplitude can be easily estimated by using this system. The proposed system has several features such as 200 Hz sampling frequency, approximately 72 dB dynamic range, text data format and data analysis tools. This system consists of a graphical user interface developed by using .NET Framework 4.5.2 and an external hardware that includes signal conditioning circuits, voltage converter circuit, external analog-to-digital converter and Arduino Uno board. The proposed system uses the low-cost vertical and horizontal geophones with 4.5 Hz natural frequency to measure three-component microtremor data. The developed software undertakes many tasks such as communication between the external hardware and computer, transferring, monitoring and recording the seismic data to the computer, and interpretation of the recorded data using the Nakamura method. The channel consistency and internal noise measurement tests were performed to demonstrate the accuracy and precision of the proposed system. Besides, the proposed system was compared to a commercial triaxial digital seismograph, and satisfactory results were obtained. The developed system is completely an open-source and open-hardware system, and can be easily used in academic studies conducted by researchers and university students who are interested in seismic ambient noise analysis.

Page 1-2, line 19-44:

Introduction.

The fundamental of the seismic methods is based on the recording of the seismic waves generated by the natural or synthetic sources. There are two type sensors, called velocimeter and accelerometer, with different bandwidths and sensing mechanisms to measure these seismic oscillations. These sensors measure the ground motion as velocity and acceleration, and convert the ground motion into a measurable

electrical signal. Accelerometers are electromechanical devices, which measure the acceleration, and are generally used for specific purposes such as vibration and inclination measurements. On the other hand, geophones are velocimeter, which are often preferred in local seismic applications because of their excellent reliabilities, highly sensitivities and low costs. Besides, accelerometers are generally less sensitive than velocimeters and are also used in strong ground motion measurements. Broadband velocimeters have a large passband than geophones, and can measure ground motions with frequencies ranging from 0.001 Hz to 500 Hz. Classical short-period velocimeters are constituted by orthogonally mounted three geophones that have natural frequencies of a few hertz. Data acquisition systems are needed to digitize the analog signals detected by these sensors and to store them in a data storage device. Recently, many studies have been performed to design seismic data acquisition systems. In a study by Khan et al. (2012), a software component was developed to digitize the analog seismic signals using the computer sound card. Llorens et al. (2016) designed a simple data acquisition system for recording the seismic data detected by the vertical geophone to an external SD card. In our previous study, we developed a hardware and software for seismic refraction method (Kafadar and Sertcelik, 2016). In another study, a hardware was designed for recording the seismic noise (Llorens et al., 2018).

In this paper, a low-cost, computer-aided and Arduino-based three-component microtremor measurement and analysis system (MicDAC) is presented. In the literature, there are many data acquisition and analysis systems developed with using the Arduino boards for scientific purposes (Llorens et al., 2016; Fisher and Gould, 2012; Huang et al., 2018; Puente et al., 2017). The MicDAC is controlled through a user-friendly graphical interface (MicDAC-GUI) developed by using the Microsoft .NET Framework 4.5.2 platform and C language. The MicDAC is not a simple digitizer. Moreover, it is an analysis tool that it can interpret the recorded ambient noise using the Nakamura method (Nakamura, 1989) and it can calculate the two parameters (H/V peak frequency and amplitude), which are too important to design earthquake-resistant structures. This study is completely different from the literature since the proposed system does not require any external software. On the other hand, it can display the calculated Fourier spectra for three-component ambient noise in real-time. This feature provides a pre-information about the frequencies of ambient noise in the survey area before starting the measurement to the user.

Comment 5: The conclusions section should be expanded considering all results of this manuscript.

Reply 5: Many thanks for your valuable suggestion. The conclusions section was rewritten to include the results of this study.

