Robust Self-Powered Wireless Hydrogen Sensor

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Start Date = January 1, 2005
Planned Completion = March 31, 2007

Research Goals and Objectives

- Research Goal:
  To Develop a Self-Powered Hydrogen Sensor with Wireless Communications Interface.
- Objectives:
  – Integrate a low-power nanosensors, a low-power wireless transceiver, an energy harvester, and a power management circuit.
  – Test the performance of integrated sensor under different use scenarios.

Relevance to Current State-of-the-Art

- Integration of three key enabling technologies
  - Nanosensors with very low bias voltages and currents to detect hydrogen
  - Wireless transceivers with very low power consumption and high efficiency (less than 90 μW standby and 50 -100 ft range)
  - Energy harvesting devices with efficient power management circuit

Relevance to NASA

- Why hydrogen sensing? **Safety!**
  - Detection of fuel leaks in spacecraft using lightweight, long lifetime sensors (Hydrogen has been used as fuels in many NASA's space exploration missions).
  - Production, Storage, Transport
    Hydrogen concentration in air reaches a dangerous level at 4%.

Budget, Schedule and Deliverables

- **Budget: $70,000 for FY04**

Phasing Plan

Q1	Q2	Q3	Q4
$3,812	$23,898	$23,898	$18,392

Project award date 9/30/04

Project started 1/1/05

Completed 1st prototype and test 4/1/05

Q1	Q2	Q3	Q4

Completed redesign to improve performance and started 2nd prototype integration 7/1/05

