No.4066

Low-Cost and Easy-Made Horizontal Seismometer with Arduino for Educational Use -Demonstration and Observation-

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Demonstration model (previous study)

We have already developed an easy made seismograph system using Arduino as an AD converter for classroom demonstration (Okamoto, 2015, Okamoto & Ito, 2015).

The features are 1) Cheap cost (<100USD) 2) Easy to assemble 3) Compatible to PC

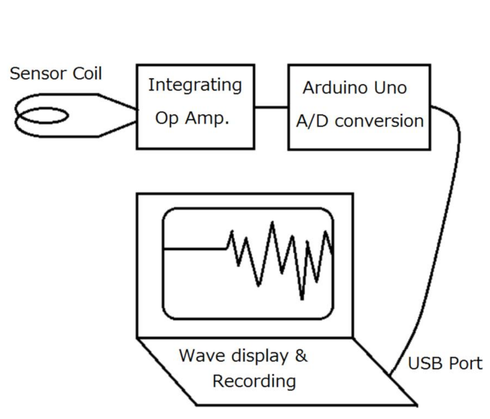


Fig.1 System over view

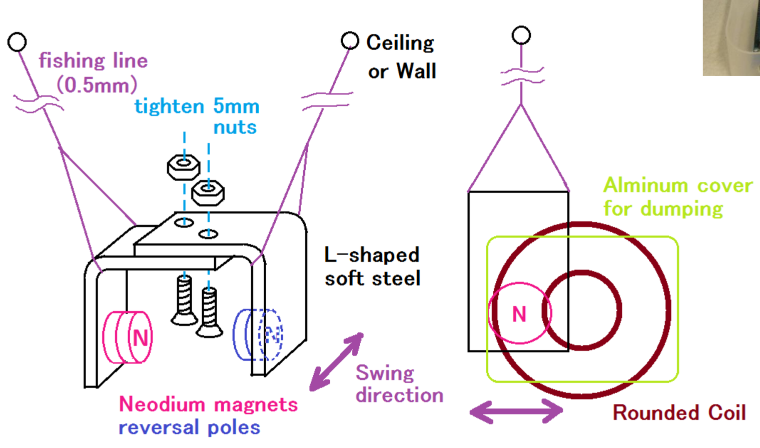
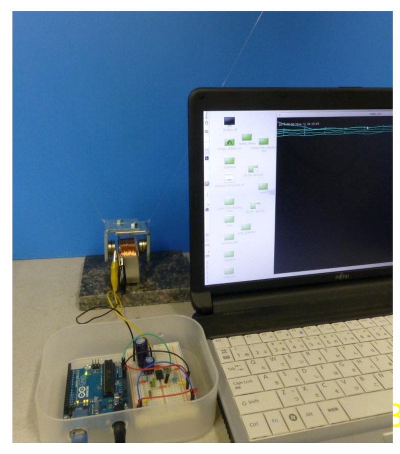


Fig.2 pendulum, magnet and coil



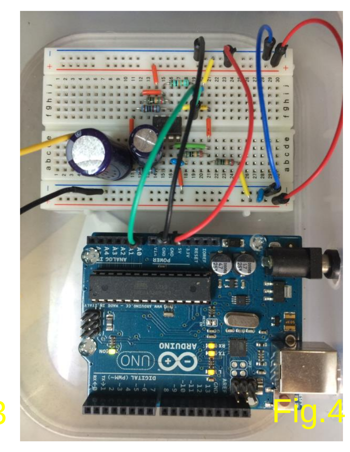


Fig.1 Block diagram

Fig.2 Bi-filer pendulum and sensor system

Fig3. Demonstration system on the desk

Fig4. Arduino + Amplifier on a bread board

Observation site

Beneath the desk, handmade standard seismometers are also installed. Two swing-gate type horizontal seismometers and an Ewing type vertical seismometer. They are used as a comparison.