Page 10, line 173: The aim of this study is to develop a low-cost, computer-aided and Arduino-based three-component microtremor data acquisition and analysis system using the basic electronic components, integrated circuits and Microsoft .NET Framework 4.5.2 application development platform. The designed external hardware can be easily assembled by readers and controlled through a developed graphical user interface using C# language. This software allows monitoring and recording the three-component microtremor data, and analyzing the recorded data using the horizontal-to-vertical spectral ratio (H/V) technique. In this way, the peak frequency and amplitude of H/V curve can be estimated. The channel consistency, internal noise measurement and comparison tests were performed to demonstrate the accuracy and precision performances of the proposed system. In the channel consistency test, it was shown that the error percentage of the difference signals were lower than 1%. Besides, it was shown that the H/V is equal to 1 when a single sensor is connected to each channel input at the same time. In the internal noise measurement test, the noise levels for three channels were observed as approximately ± 3 counts. In particular, the H/V curves obtained from data recorded simultaneously with MicDAC and GeoBox and their peak frequencies and amplitudes proved the reliability of the proposed system. Finally, an experimental study was performed to test the performance of MicDAC in field conditions. The obtained H/V peak frequency and amplitude from the experimental study were compared to a previous study, and it was shown a good correlation between them.

Therefore, it can be concluded that MicDAC is a suitable and inexpensive alternative system for three component microtremor measurements and H/V analysis.

Interactive comment on Geosci. Instrum. Method. Data Syst. Discuss., https://doi.org/10.5194/gi-2020-11, 2020.

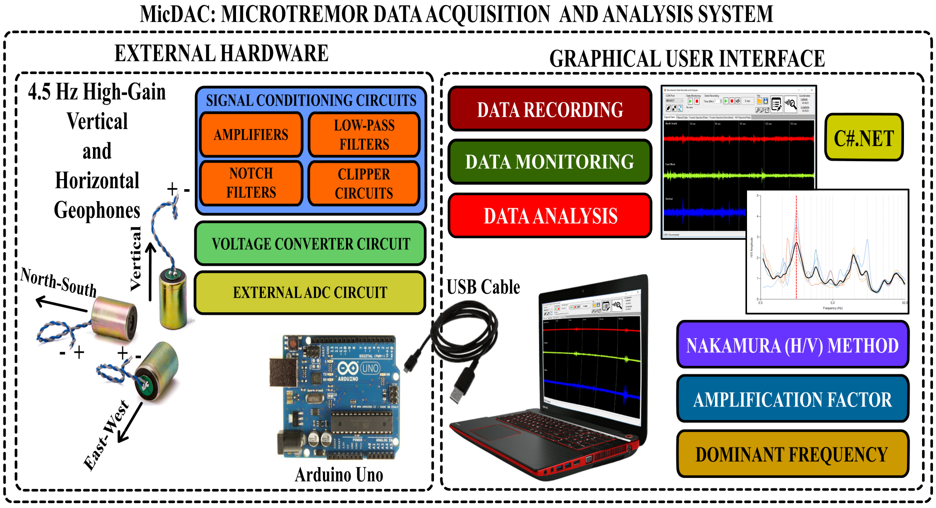

Fig. 1. Graphical abstract of the proposed system for measurement and analysis of three-component microtremor data.

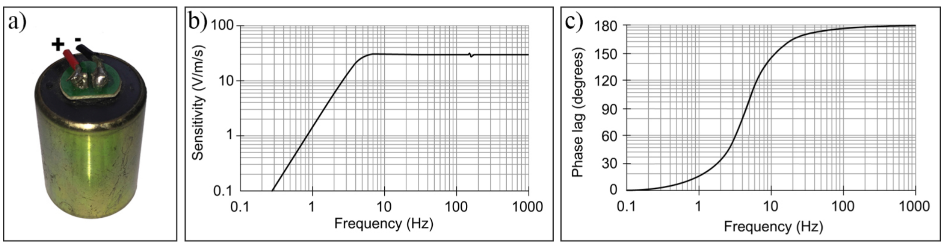

Fig. 2. For the geophones with 4.5 Hz natural frequency a) External view b) Amplitude response c) Phase response.

