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# High-precision Time Synchronization Digital Sensing Platform Enabling Connection of a Camera Sensor

Tsukuba University of Technology, Japan

**Narito KURATA**

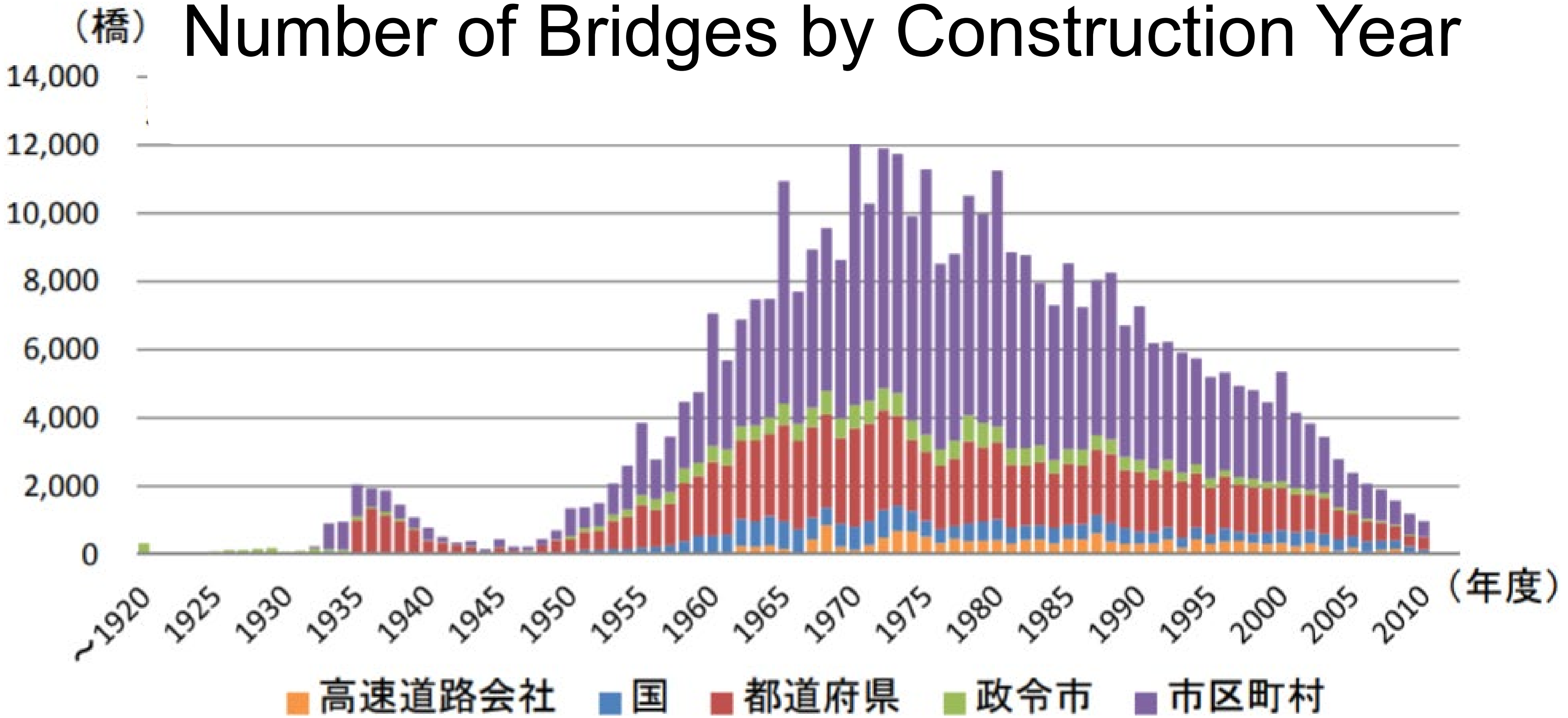
**kurata@home.email.ne.jp**

# Narito KURATA
## Tsukuba University of Technology

- Background
  - Architectural & Structural Engineering
  - Earthquake Engineering
- Research & Development
  - Structural Control Systems for Earthquake Hazard Mitigation
  - Structural Health Monitoring
    - Earthquake Monitoring and Structural Health Monitoring by Sensor Networks
    - Risk Information Delivery System
    - Energy Monitoring
    - Environmental Monitoring
  - Application of Sensor Networks to Smart Buildings and Civil Infrastructures

# Necessity of smarter inspection and maintenance of civil infrastructure

## Number of Bridges by Construction Year




https://www.mlit.go.jp/road/road_e/03key_challenges/1-2-2.pdf

# Benefits of installing earthquake sensors to all the houses and buildings

- Situation just after the earthquake can be grasped in a single house by the local government


- The data can be used in decision-making of crisis management

# Benefits of installing earthquake sensors to all the houses and buildings

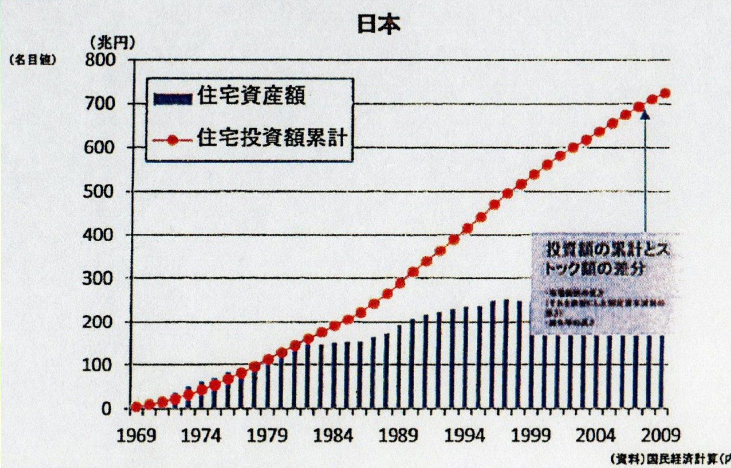
- Residents of the houses that have earthquake sensors, can see the measurement data of a wide range of areas
- They can confirm **the need for refuge and safety place** immediately after the earthquake


# Benefits of installing earthquake sensors to all the houses and buildings



- From sensors installed on the ground (first) floor, liquefaction of the ground can be detected
- The data has a significant effect on the real estate price

# Benefits of installing earthquake sensors to all the houses and buildings


- From sensors installed on the roof, earthquake data over a lifetime of house can be stored
- This data affects the price of used houses

