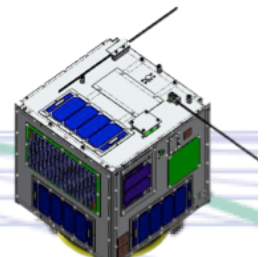


# Development of a Very Small on-Board Oscilloscope for a Cube-Satellite HORYU-3

Dr Tatsuo Shimizu  
Research Fellow

Mr H Fukuda, Mr S Hidaka, Mr S Iwai, Dr K Toyoda, Prof M Cho

Kyushu Institute of Technology  
Fukuoka, Japan





# Contents

## Introduction

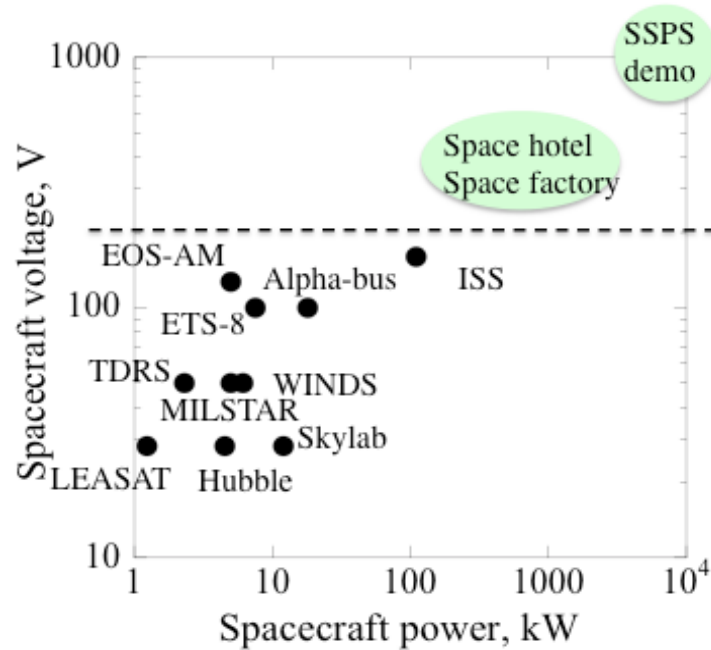
Advantages and Issues of Using High Voltage In-Orbit  
HORYU Satellite Series (In-Orbit Laboratory)

## Small On-Board Oscilloscope

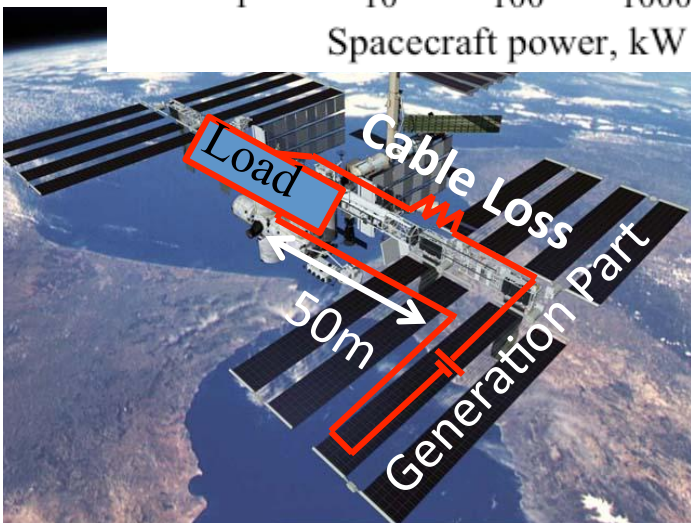
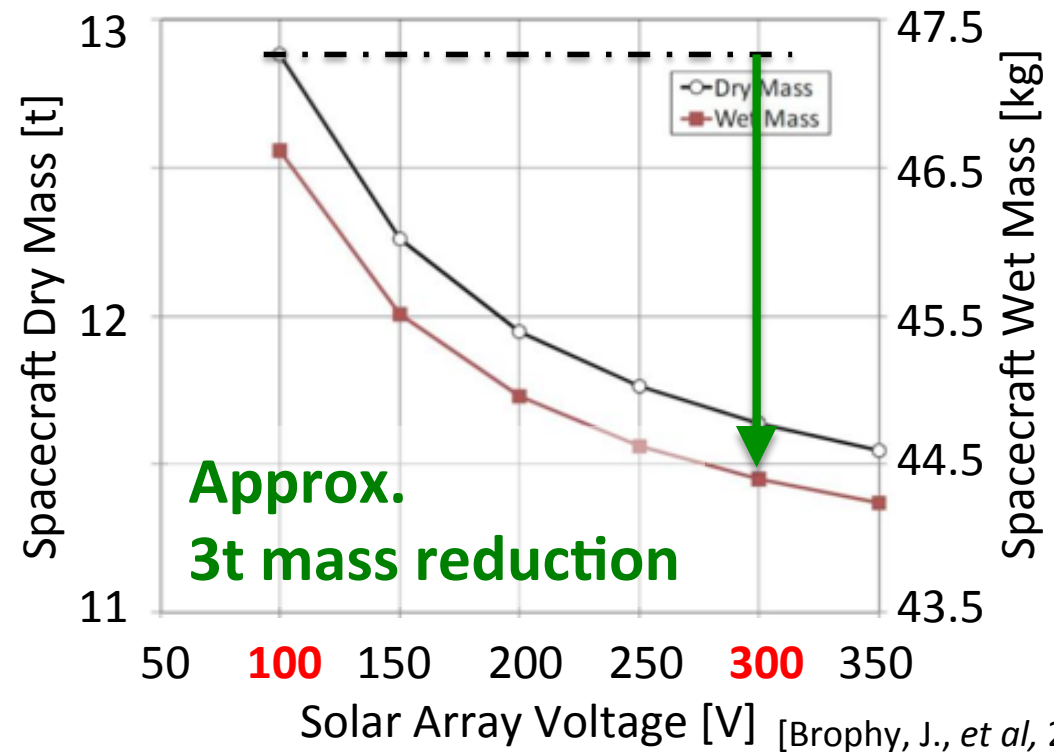
## Initial Results

## Conclusion and Future Works

High voltage is advantageous (energy efficient)



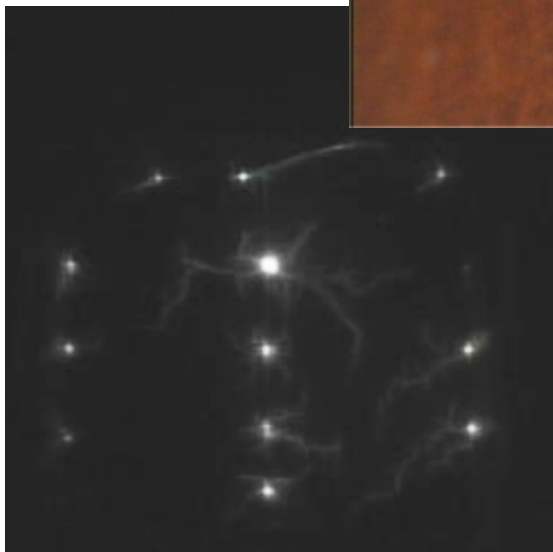
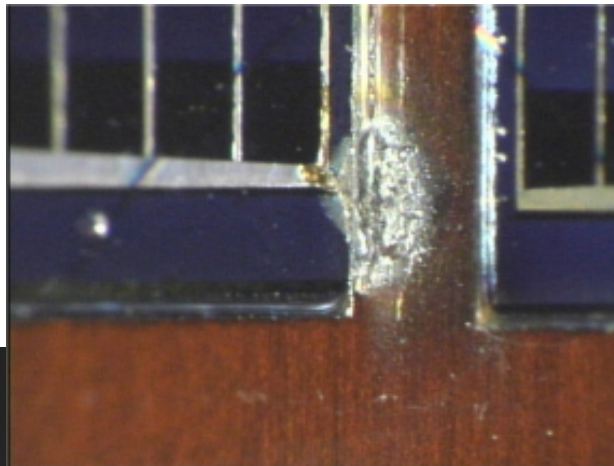
For example: Inter-Planetary Exploration Spacecraft



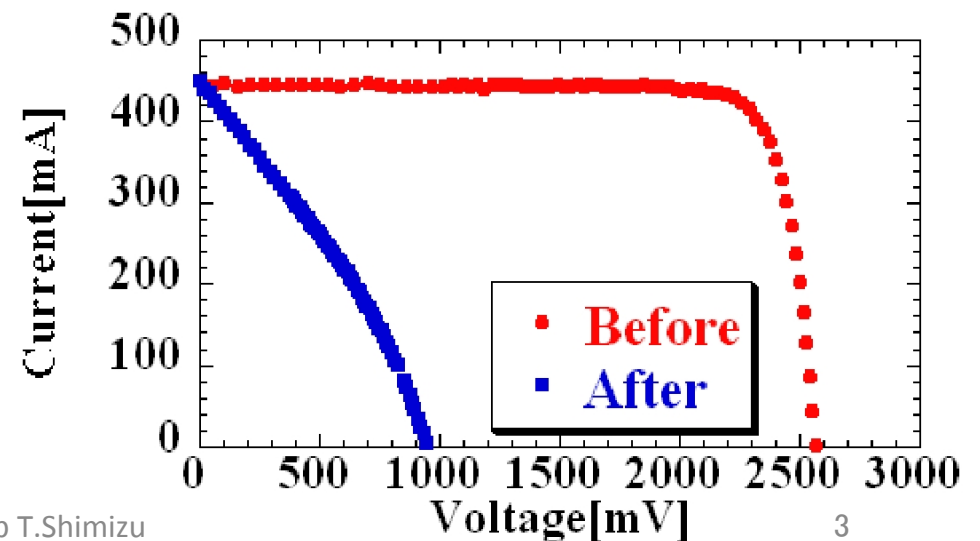
High voltage is advantageous (energy efficient), **but...**

Arcing on spacecraft solar array has been observed since 3 decades ago...