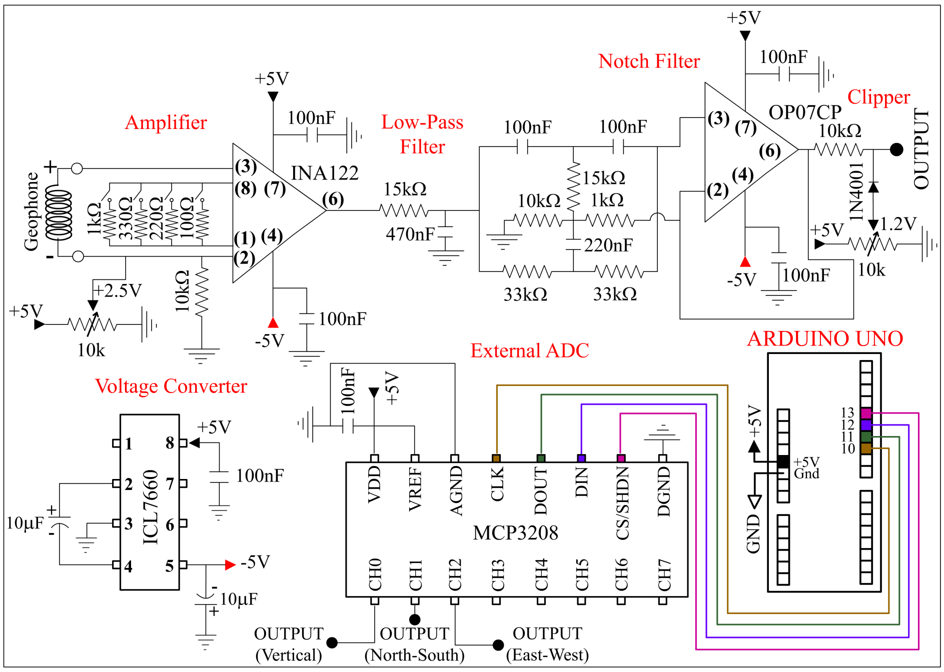

Fig. 3. Schematics of external hardware and pin connections.

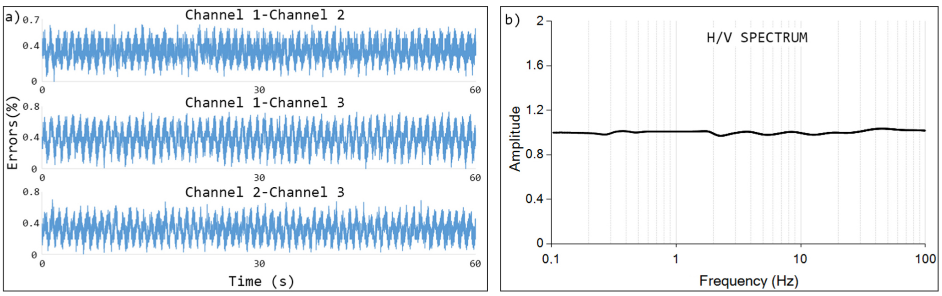

Fig. 4. a) Error percentage of difference signal estimated during the first channel consistency test b) H/V spectral ratio.