# The need for accurate time information

- Accurate time information as well as location information are necessary to develop the Earthquake big data and analyze the data for maintenance of civil infrastructure
- Time synchronization between the sensors in a wide area is not easy
  - GPS cannot be used in the houses and buildings
  - The wire and wireless communication is limited
- It is desirable that the sensor itself has autonomously accurate time information

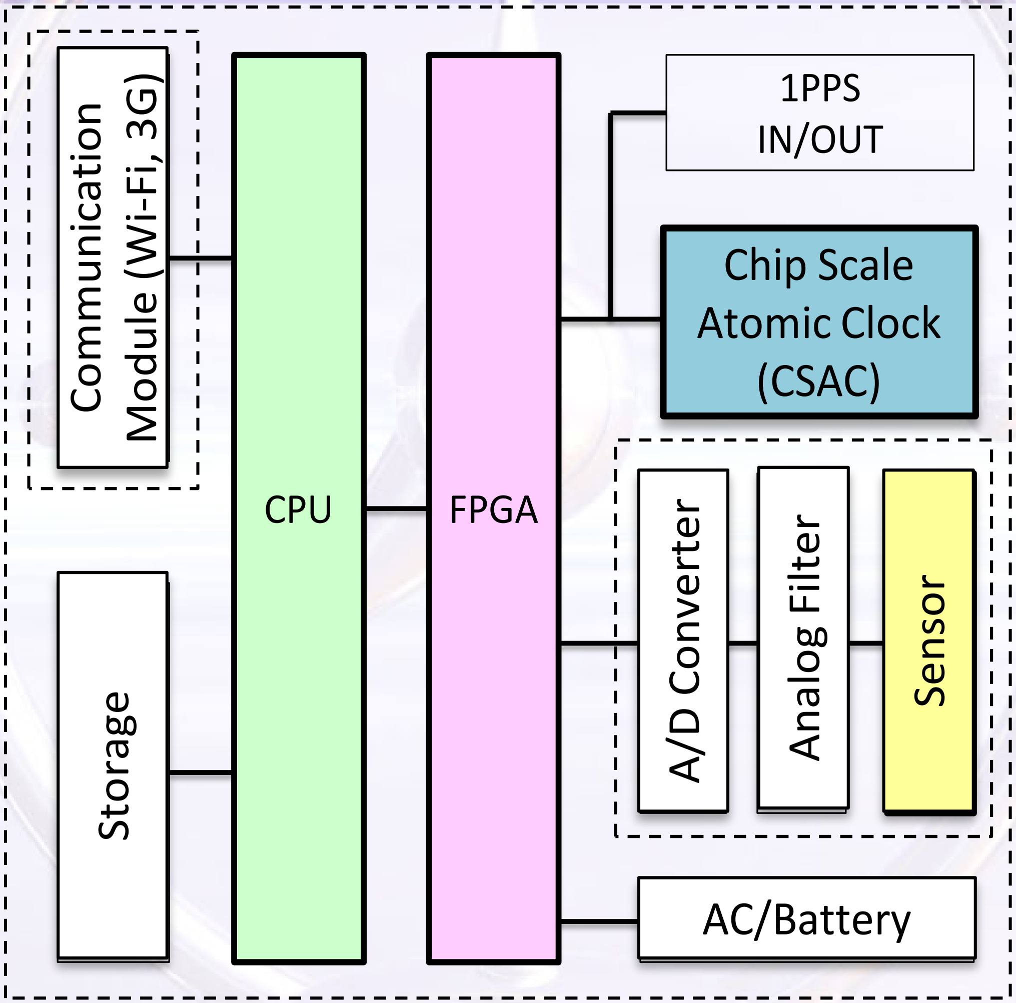

# Development of a Sensor Device Capable of Autonomously Keeping Accurate Time Information Equipped with a Chip Scale Atomic Clock

# Chip Scale Atomic Clock (CSAC) is available

- Comparison among various atomic clocks and oscillator

| | Cesium atomic clock | Rubidium atomic clock | CSAC | Crystal oscillator |
|---|---|---|---|---|
| Time for 1-sec. delay | 50,000 years | 1000 years | **1000 years** | One day |
| Size | $0.1\ m^3$ | $1000\ cm^3$ | **$17\ cm^3$** | $10\ mm^3$ |
| Power consumption | 50 W | Several 10 W | **120 mW** | 10 μW |