Completed 2nd Prototype and start testing 10/1/05

On Target

Deliverables: schematics and test results of prototype circuits

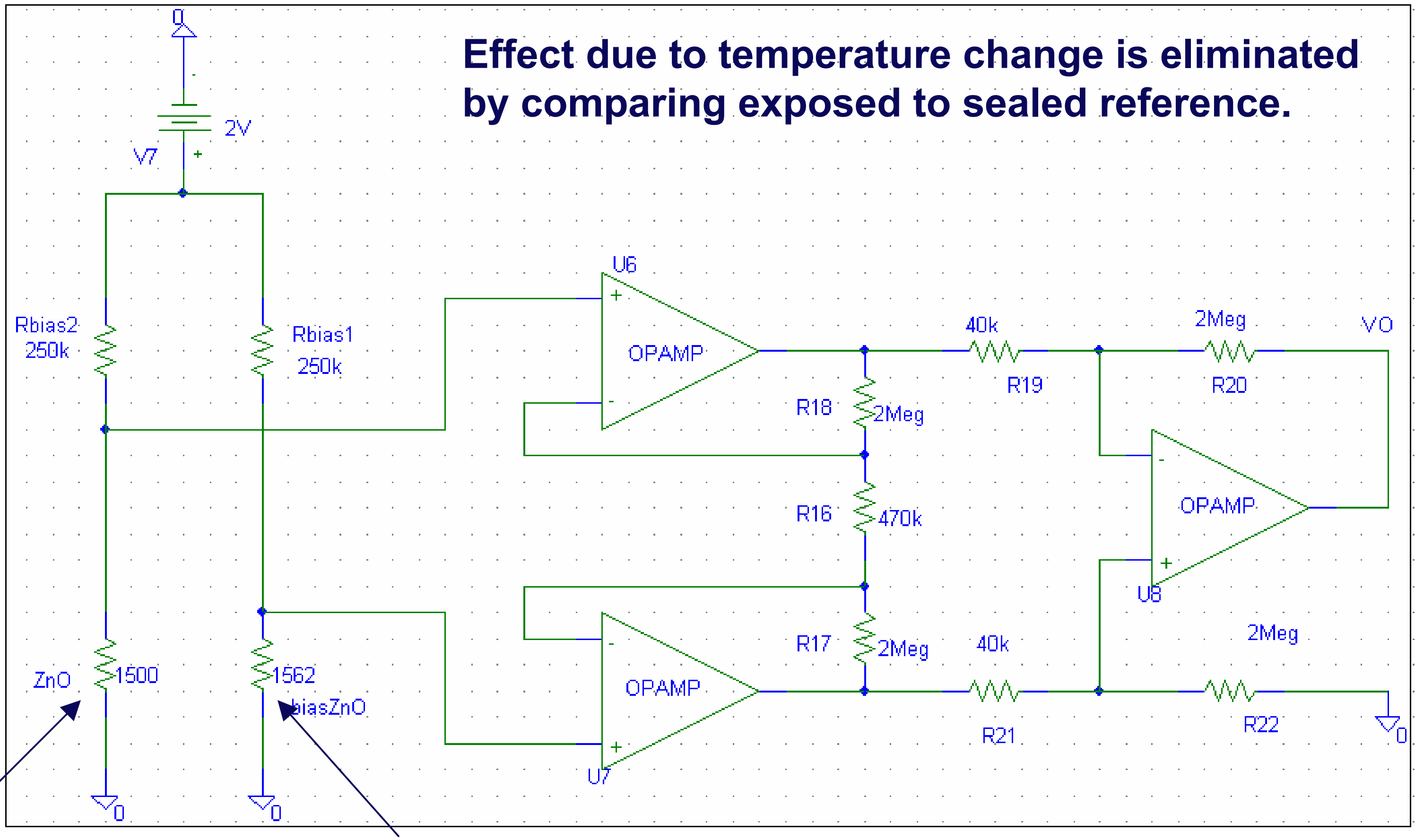
Anticipated Technology End Use

- Hydrogen leak detection in process plant, storage tank, and during transport.
- Monitoring hydrogen concentration during production.
- Distributed low power sensor system with very long lifetime. No need to replace batteries and sensor devices. Low maintenance.
- Integrating various sensors with wireless data interface using high temperature electronics for adaptive sensing and control in fuel cells.

Accomplishments and Results

- Significantly reduced the standby power consumption from 180mW in the first prototype to **86μW (2μW from micro-controller)** in the second prototype. A factor of 2,000 times improvement!
- Reasons:
  - low power ZnO nanorod sensor reduced power consumption from 2mW (GaN Schottky diode) to **84-88μw (0-500ppm)**, and operating at room temperature.
  - Low power detection circuit and RF transceiver running from 2V supply.
  - Optimized power management design at 2V supply, reducing huge efficiency loss from 9V battery to old 5V circuits – cutting down 160mW.
- Transmission distance tested up to 14.5m.
- Currently conducting test in hydrogen chamber.