**Arcing**



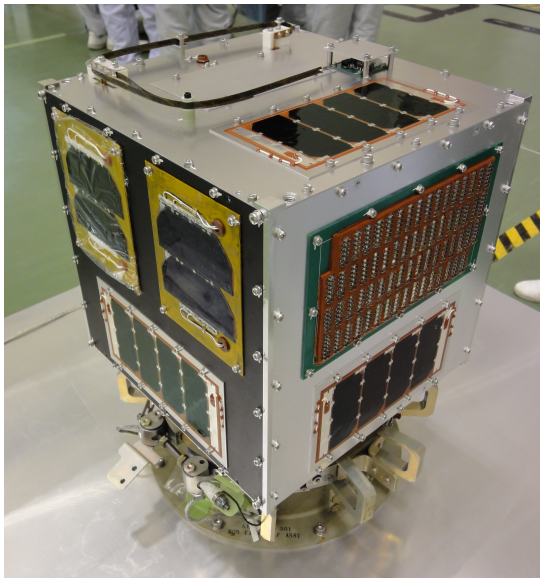
Sometime, arcs cause severe damages..





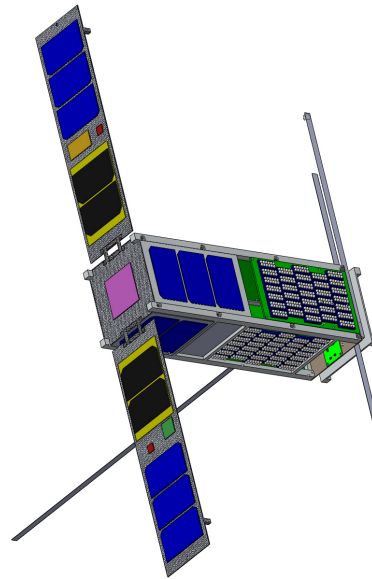
## **HORYU:** Low-Cost High Voltage Technology Demonstration Satellite Series

HORYU-2



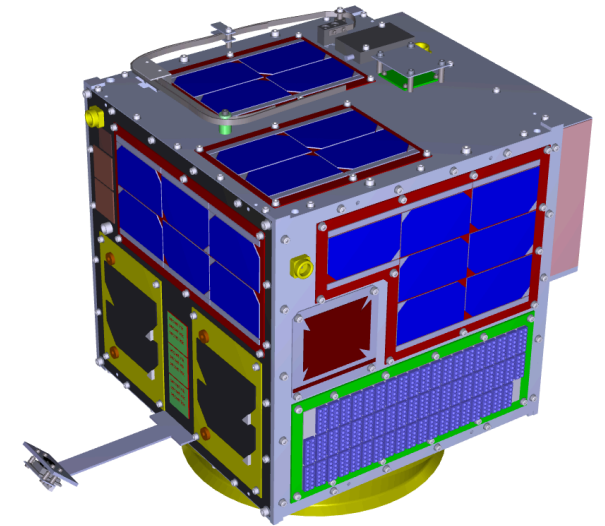
Launched in 2012

HORYU-3



Planned to be Launched  
in 2014

HORYU-4

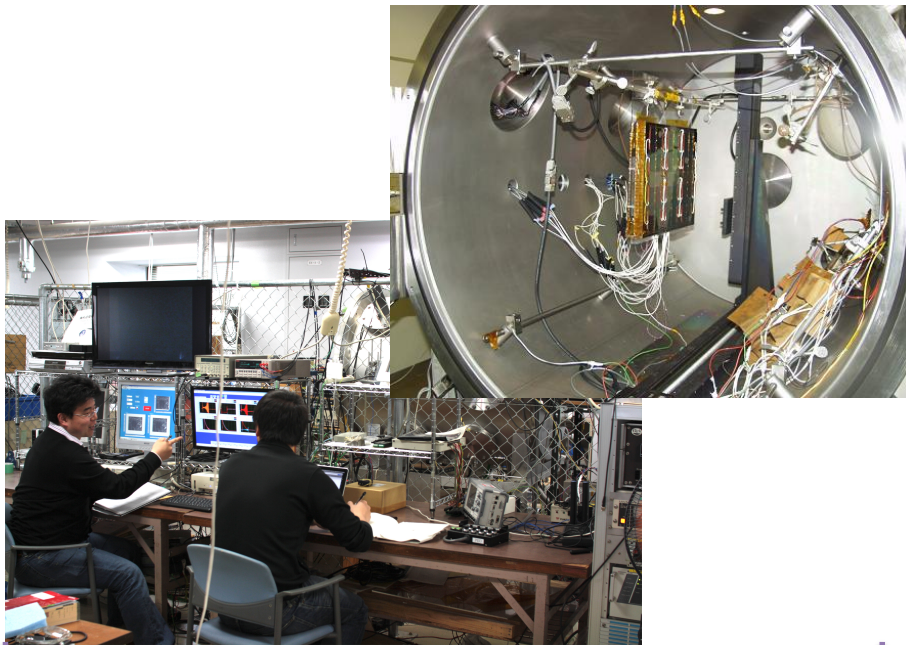


Planned to be Launched  
in 2015

# Introduction Concept of HORYU-Series

## In-Orbit Laboratory

Repeat similar tests performed on ground (Testing in Real Space!)



**Low Cost and Rapid Platform for:**

**Verify Ground Testing Method**

Such as ISO-11221

**Qualify New (High Risk) Technologies**

Such as High Voltage Solar Array

also... In-Orbit Measurement Instruments

New Components

In-Orbit Laboratory

Platform

Samples, Materials

Measurement Instruments

Spacecraft Basic Bus System  
(e.g. Comm, OBC, GPS...)

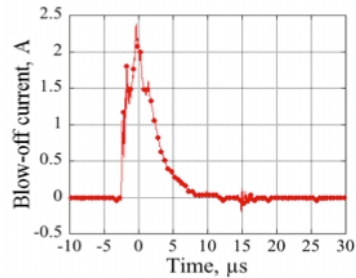
Idea  
New  
Technology

Simulation  
Ground Testing

**In-Orbit  
Demonstration**

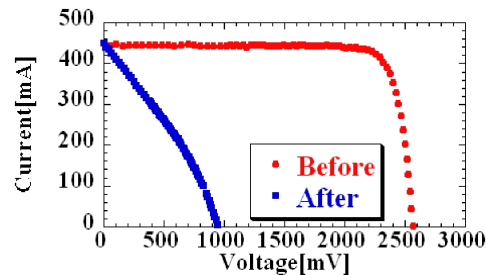
Practical  
Application

## Oscilloscope (High Speed V and I Measurements)



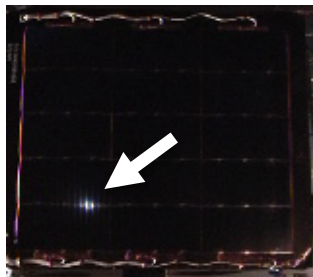
- Determine Magnitude and Type of Discharge
- Discharging Duration
- Rising Time
- Current Direction