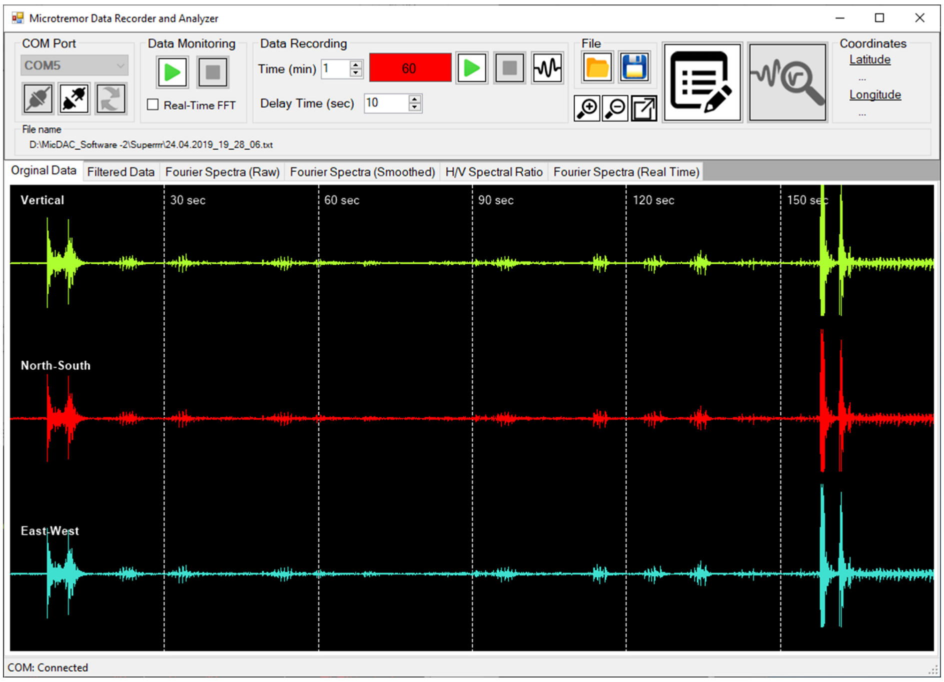

Fig. 5. Screenshot of MicDAC-GUI and detected signals using a 4.5 Hz vertical geophone connected to each channel inputs.

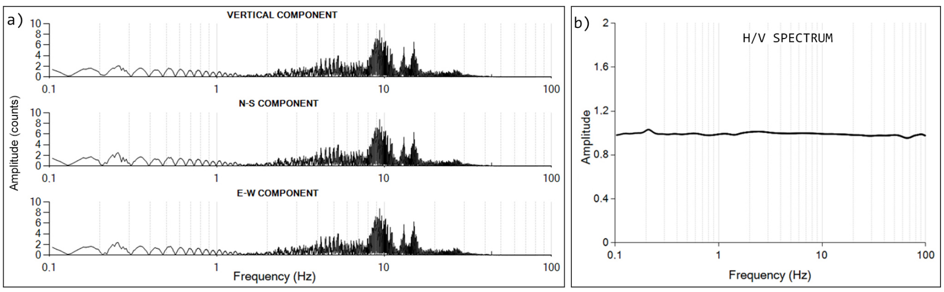

Fig. 6. a) Fourier spectra for the recorded three-component data during the second channel consistency test b) H/V spectral ratio.

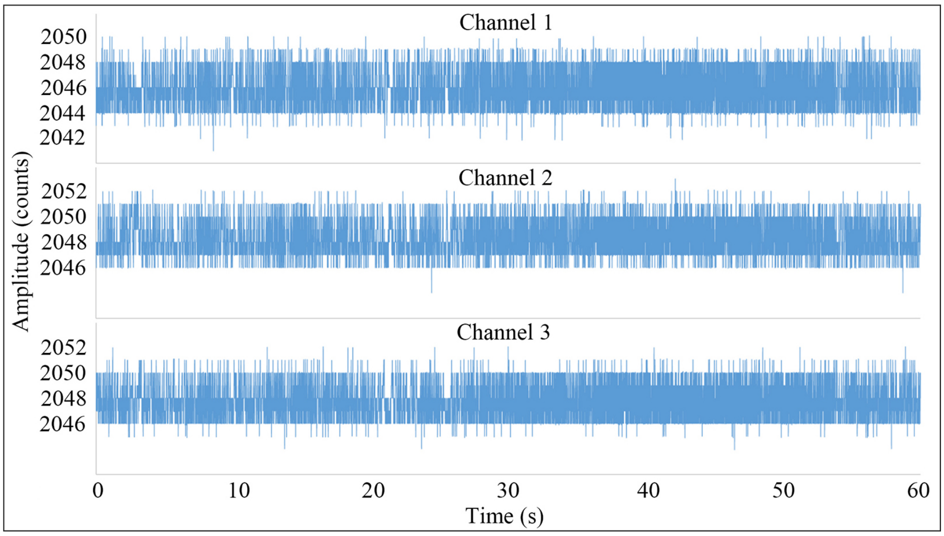

Fig. 7. Internal noise measurements for each channel.