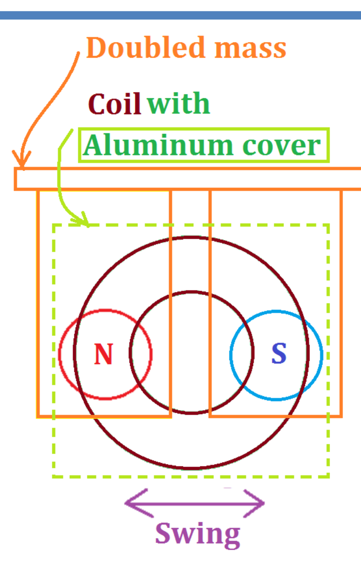
Observation at the campus of Osaka Kyoiku University(OKU) located at the hill top in the eastern superb of the Osaka urban area. The right picture shows the whole seismograph system including standard seismometers also our hand-made! Two pendulums are hung along the wall and window.

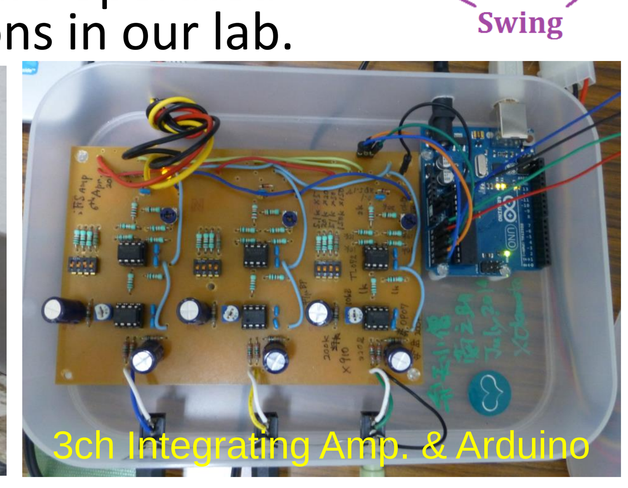
Observation system (this study)

A bifilar horizontal pendulum (3m long) is composed by two L-shaped steel bars + neodium magnets. A rounded coil coupled with the mass of the pendulum produces signals proportional to ground velocity.

A Doubled sensor (photo) was used to increase sensitivity and stability compensating two alternative magnetic fluxes.

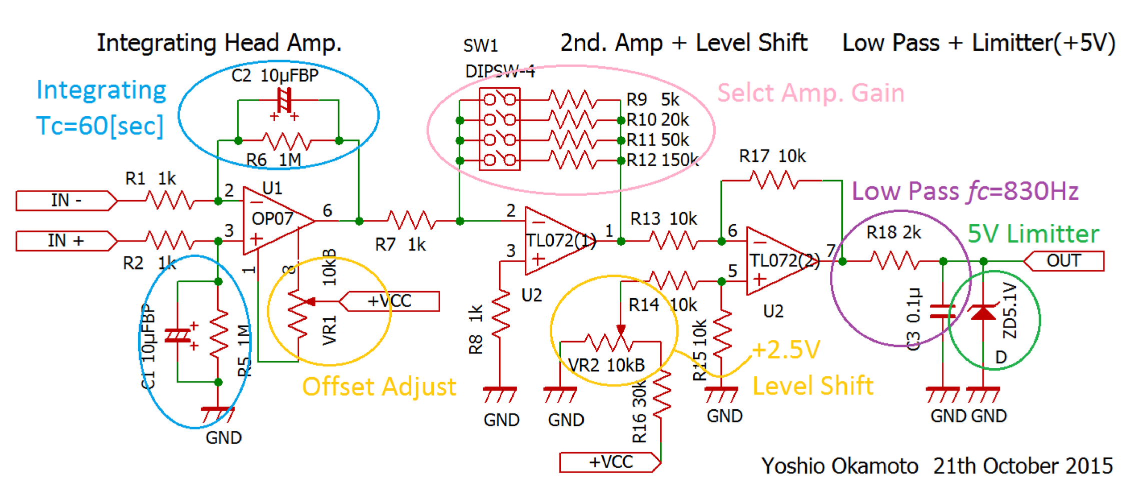
Two of rectangular placed sensors are operated to observe horizontal ground motions in our lab.