## VI Characteristics Measurement



- Determine Impact of Discharge
- Degradation

## Video Camera and Image Capturing



- Identify Location and Magnitude of Discharge
- Visual Inspection

## Surrounding Environments (e.g. Attitude, Orbit, Temp, Plasma Density)

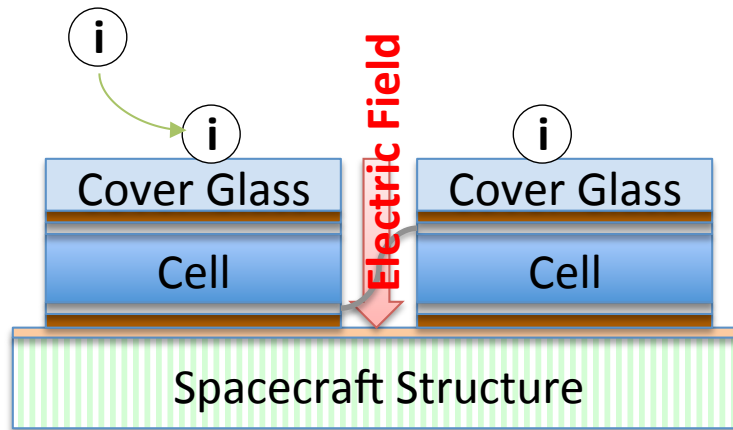


# Introduction

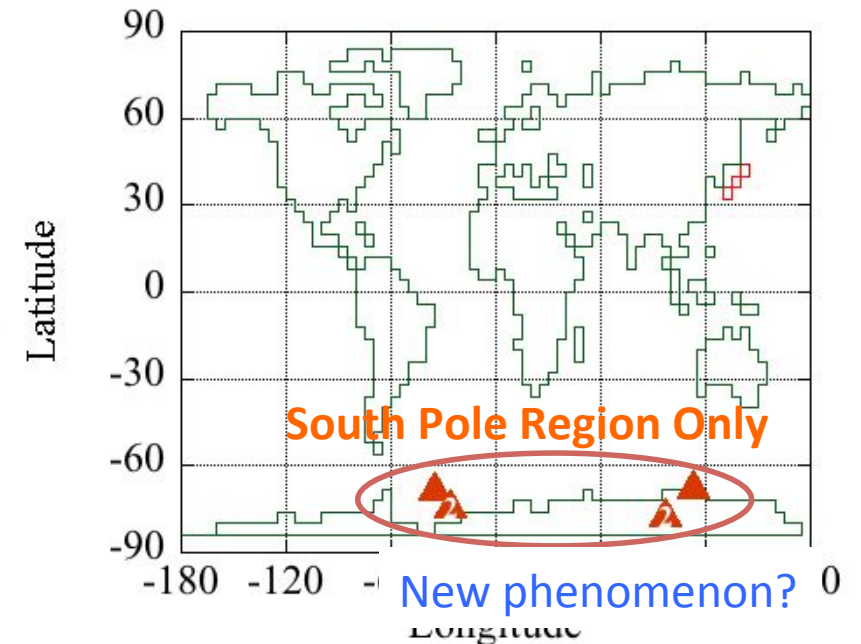
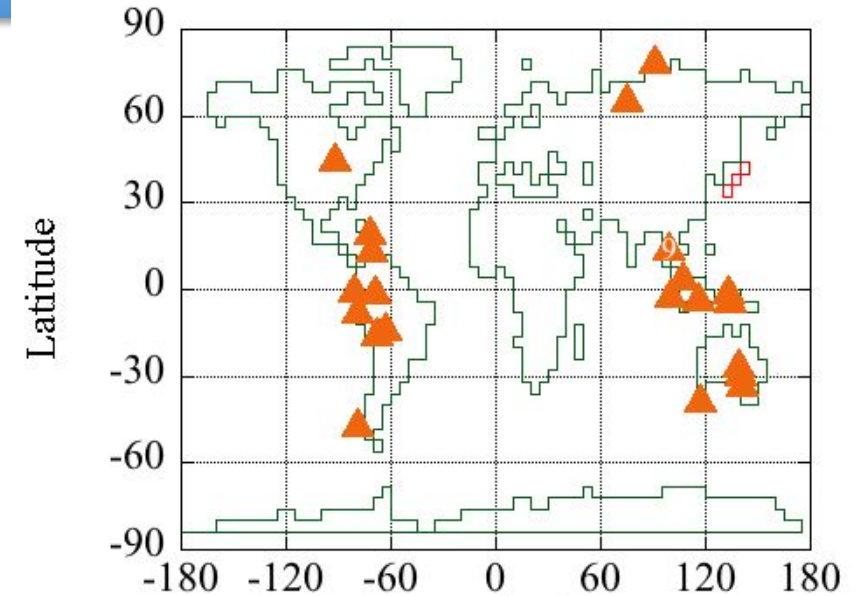
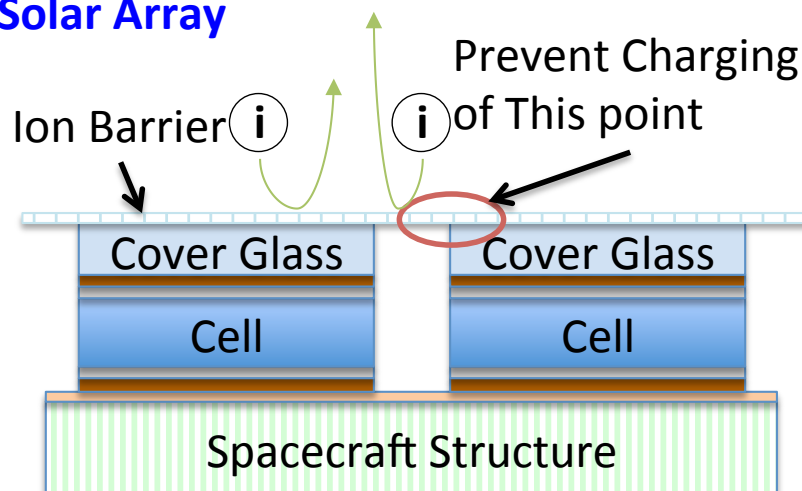
## HORYU-2

# Kyutech

### Conventional Solar Array

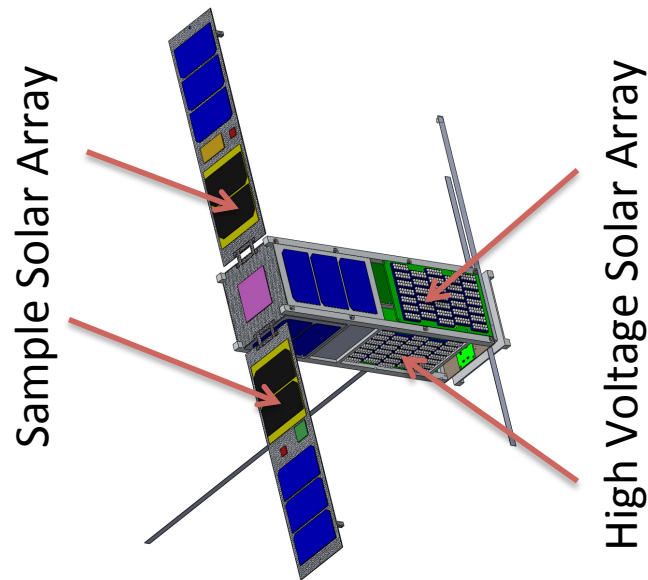


### Arc-Proofed Solar Array





# On-Board Oscilloscope Design Constrain



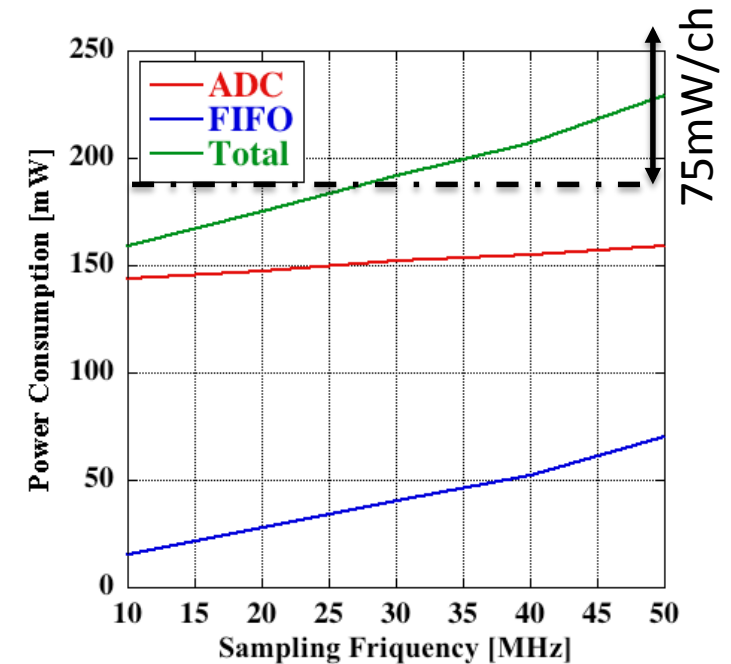
Surface is mainly used for high voltage experiment.  
No contribution to spacecraft power supply.