Schematic of Low-Power Detection Circuit



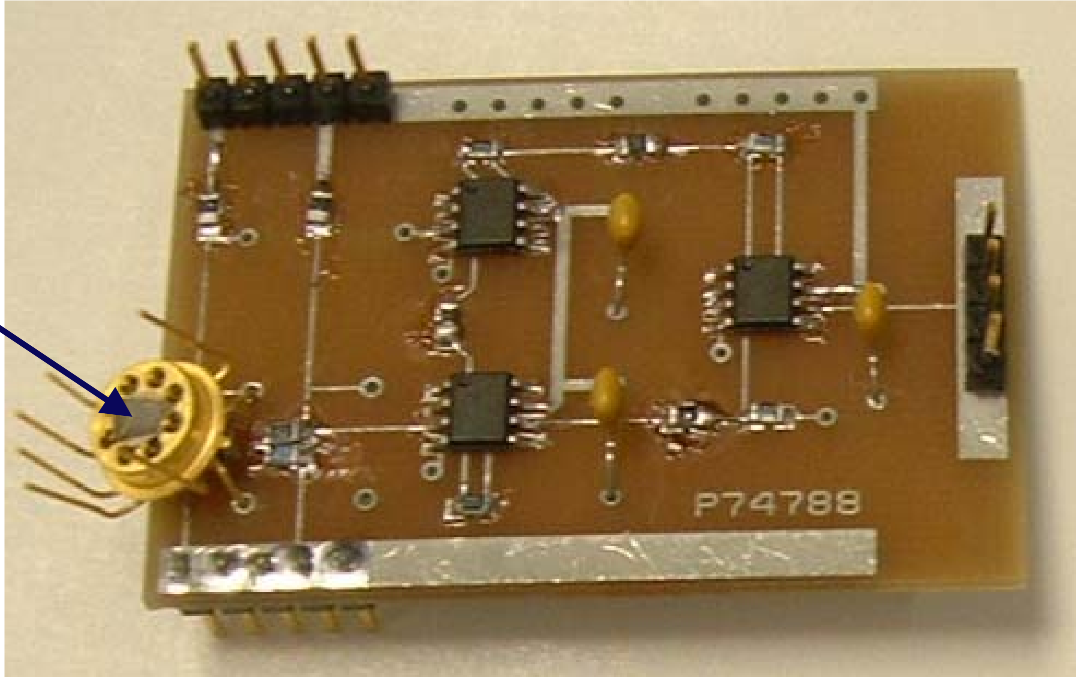
ZnO Nanorod Exposed

ZnO Nanorod Sealed

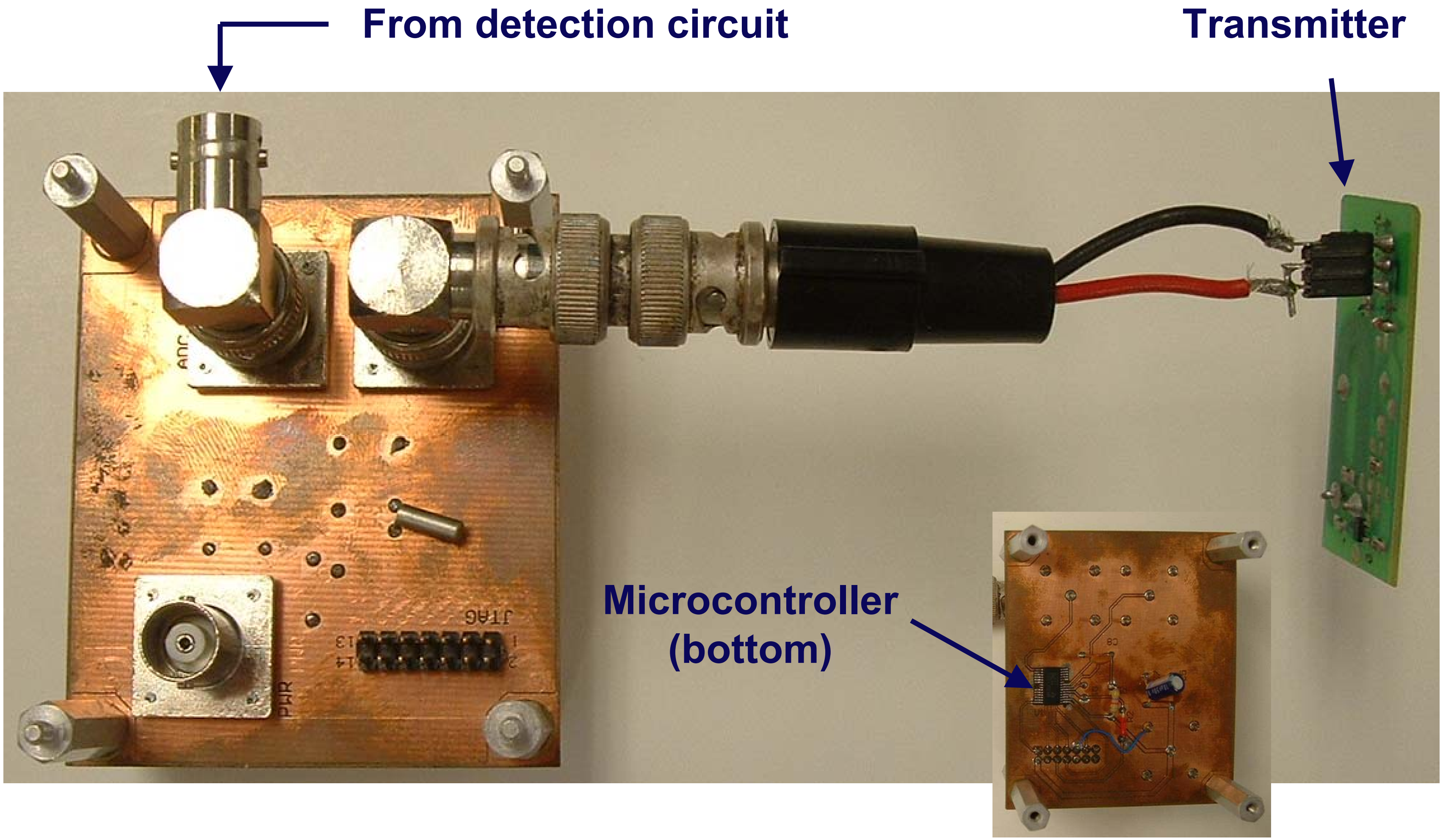
Power consumption = 83.6 μw

Detection Circuit Integrating ZnO Nanorod Sensor

ZnO Nanorod