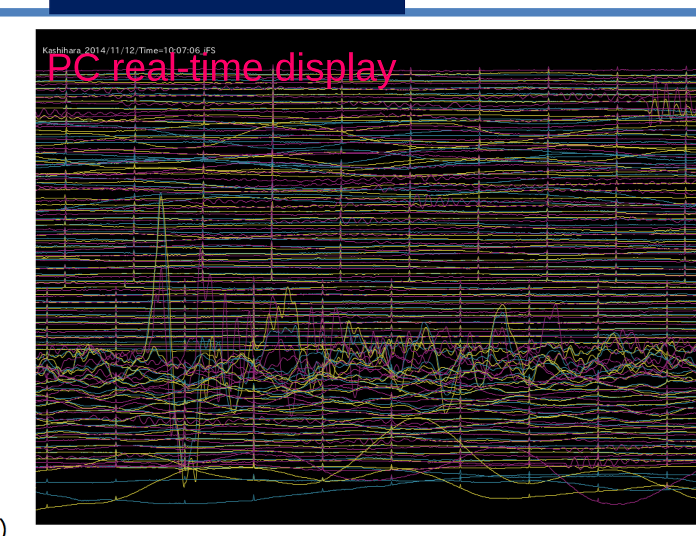


Amplifier + Arduino

The signal from the sensor is integrated, amplified, and introduced to Arduino for AD-convert. After guided via USB port to the PC, digitized signals are displayed and saved with a software written in Processing language. This JAVA like source code can be run on any platforms such as Windows, Mac-OS, Linux even on Android tablet.