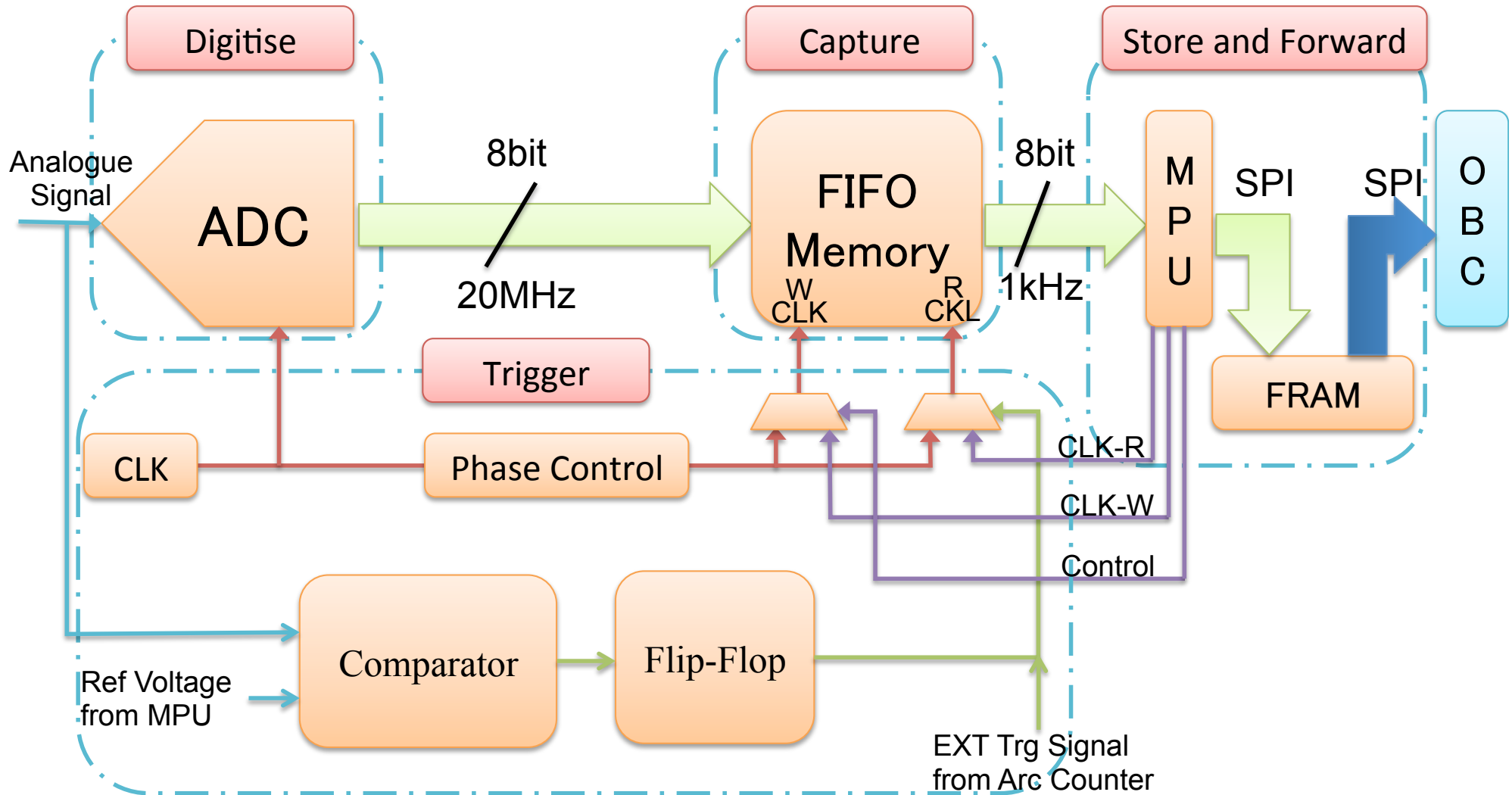
Very limited Orbit Average Power.  
Besides, need to operate continuously for long time.

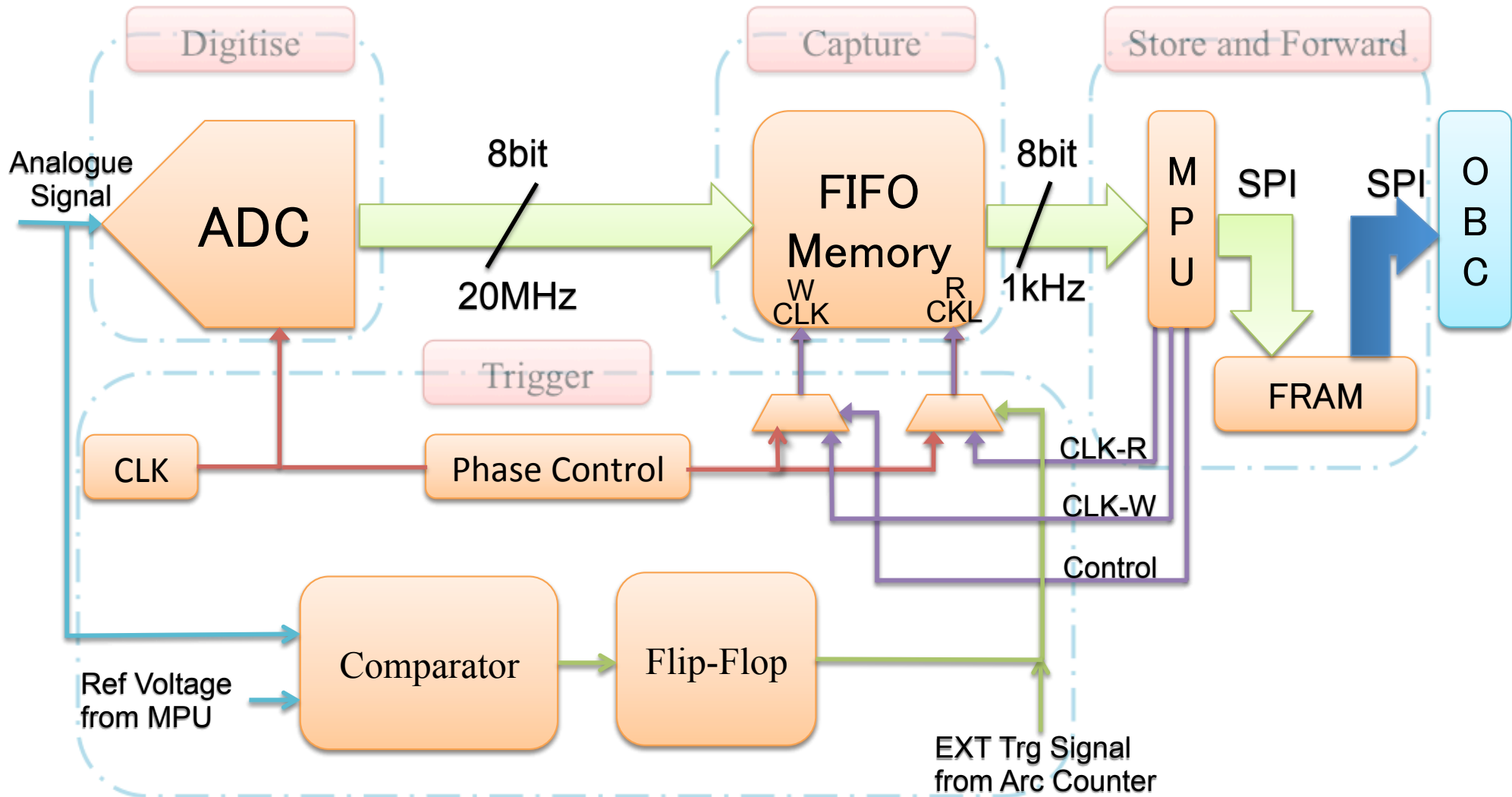


Low Power Consumption is the top priority in the design.

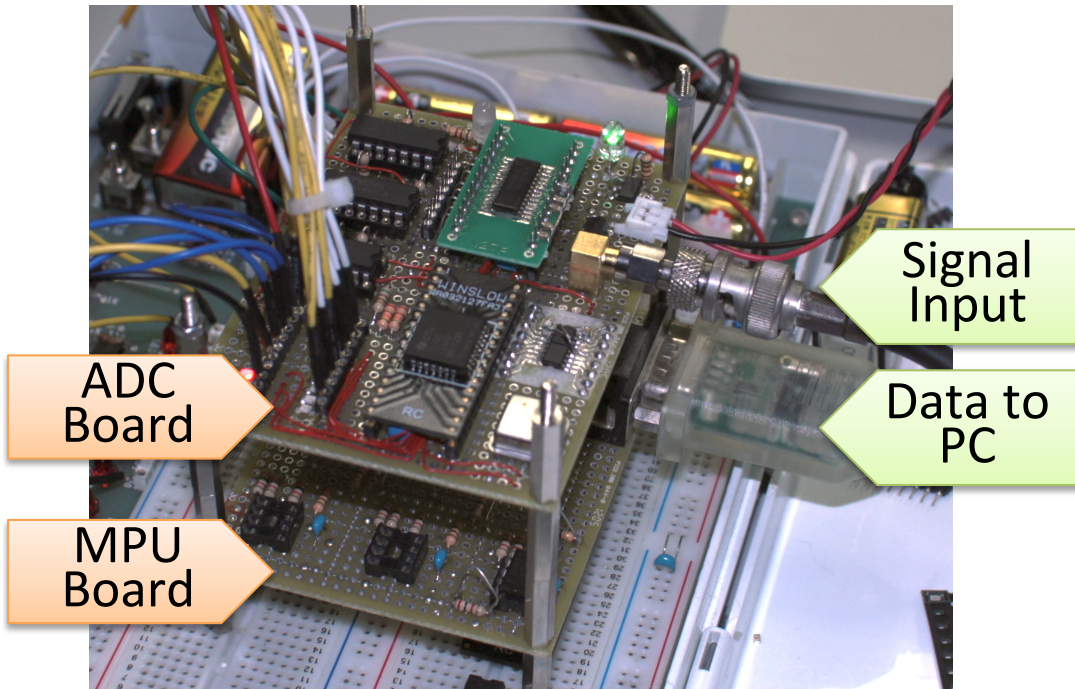
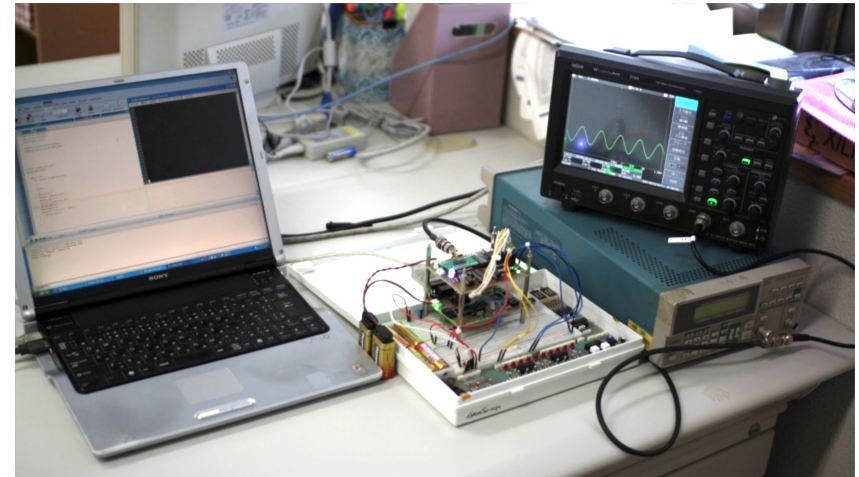