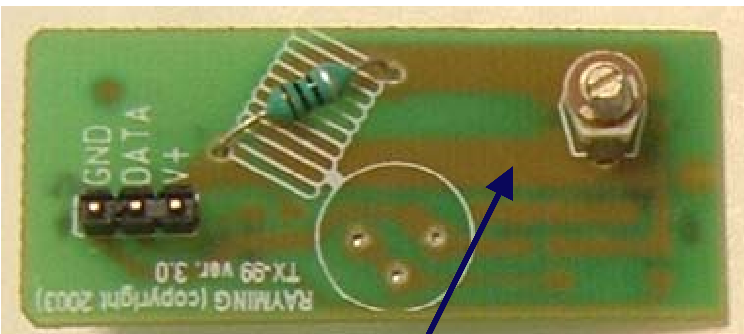
Microcontroller and Transmitter



Transmitter and Receiver

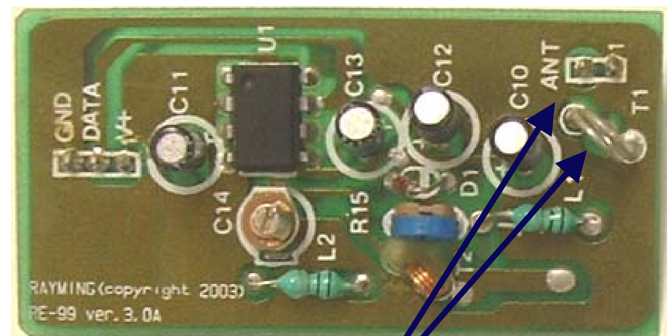
Radio Frequency: 300 MHz

Transmitter



Integrated Antenna

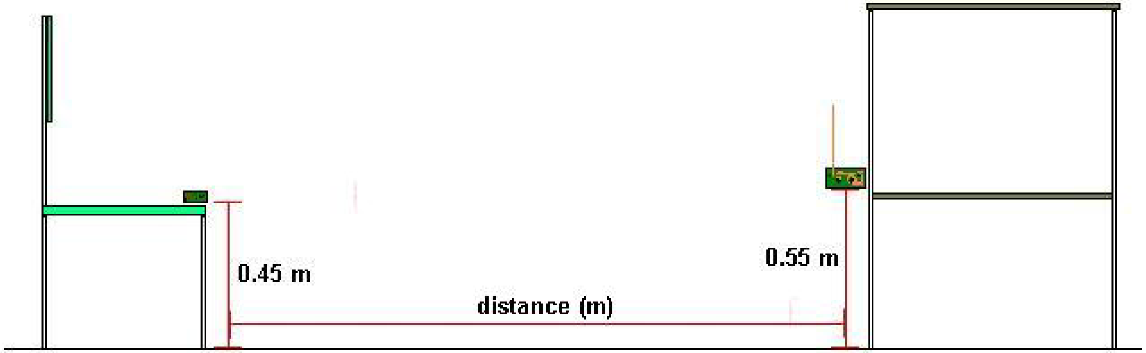
Receiver