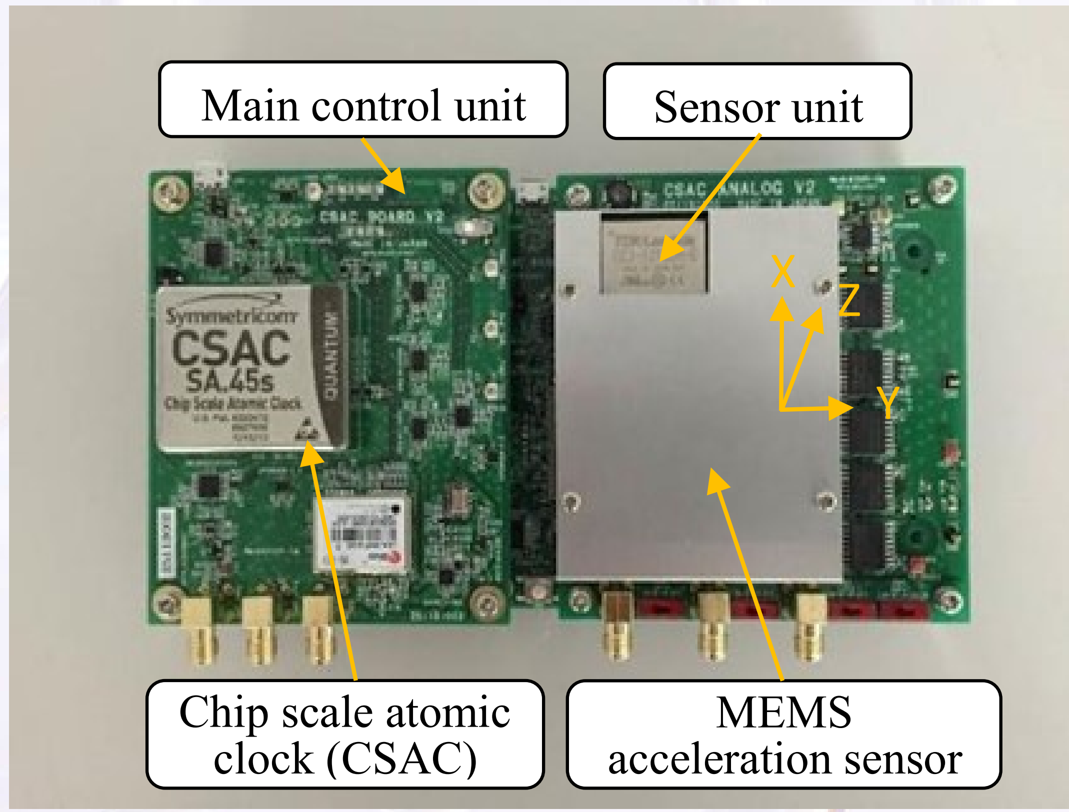
# Mechanism of Sensor Device with CSAC



# Development of Sensor Device with CSAC

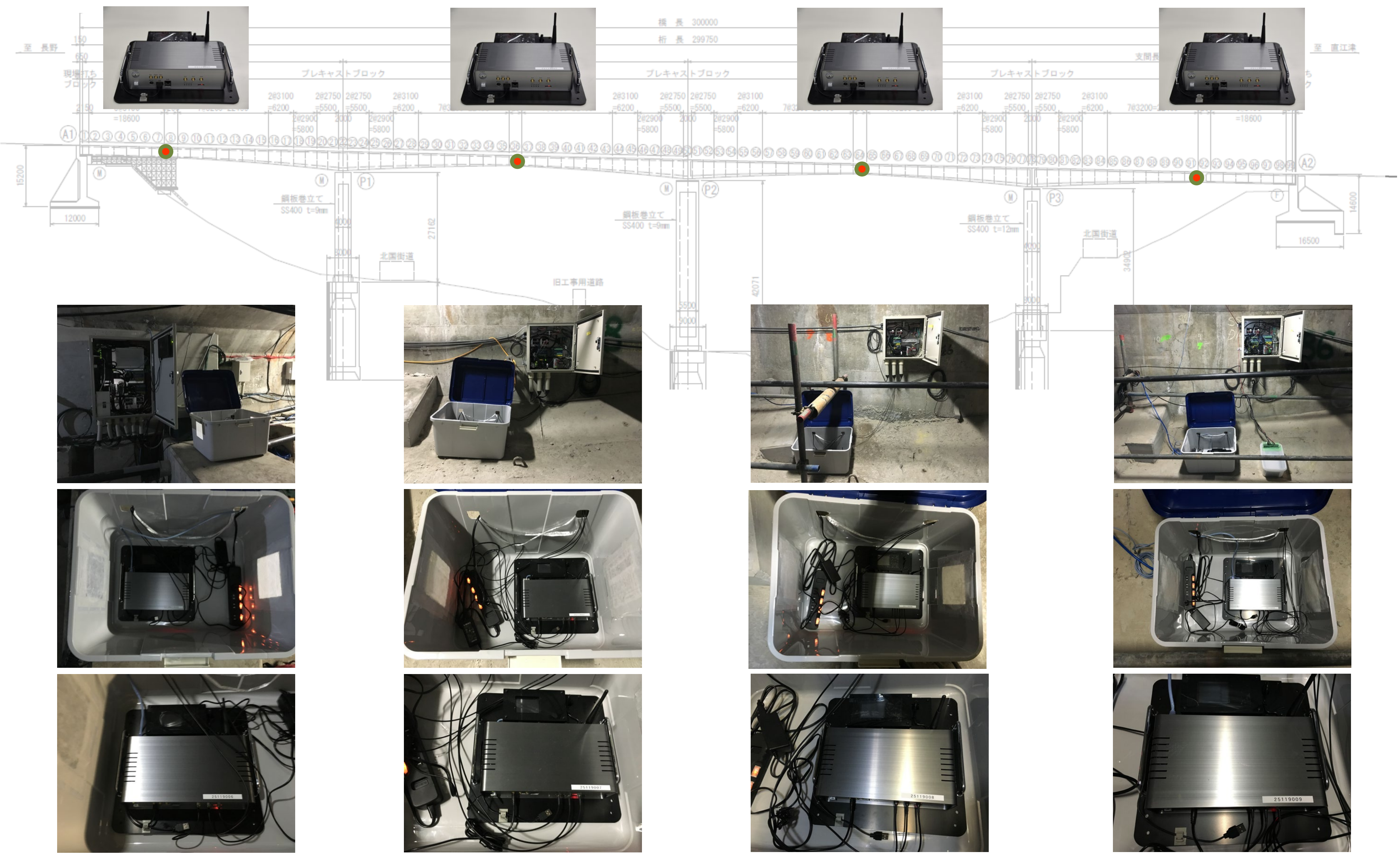
- After the development of prototype device, practical device has developed