# On-Board Oscilloscope Design Principle

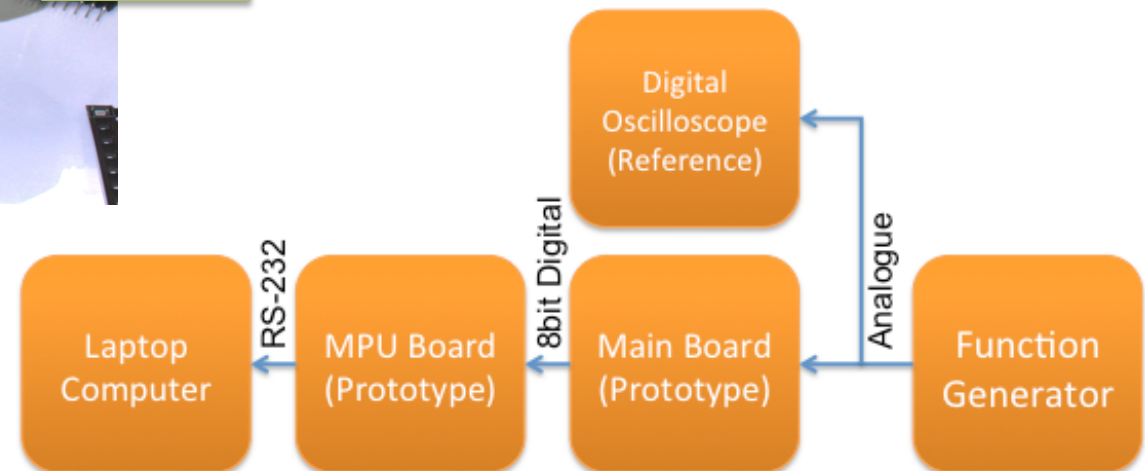




# Prototype of On-Board Oscilloscope

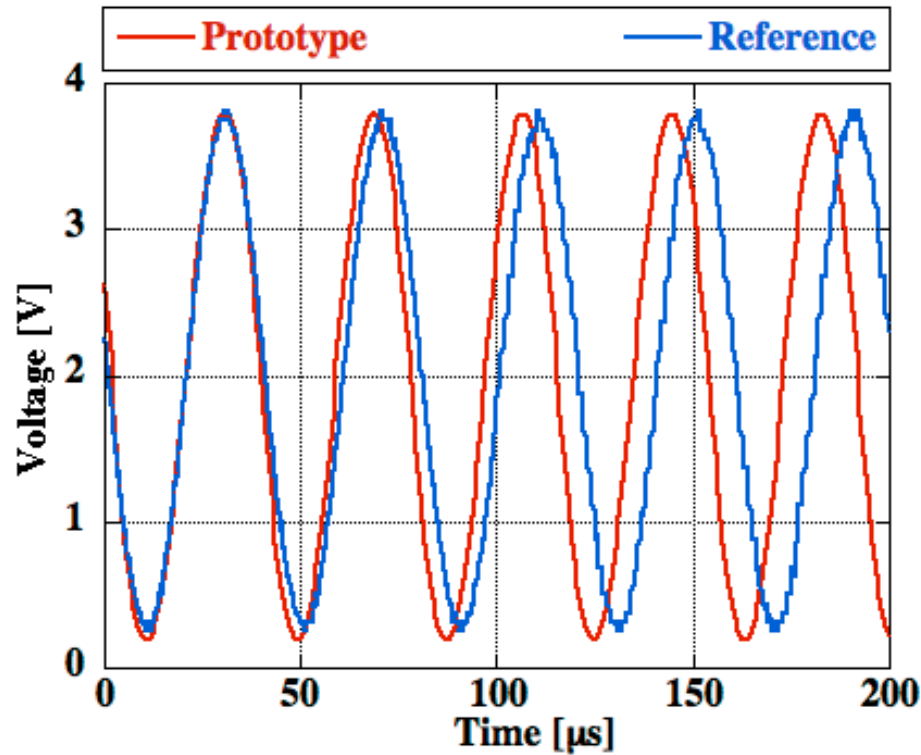


2MHz and 4MHz Sampling Clocks

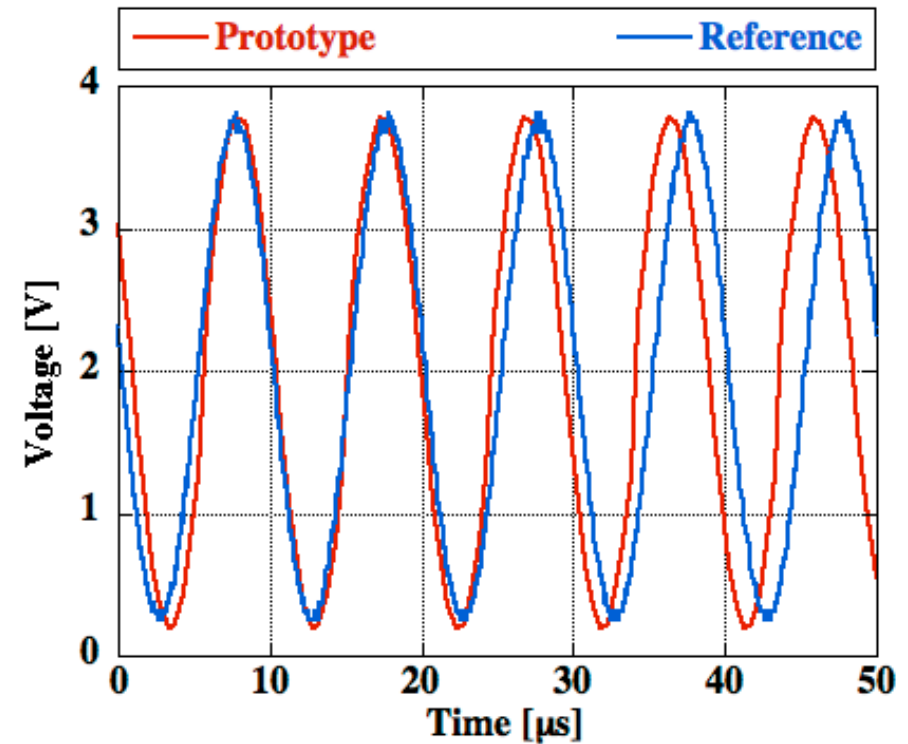




## 2MHz Sampling Oscillator

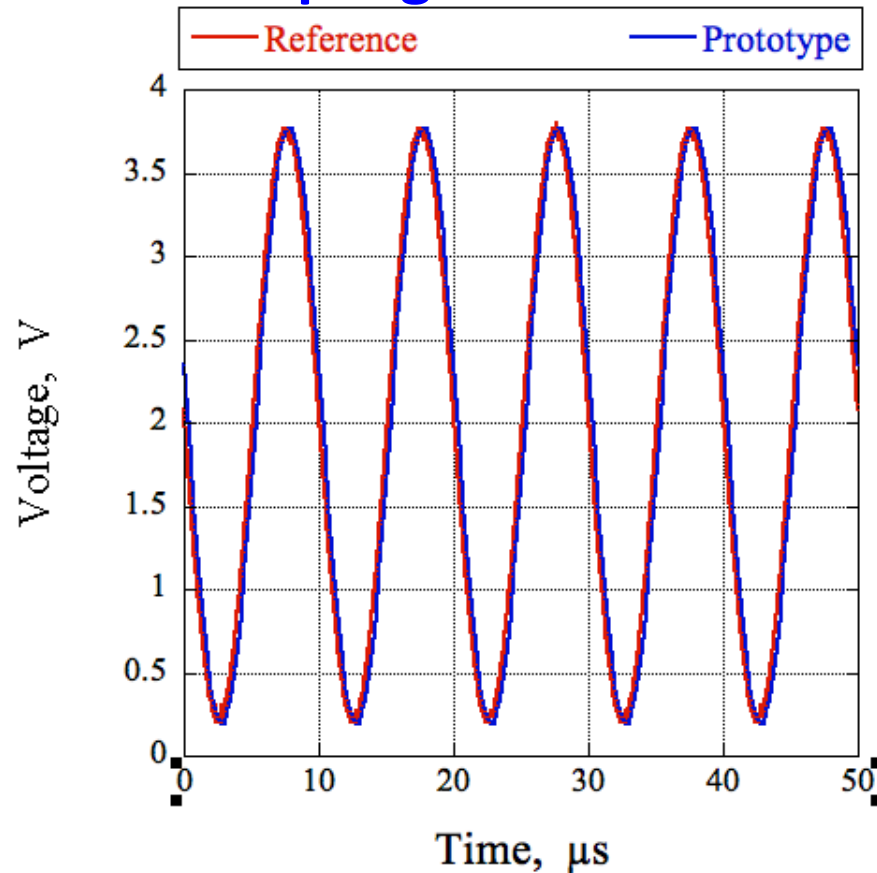


	Prototype	Reference	Differ
Freq	104.6 kHz	100.1 kHz	4.5%
Cent	1.984 V	2.00 V	0.8 %