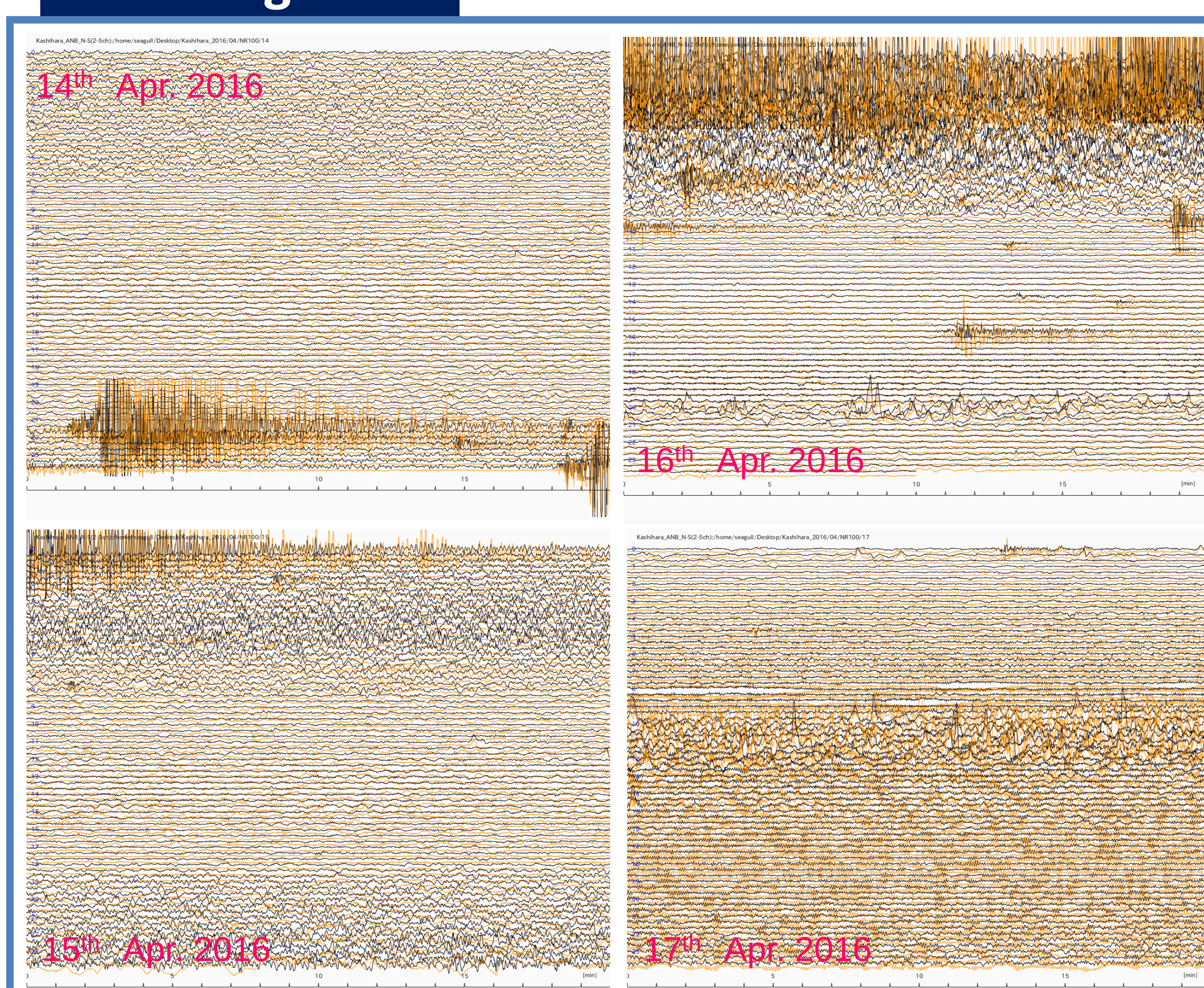


Software




```
const int accel_pin[] = { 0, 1, 2 };

int accel_val[] = { 0, 0, 0 };

void setup() {
  Serial.begin( 9600 );
}

void loop() {
  byte buffer[2];

// AD convert for 3-ch
  for ( int i = 0; i < 1; i++ ) {
    accel_val[i] = analogRead( accel_pin[i] ); // read pin[i]
  }

// Data transfer: if processing send one byte character * to Arduino
  if ( Serial.available() > 0 ) {
    for ( int i = 0; i < 1; i++ ) {
      buffer[0] = byte( accel_val[i] );
      buffer[1] = byte( accel_val[i] >> 8 );
      Serial.write( buffer, 2 );
    }
    Serial.read(); // take off * character
  }
}
```

Seismograms



One day seismograms like drum recorders at the lab. in the OKU. (black: this sensor orange: "swing-gate" sensor)