prototype device

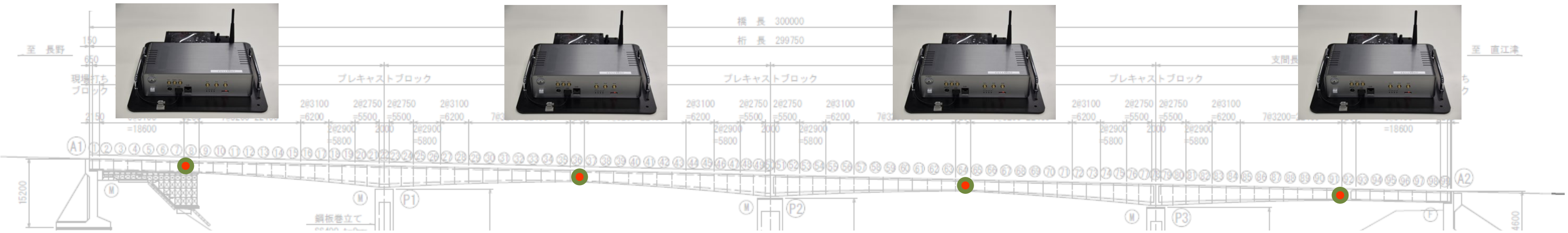



Practical device

# Installation of Practical Device to Aging Bridge

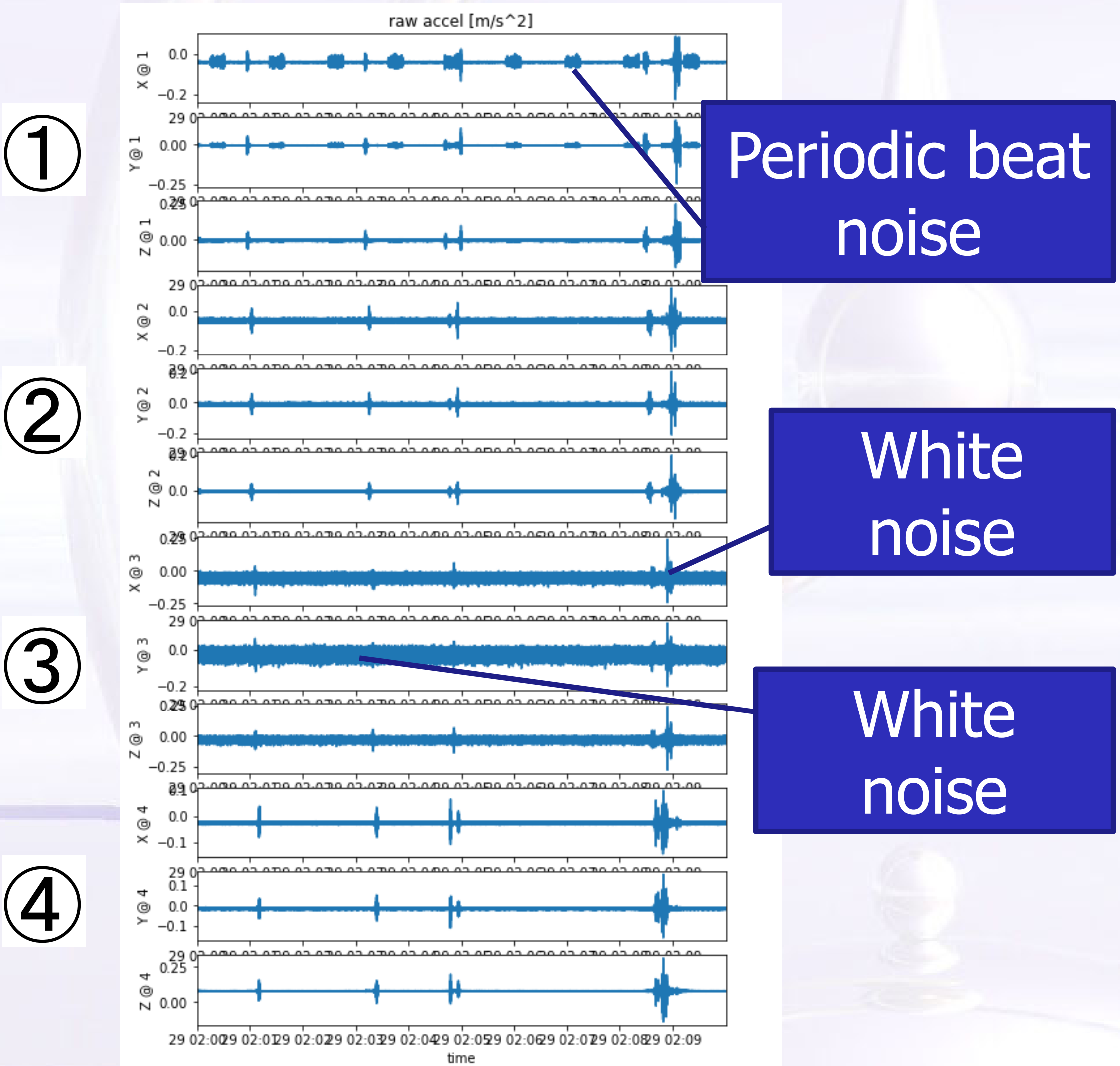


# Installation of Practical Device to Aging Bridge




- The built-in MEMS acceleration sensor and external analog sensor input interface can only be used exclusively.
- A high performance acceleration sensor was connected using an external analog sensor input interface to measure microtremors of the aging bridge.