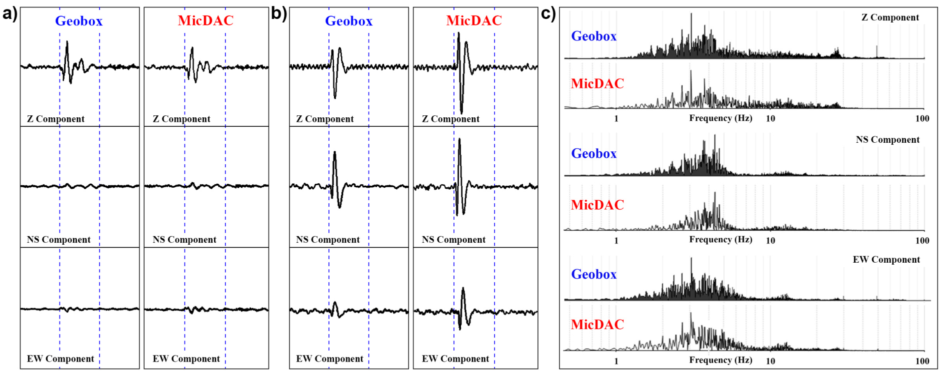

Fig. 8. Three-component seismic data recorded simultaneously using both devices a) MicDAC with 46 dB gain b) MicDAC with 60 dB gain c) Comparison of Fourier spectra of recorded three-component microtremor ...

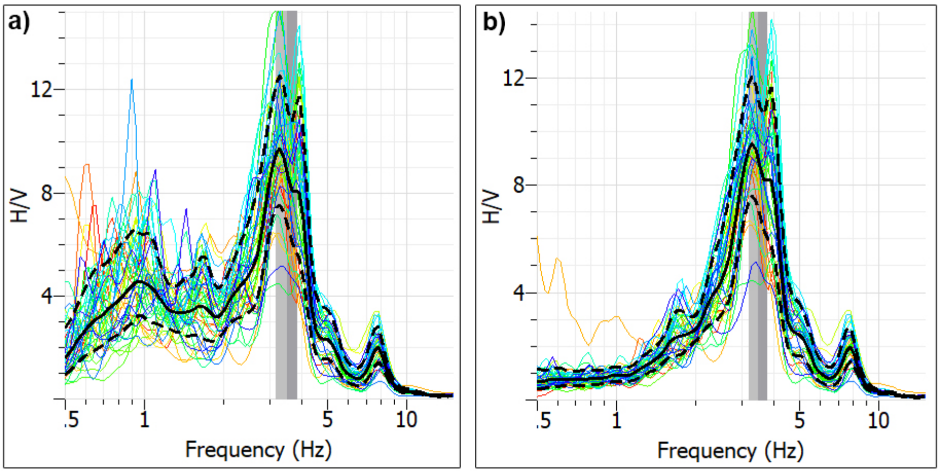

Fig. 9. The obtained H/V spectrum ratios of recorded data by a) GeoBox b) MicDAC

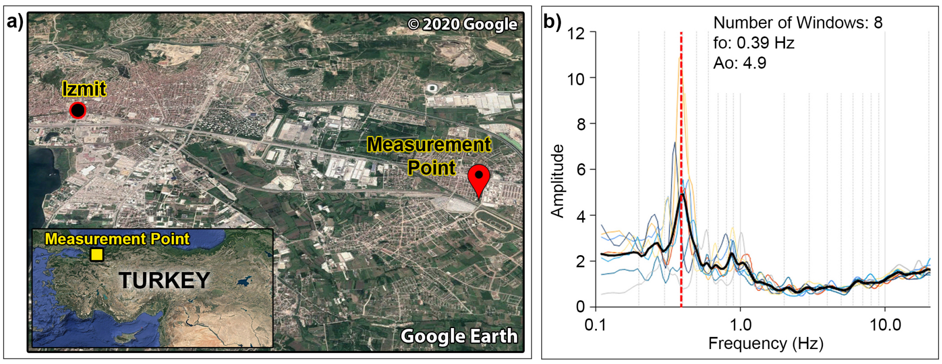

Fig. 10. a) Location of test measurement point on Google Earth© view b) H/V spectral ratio.