Integrated Antenna or External Antenna

Testing Transmission Range

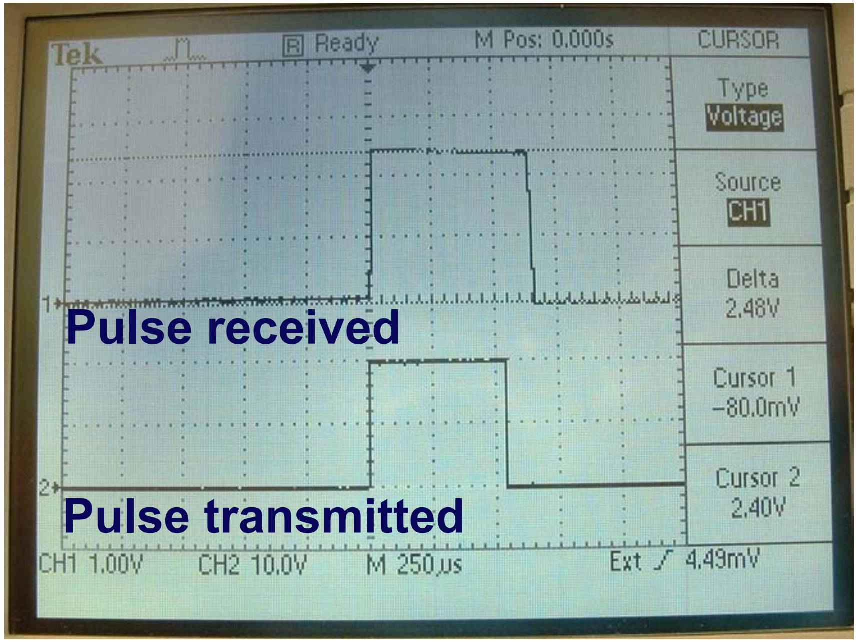
Experiment Setup:



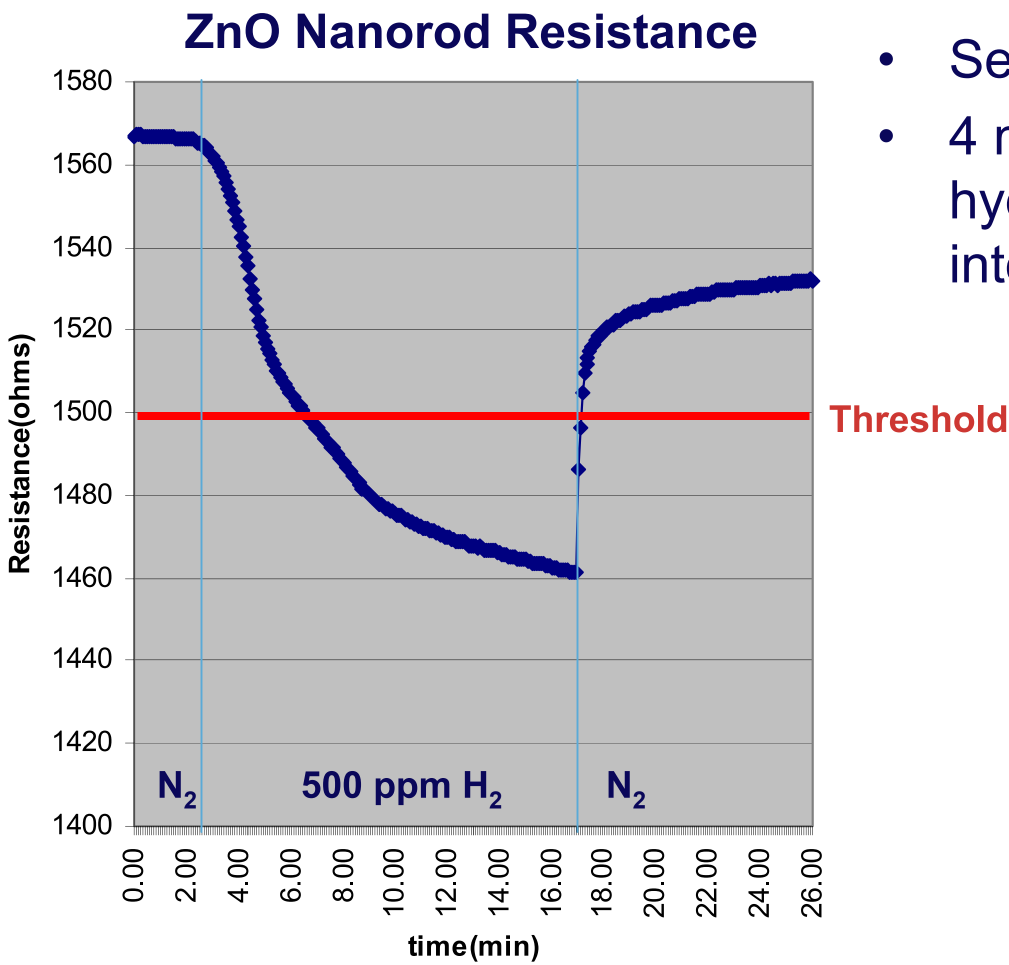
- Transmitter height: 0.45 m
- Receiver height: 0.55 m
- Transmitter sends a continuous pulse of width 400 uS