# Measured Data and Noise Problem

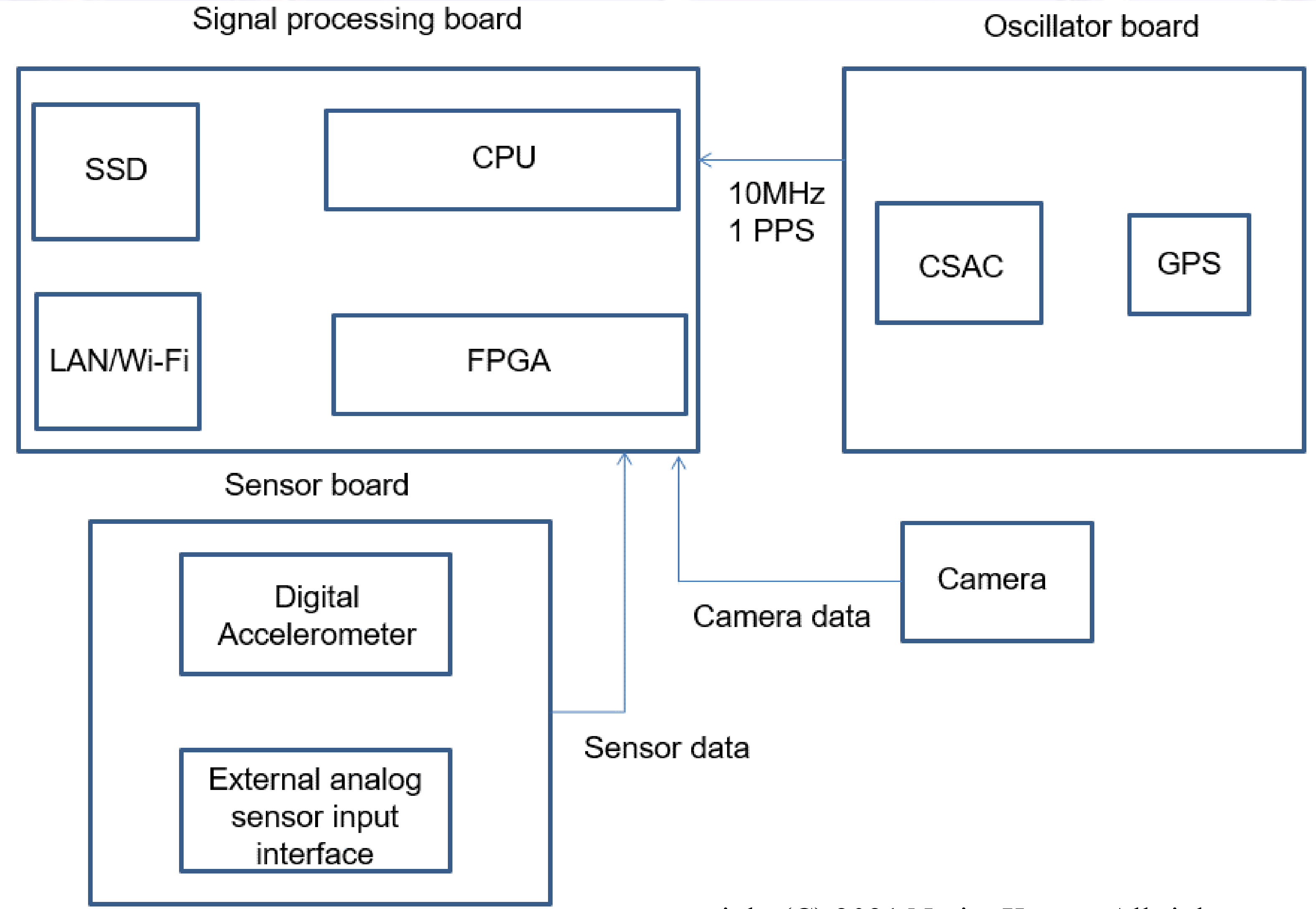



- Periodic beat noise and white noise are generated on the measurement line.
- The correct signal is included in white noise and cannot be separated.
- Environmental noise for analog signals is a serious risk.

# Development of Digital Sensor Platform

- As the developed sensor device had an analog MEMS accelerometer, it was difficult to measure minute vibrations accurately, and there was a risk of noise being mixed with the analog signal.
- The risk of noise was eliminated by making the accelerometer mounted on the sensor device a digital type.
- In this research, a different type of digital sensor platform with CSAC is further developed wherein a camera sensor can be connected to the sensor device.

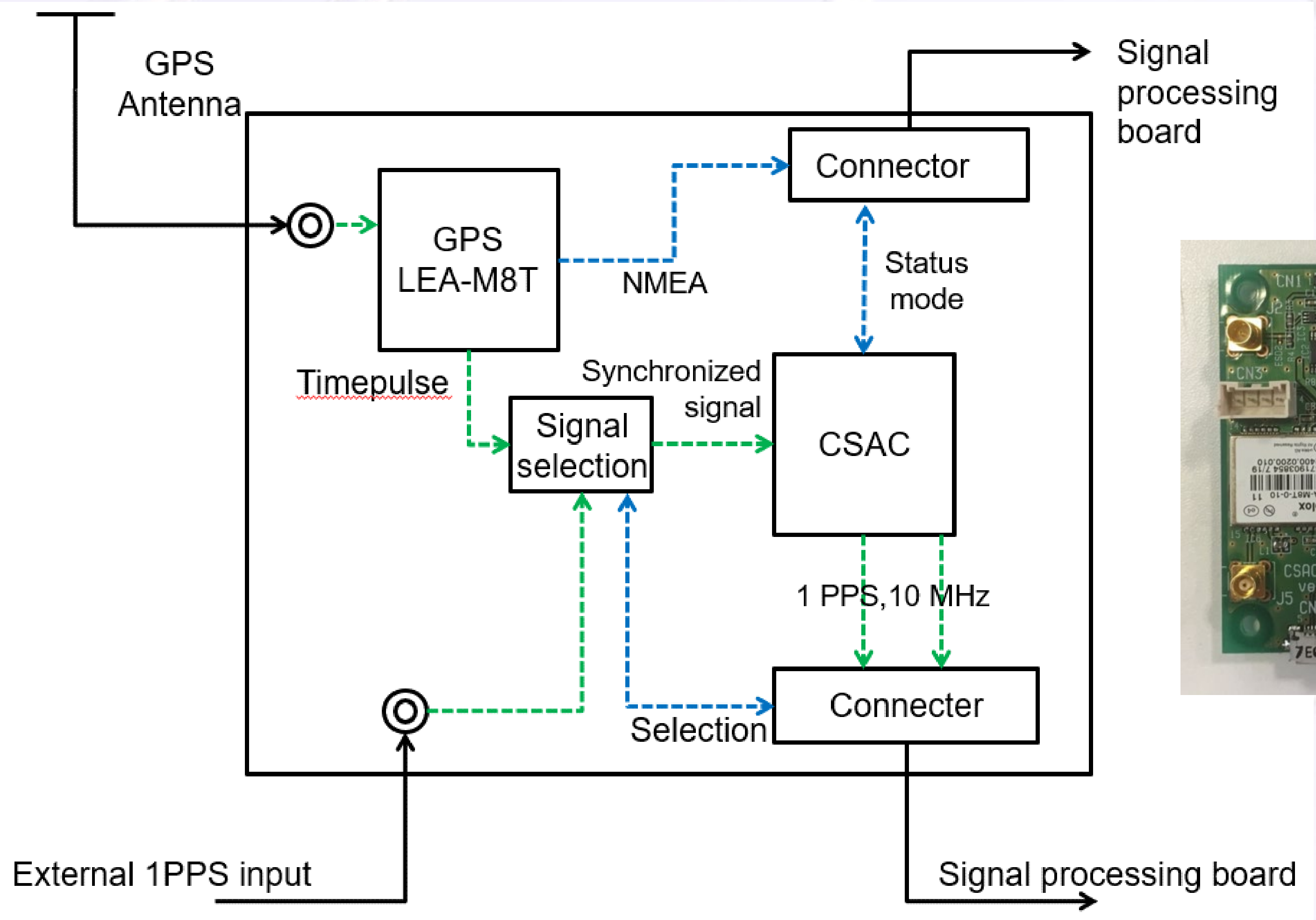
# System Configuration



# System Configuration


- The sensor device in this research consists of
  - an oscillator board that synchronizes GPS Time with the CSAC and supplies a stable reference signal,
  - a sensor board on which a digital accelerometer and external analog sensor input interface are mounted,
  - a signal processing board on which a CPU and FPGA are mounted, and a camera that captures images.