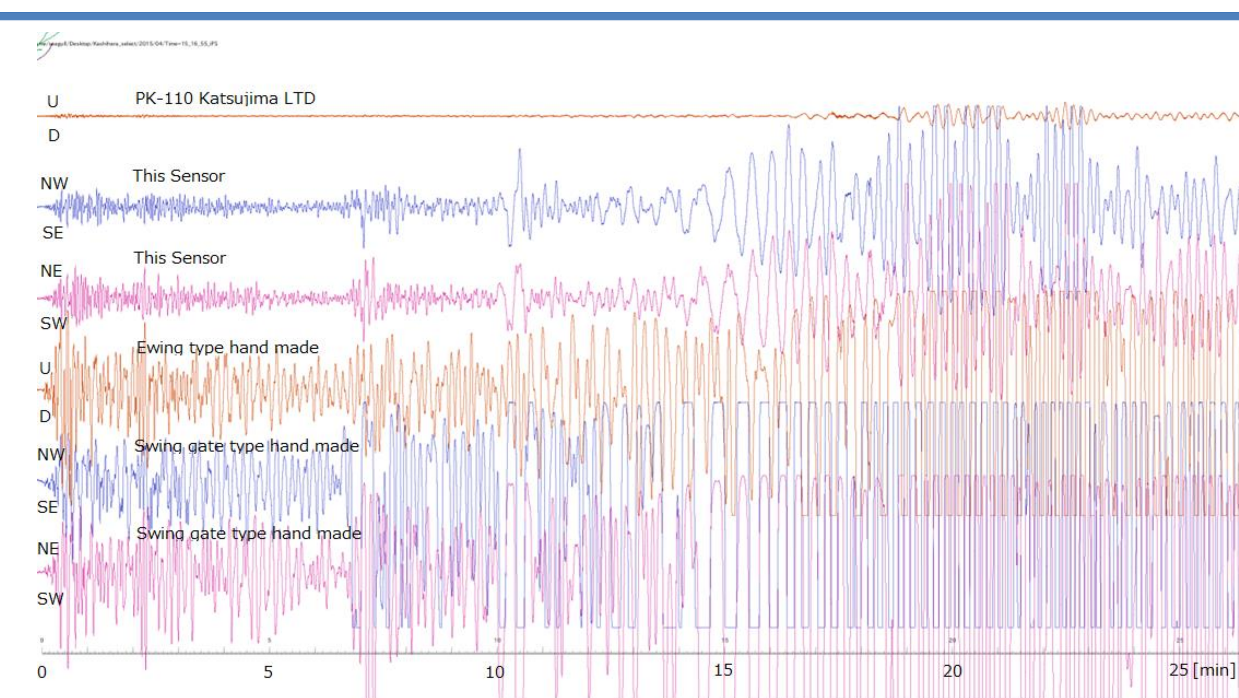
14th to 17th Apr.2016

Each line is 20 min. The sheet shows a day record. Only NW-SE component is shown.

Local earthquakes are the 2016 Kumamoto EQs.(14th Mj6.5 and 15th Mj7.3 and related.)

Some air convection noises are seen particularly in the midnight to morning, due to the temperature gap in and outside the room.

Among the noises, Ecuador EQ.(17th Mw7.8) is recorded, epi-central distance, 14700km



A comparison seismogram of the Napal Mw7.8 earthquake on 25th Apr.2015, epi-central distance of 4600km. The 2nd and 3rd lines are recorded by this sensor. Lower three records are recorded conventional type seismometer (our own made!) P, PP, S, SS phases and reverse-dispersed surface wave are clearly recorded in spite of a cheap cost of assembly.

Discussions

The merits of using an integrating amplifier are capability of 1) Recording displacement motions of the ground instead of velocity output. And 2) Amplifying the lower frequency signal of foreign earthquakes. The low boost effect of 2) is particularly useful for foreign earthquake study, while the system treats mainly local earthquakes, the velocity output is recommended. The use of neodium magnet is necessary, because its strong magnetic flux (>400 mT at the surface) supplies an induced current sufficiently. The 2-3mm gap of the magnet and the aluminum cover + 1 kΩ shunt register of the amplifier yield a critical damping (h~1). So, the total system (To=3[sec], h~1) are appropriate to detect most of local and foreign earthquakes.

The drawbacks of this system (due to its "fragile" pendulum) are 1) weakness for air convection and 2) rotational instability of the sensor. Parasitic swings and wind stirs may be the most nuisance problems for our pendulum. The doubled sensor is our solution for 2). The air stirs problem is still unsolved (see seismograms). The creep of nylon wire is negligible after a month or more, although their exponential decay for a long time.

The comparison of this system with our conventional system (swing-gate type horizontal sensors and Ewing type vertical sensor (To = 6~7 [sec], h~0.7), they are also our own made!) shows a good performance of this system. This system currently has horizontal components only. And a new vertical seismometer of the same concept is expected to be developed. For data analysis and making seismograms, we have used our original softwares written in "Processing", although there are some famous softwares for seismogram analysis; eg. "AmaSeis(Braile,2004)" or "win system(Urabe,1994). The softwares are the improved version of the previous ones we developed. The overall performance of our system can record M5.5 or greater for domestic earthquakes, and M7.0 or greater for foreign earthquakes.

Despite some drawbacks, our system has a significant advantage in the classroom or school use for both demonstration and routine observation. The comprehensive structure of the sensor is suitable for students not only to see the structure but also to assemble by themselves.

Conclusion

An easy assembled, inexpensive and high precision seismograph system for educational use has been developed and improved. The performance of the system is evaluated and calibrated through a couple of year's observation at our University campus. The system is now still improving its performance and recording daily earthquakes. Students can learn about seismometer and seismology with using our system.

References and Acknowledgements

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