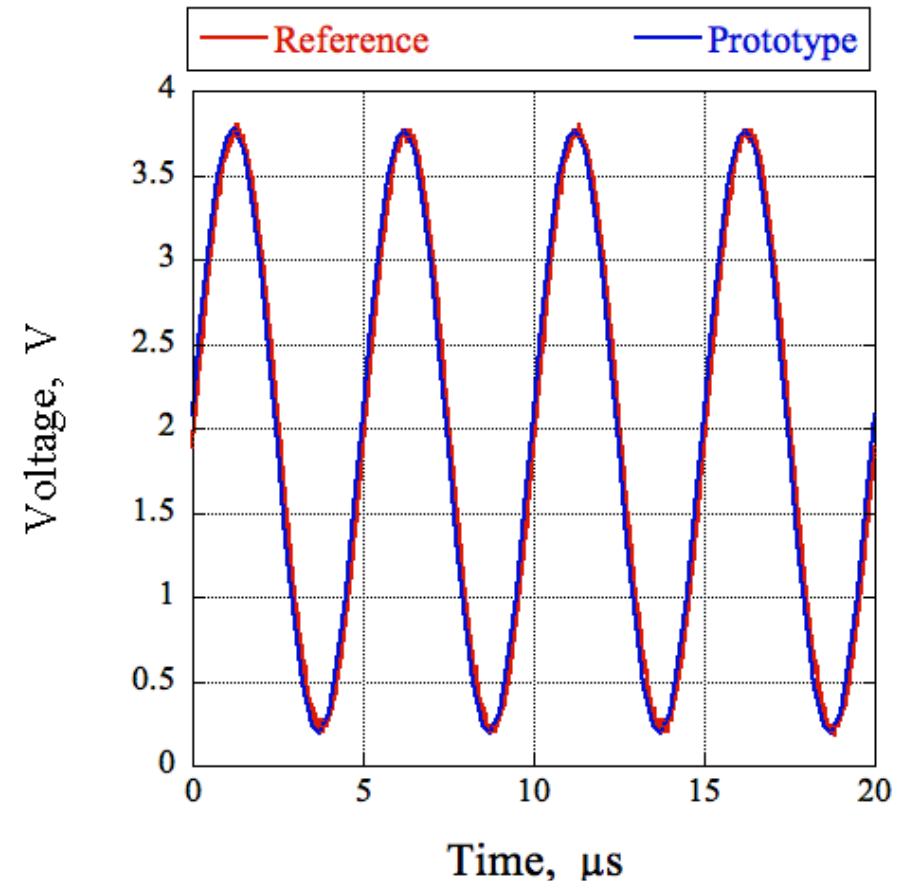


	Prototype	Reference	Differ
Freq	26.36 kHz	25.08 kHz	5.1 %
Cent	1.984 V	2.03 V	2.27 %

## 4MHz Sampling Oscillator

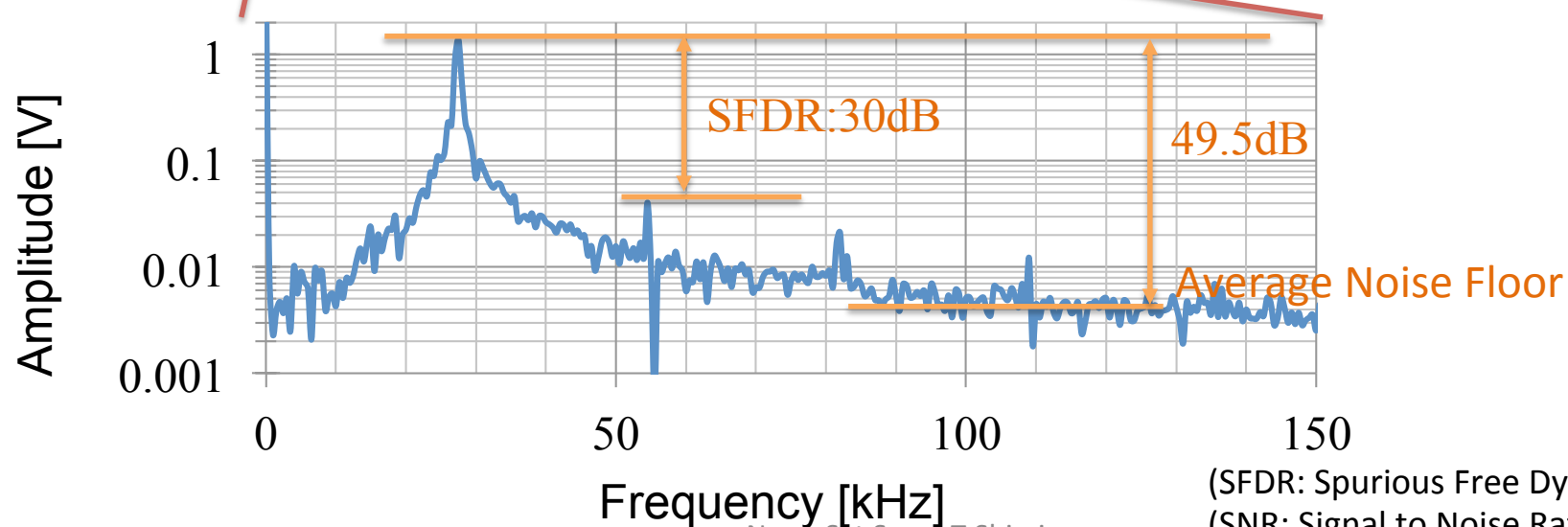
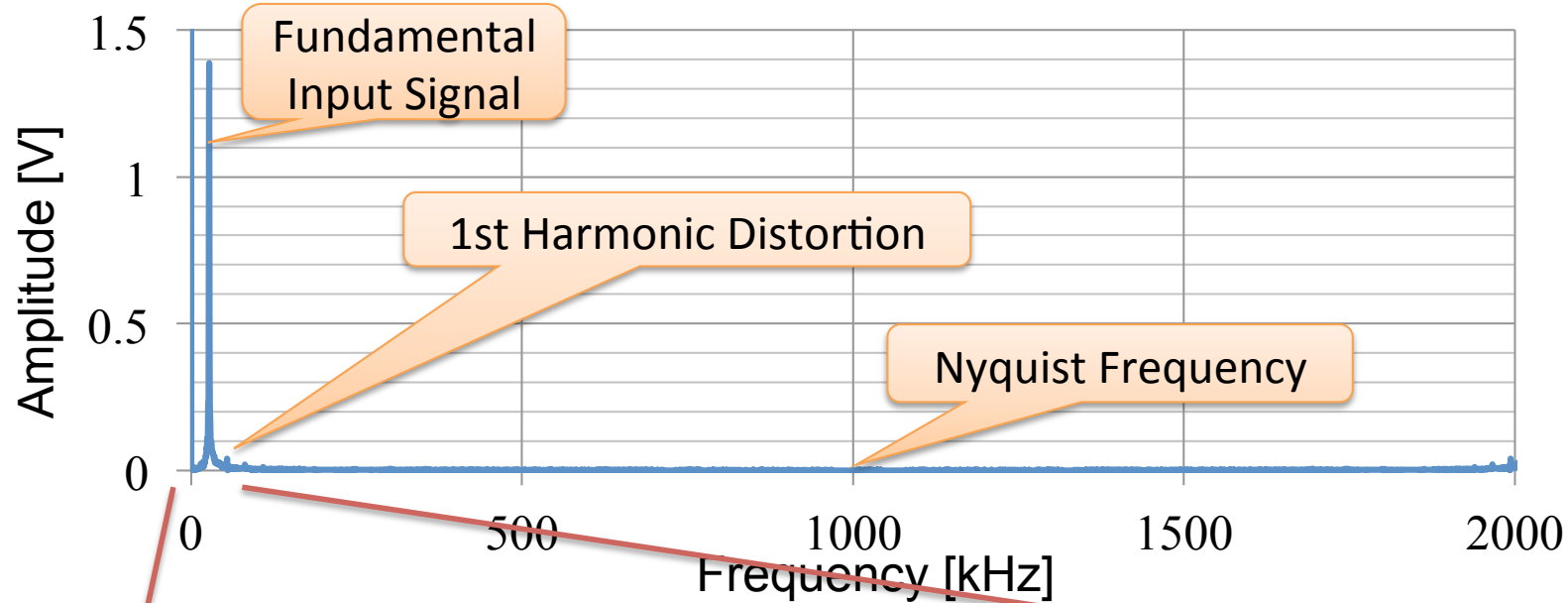