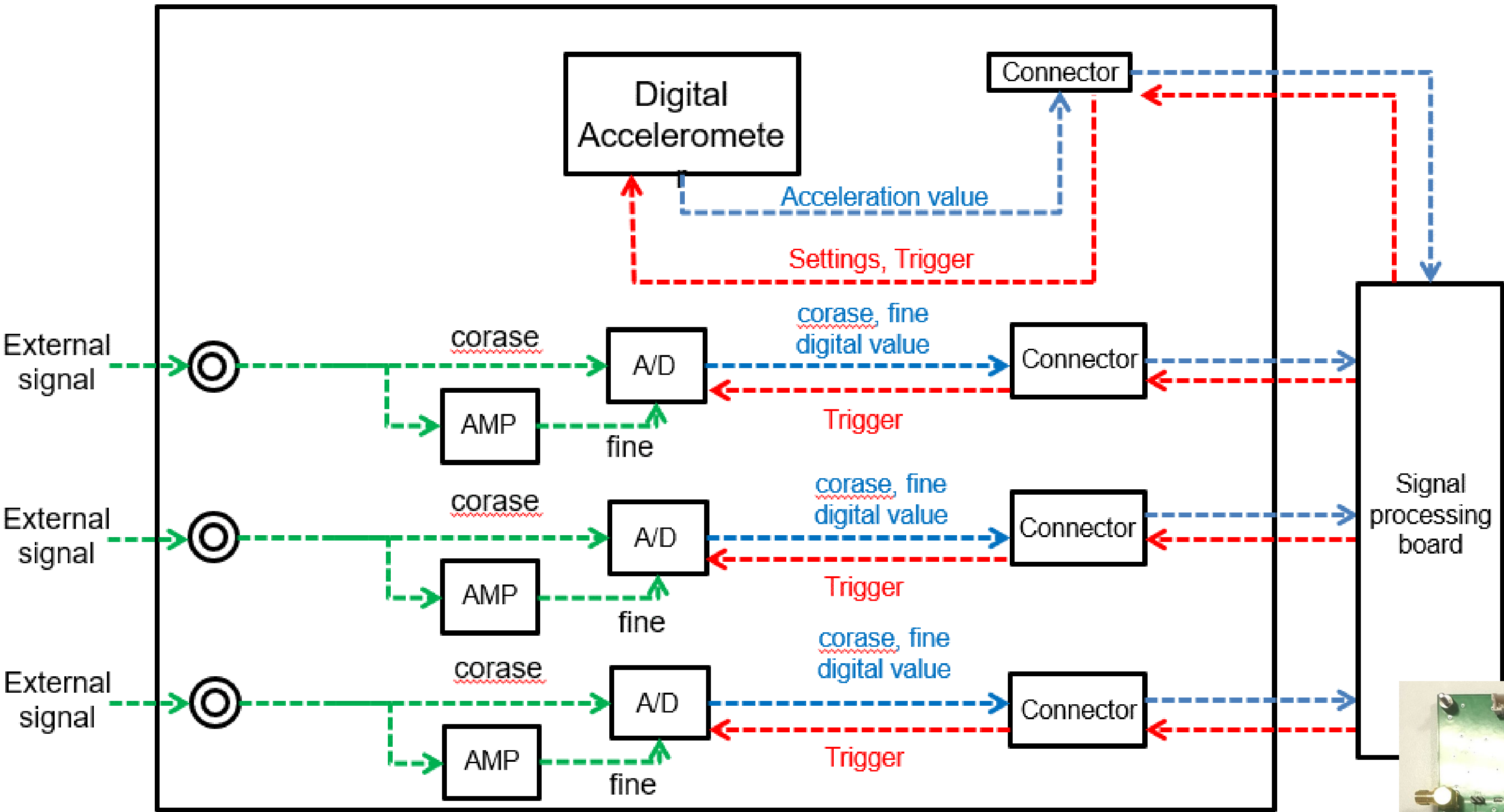
# Oscillator Board

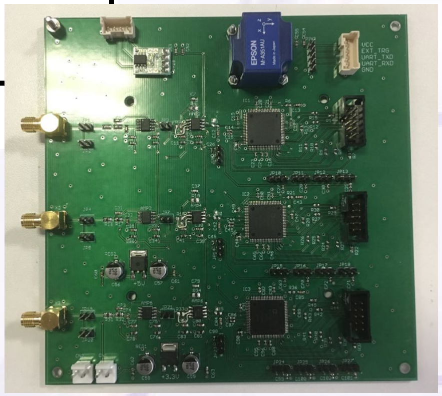



# Oscillator Board

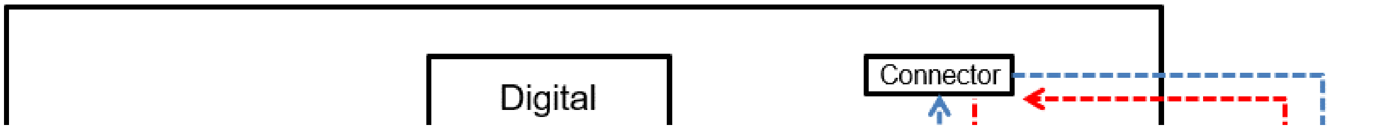
- The oscillator board has a function to synchronize the CSAC with 1 PPS output by the GPS module or 1 PPS input from outside
- The 10MHz and 1 PPS output by this board are clock sources for this system


# Sensor Board



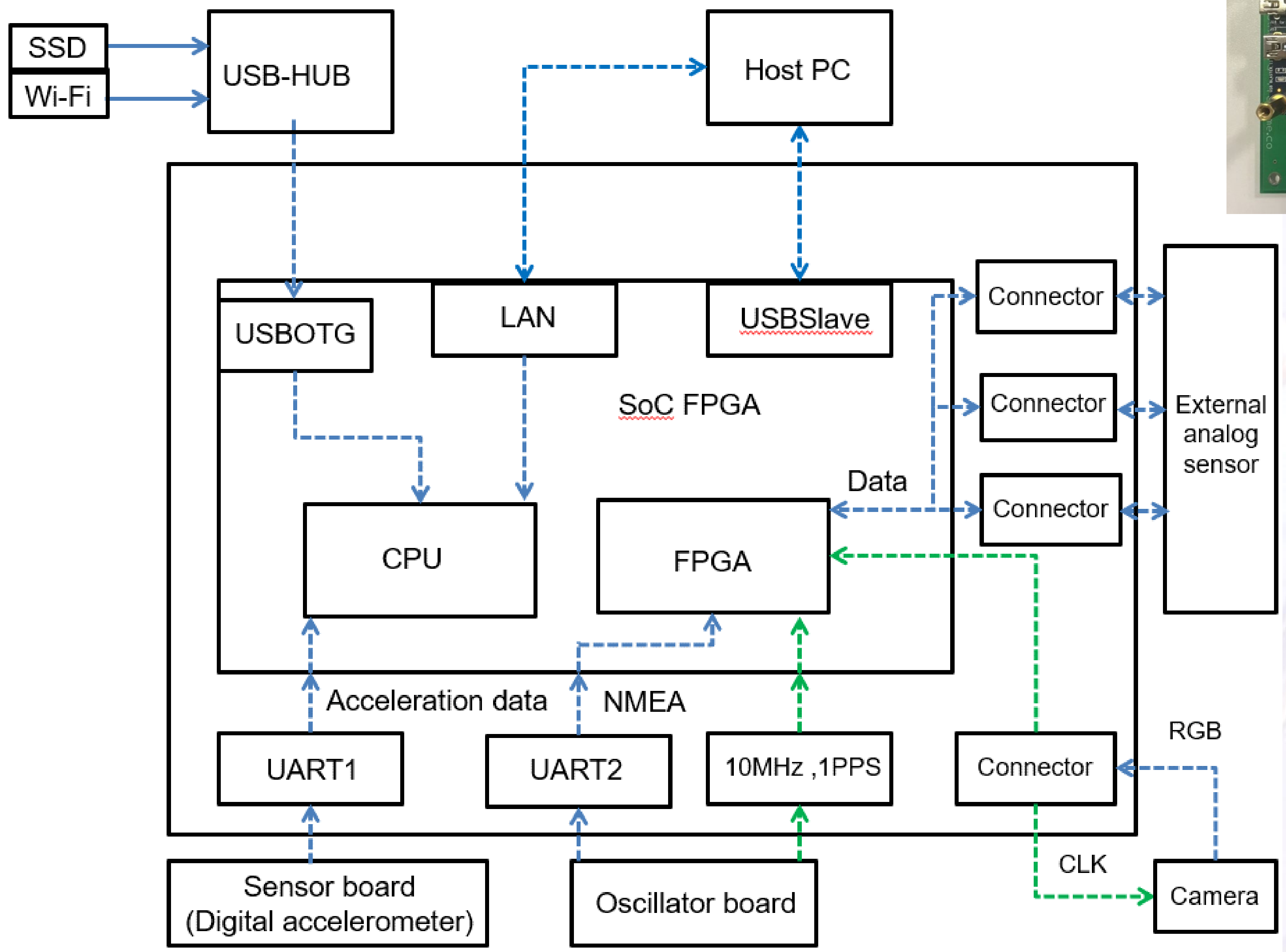



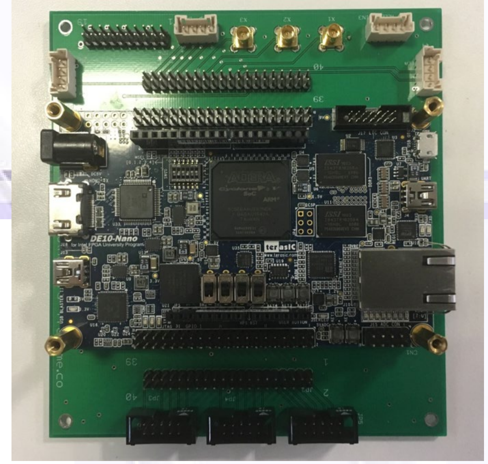
# Sensor Board



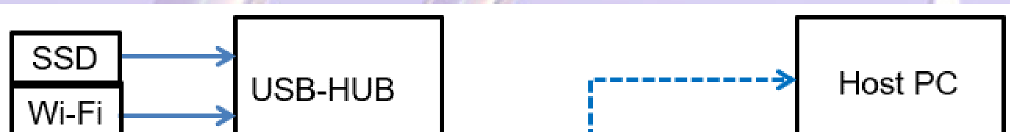

- The sensor board is provided with a digital accelerometer and an external analog sensor input interface.
- The data obtained by the digital accelerometer can be sampled at the timing of the trigger.
- The signal input from the external analog sensor interface is converted by the A/D converter.

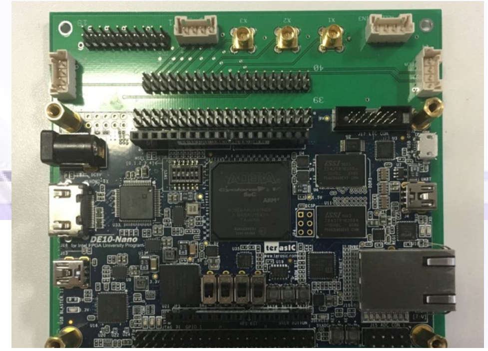
# Signal Processing Board



# Signal Processing Board



- The FPGA mounted on the signal processing board.
- The FPGA adjusts the internal RTC (real-time clock), and generates the trigger signal based on the clock obtained from the oscillator.
- It also constitutes a data acquisition block for the various sensors and camera.

# Specifications of Digital Accelerometer

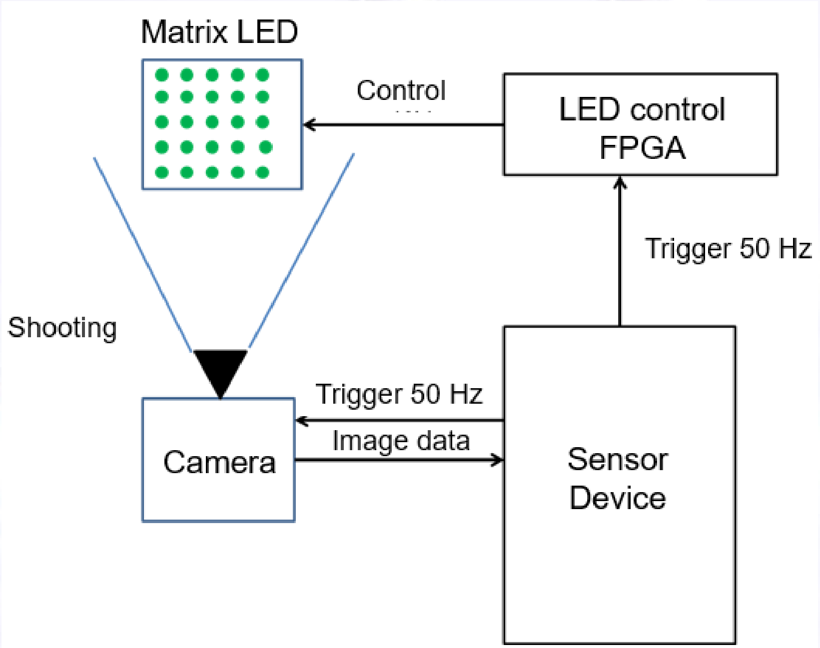
| | |
|---|---|
| Model | EPSON M-A351AS |
| Range | ±5 G |
| Noise Density | 0.5 μG/√Hz (Average) |
| Resolution | 0.06 μG/LSB |
| Output Range | 1000 sps (selectable) |
| Outside Dimensions (mm) | 24 × 24 × 18 |
| Operating Temperature | -20 ℃ to +85 ℃ |
| Power Consumption | 3.3 V, 66 mW |