	Prototype	Reference	Differ
Freq	100 kHz	100 kHz	0%
Cent	1.98 V	2.0 V	1 %



	Prototype	Reference	Differ
Freq	200 kHz	200 kHz	0 %
Cent	1.978 V	2.0 V	1.09 %

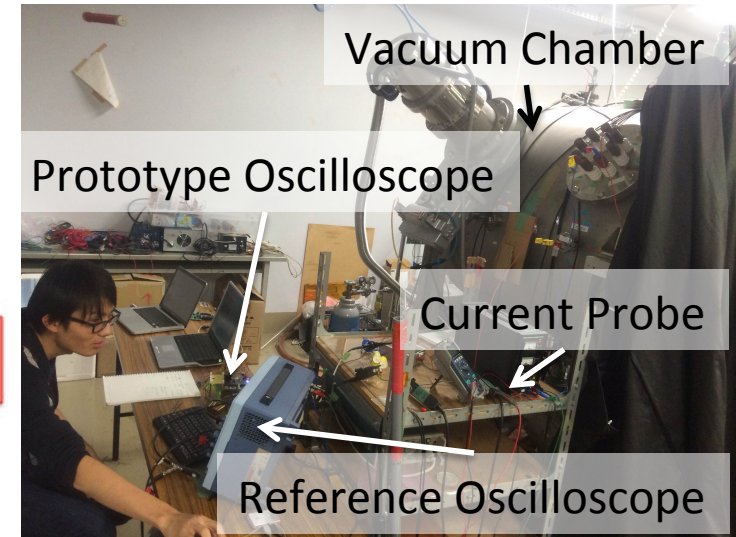
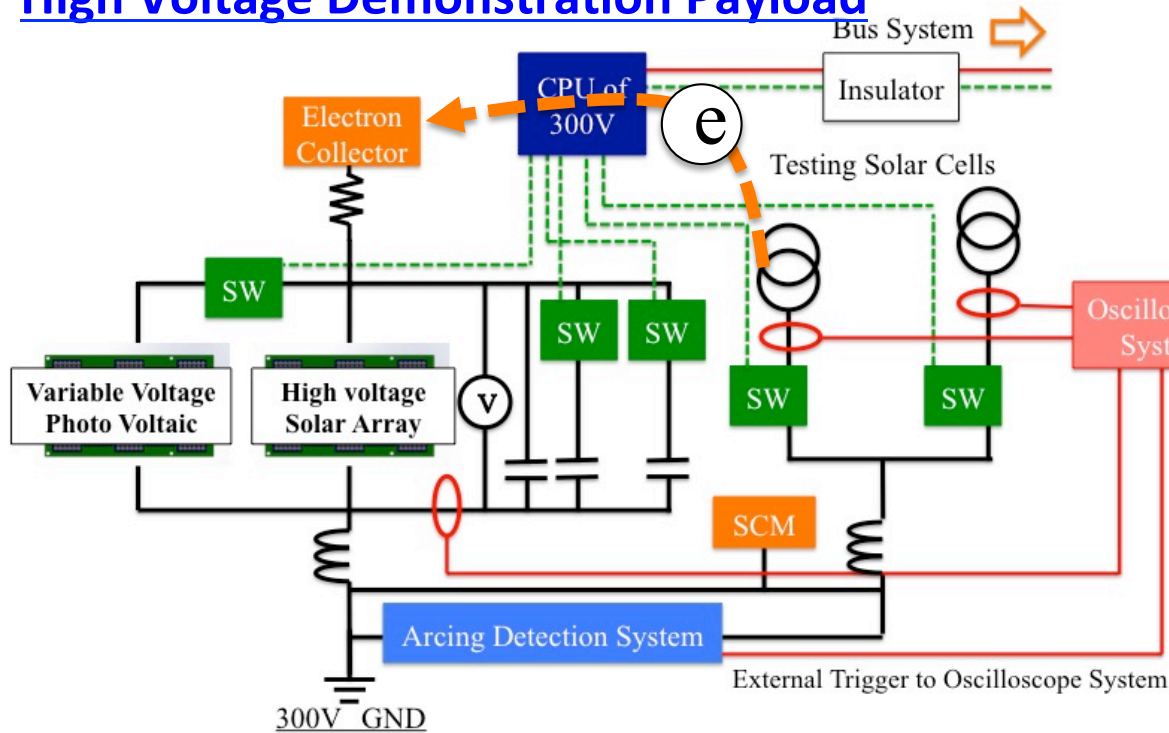
# Prototype of On-Board Oscilloscope



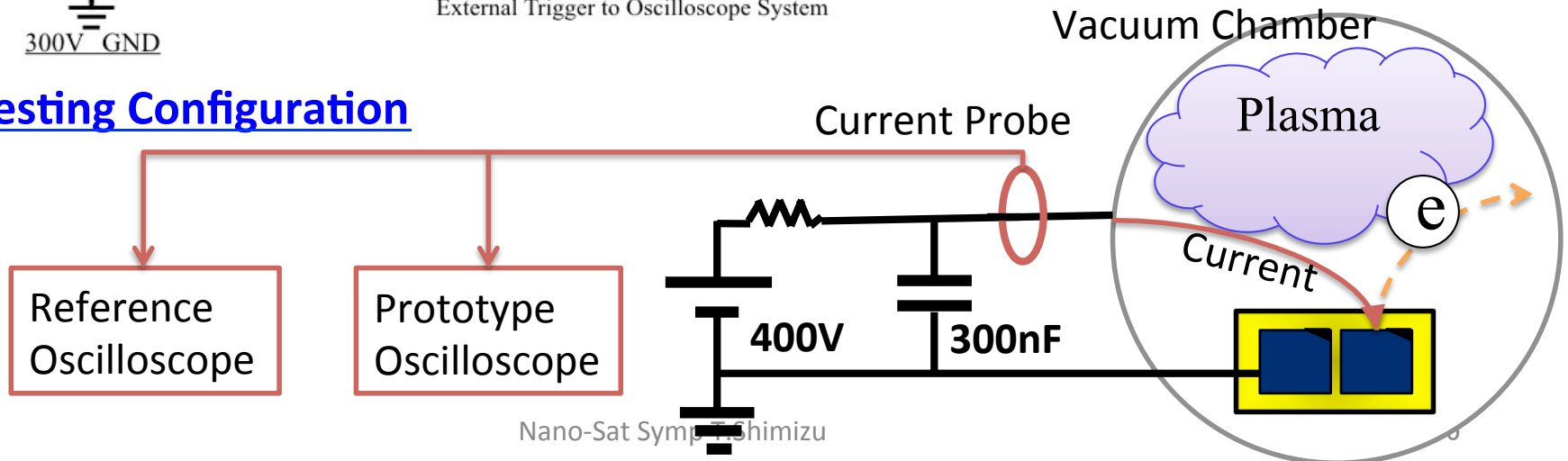
(SFDR: Spurious Free Dynamic Range)  
(SNR: Signal to Noise Ratio)