# Specifications of Camera Sensor

| | |
|---|---|
| Model | OmniVision OV5642 |
| Active Array Size | 2592 x 1944 |
| Power Supply | core: 1.5VDC±5%, analog: 2.6-3.0 V, I/O: 1.7-3.0 V |
| Lenz Size | 1/4” |
| Input Clock Frequency | 6-27 MHz |
| Shutter | rolling shutter |
| Maximum Image Transfer Rate | 5 megapixel (2592x1944): 15 fps<br>1080p (1920x1080): 30 fps<br>720p (1280x720):60fps<br>VGA (640x480): 60 fps<br>QVGA (320x240): 120 fps |
| Scan mode | progressive |

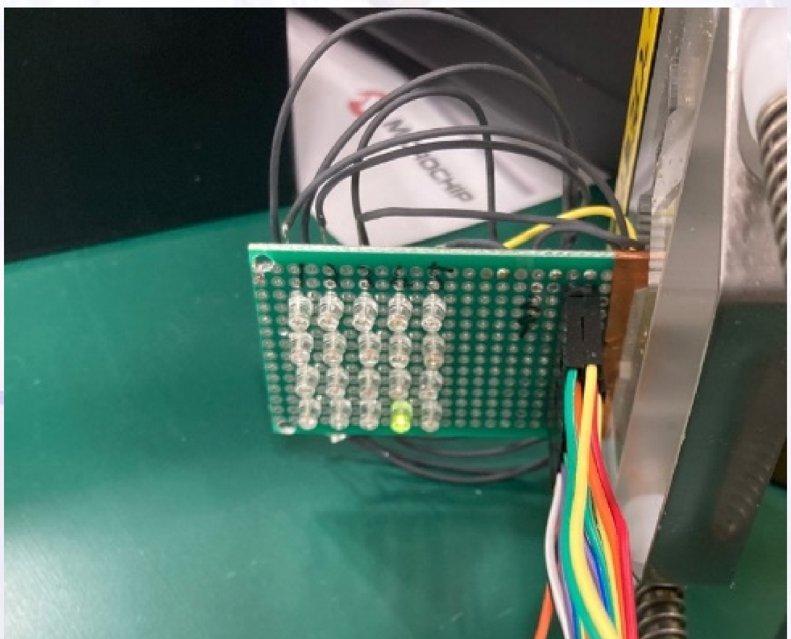
# Performance Verification Experiment on Time Synchronization Function of Camera Sensor

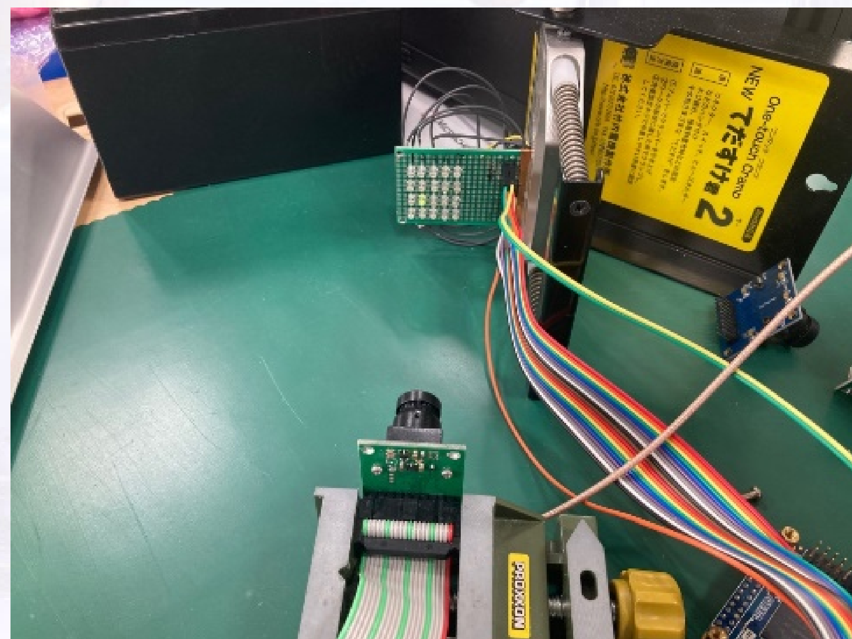
- The trigger signal generated by the signal processing board is transmitted to the camera sensor and the FPGA of the LED control simultaneously.
- Since the shutter of the camera sensor and the lighting of the LEDs are synchronized, if the image can be acquired when the LEDs light up, it is considered that the image acquired is synchronized with the trigger.



# Performance Verification Experiment on Time Synchronization Function of Camera Sensor

- 5×5 matrix LEDs light up one by one from upper left to lower right according to the rise of the trigger signal.
- The matrix LEDs are photographed with the camera sensor fixed.

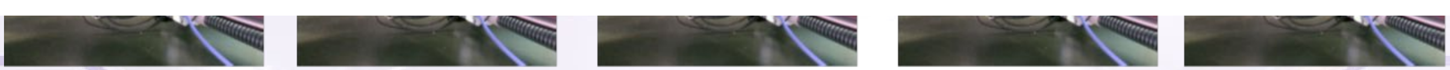




# Performance Verification Experiment on Time Synchronization Function of Camera Sensor

# Performance Verification Experiment on Time Synchronization Function of Camera Sensor

- Time elapses from the upper left to the lower right.
- Since the LEDs in the image light up one by one, images can be acquired according to the signal input to the FPGA for LED control.
- In the images, the LEDs light up two at a time, and it can be seen that the camera sensor has a certain delay with respect to the trigger.
- It was verified that images could be continuously acquired in synchronization with the trigger.



# Conclusion

- Research and development relating to a digital sensing platform that autonomously retains highly accurate time information by applying a CSAC, was reported.
- First, a system based on a digital sensor and autonomous time synchronization by a CSAC was described, in which the development of a mechanism and a sensor device that add ultra-high-accuracy time information to sensor data using the CSAC were explained in detail.
- A function was added to assign the same time stamp as that of the output of the built-in digital accelerometer, to the output of the camera sensor.

# Conclusion

- The results of an experiment carried out to verify the time synchronization performance of the camera sensor were also reported.
- In the future, the author plan to apply this new, different type of digital sensing platform to actual structures to acquire acceleration and video data that retain accurate time information.

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Thank you for your kind attention