# Prototype of On-Board Oscilloscope

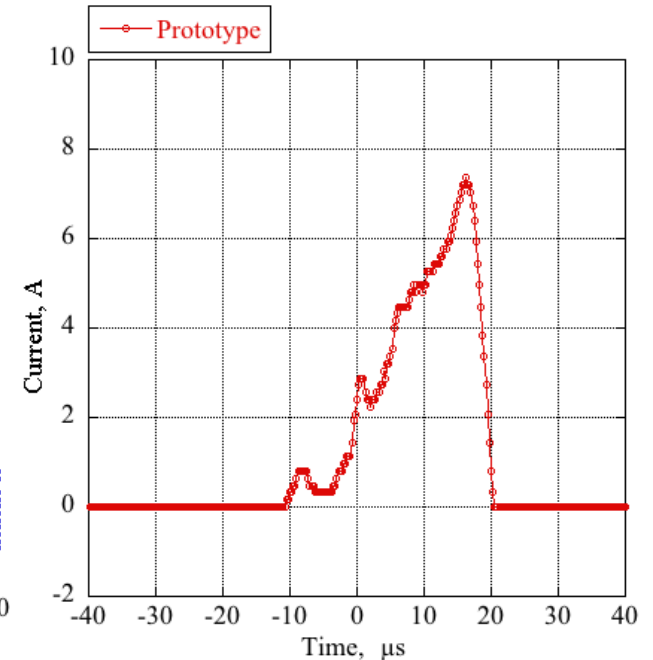
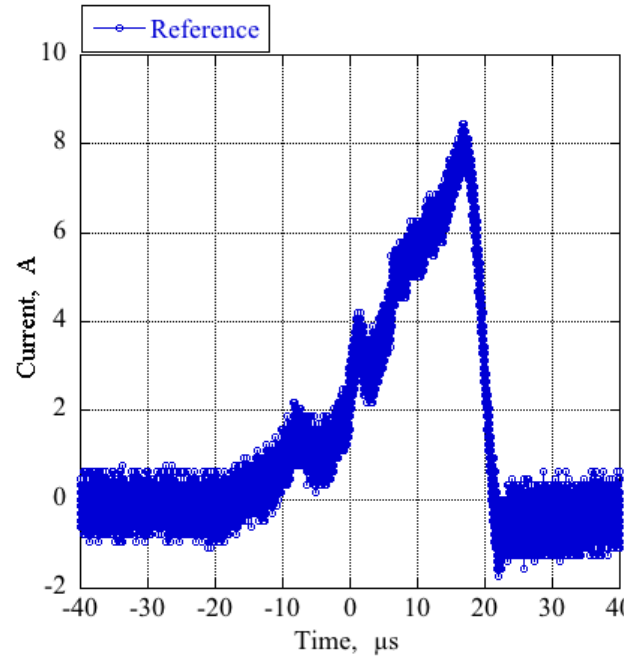
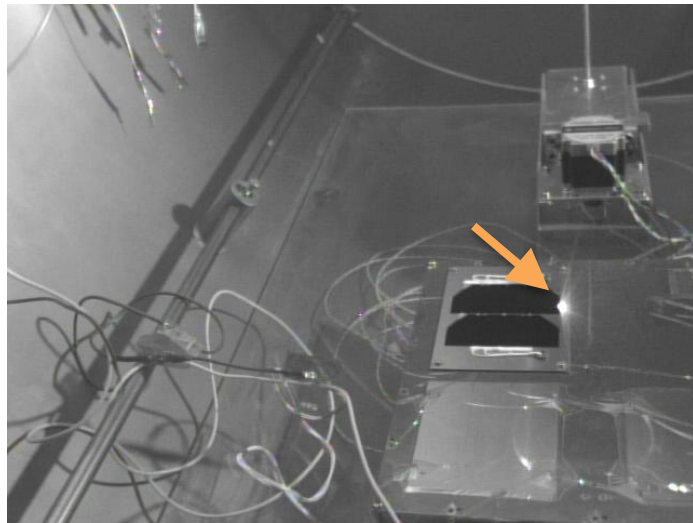
## High Voltage Demonstration Payload



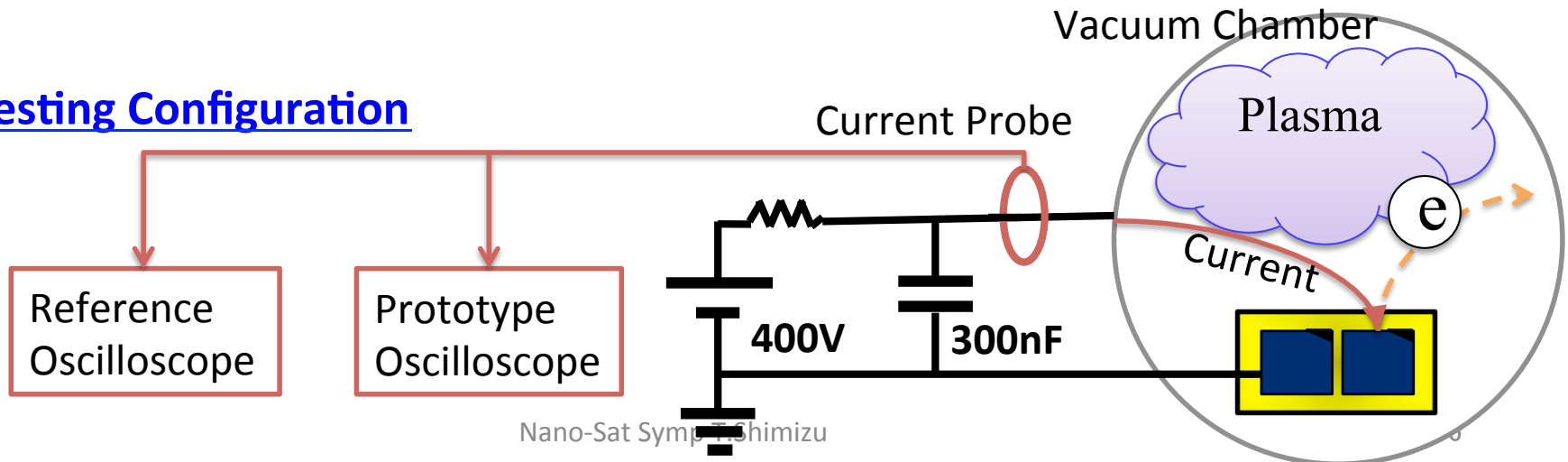
## Ground Testing Configuration



# Prototype of On-Board Oscilloscope



## Ground Testing Configuration



# On-Board Oscilloscope Flight Version

Number of Channels: 4ch

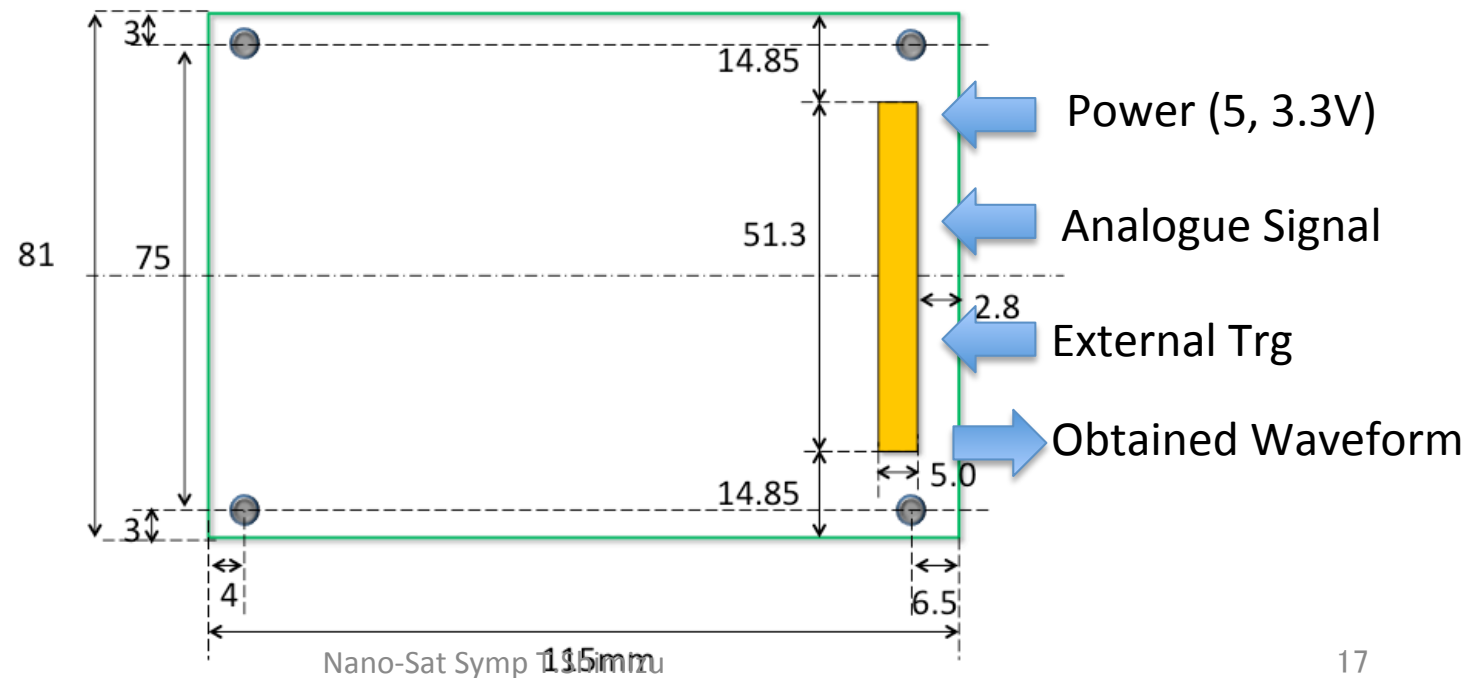
Sample Rate: MAX 40MHz (20, 10 and 5)

Number of Samples: 8192

Trigger Position: 1 to 8192

Trigger Mode: Up/Down Edge

Trigger Source: Internal and External





# Conclusion and Future Works

The Low-Cost Low-Power On-Board Oscilloscope has been developed for Small Satellite Missions, such as CubeSat (HORYU-3) and HORYU-4.

The first mission will be High Voltage Technology Demonstration, which measures arcing current waveforms in-orbit. Such waveform has not yet been obtained in-orbit, and therefore may find new phenomenon.

The prototype has been tested with real arcing and showed promising results.

Flight model will soon be manufactured based on this prototype design and the results.

# Thank You

Any questions?

[shimizu@tobata.isc.kyutech.ac.jp](mailto:shimizu@tobata.isc.kyutech.ac.jp)