Testing Using Threshold Detection

- In threshold detection, the transmitter sends a pulse when hydrogen concentration level is over a preset limit.
- When sending the signal continuously, the power consumption would be 1.5mA x 2V = 3mW. However, when sending a pulse of 500 μS in every second, the effective power consumption is only 1.5 μW.



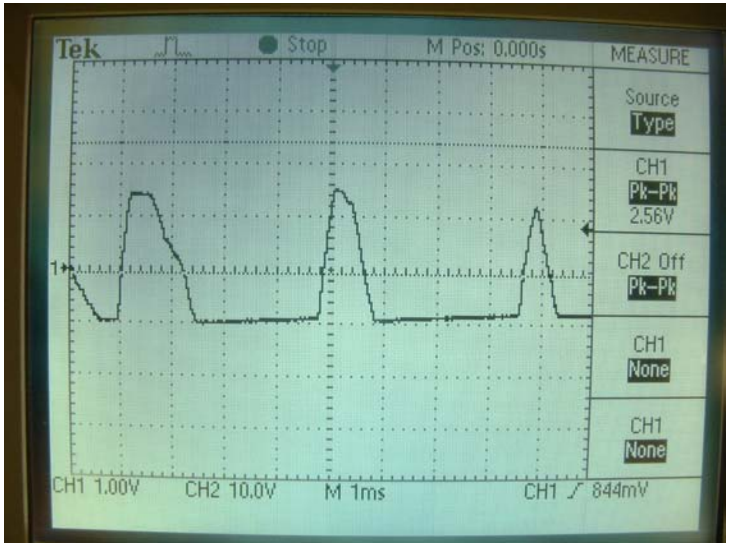
Threshold Detection



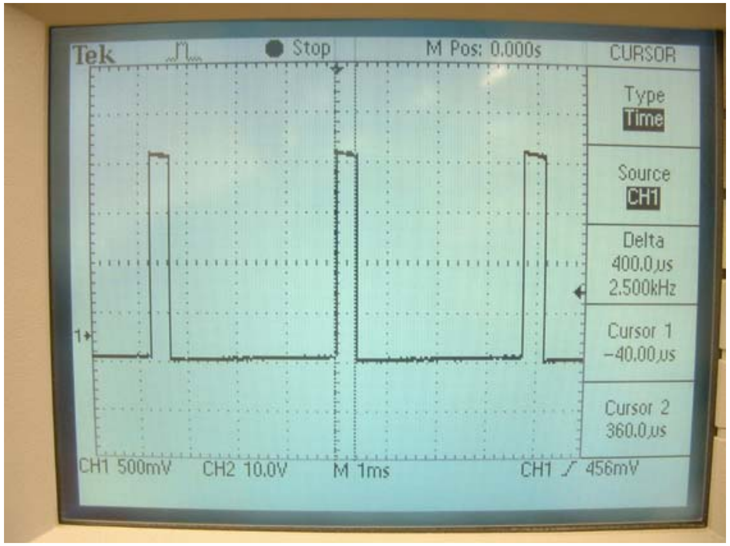
- Set threshold at 1500Ω
- 4 minutes after turn on hydrogen of 500ppm to flow into the test chamber.

Transmission Range Test Results

- Without External Antenna: Max Distance ~ 3.5 meters



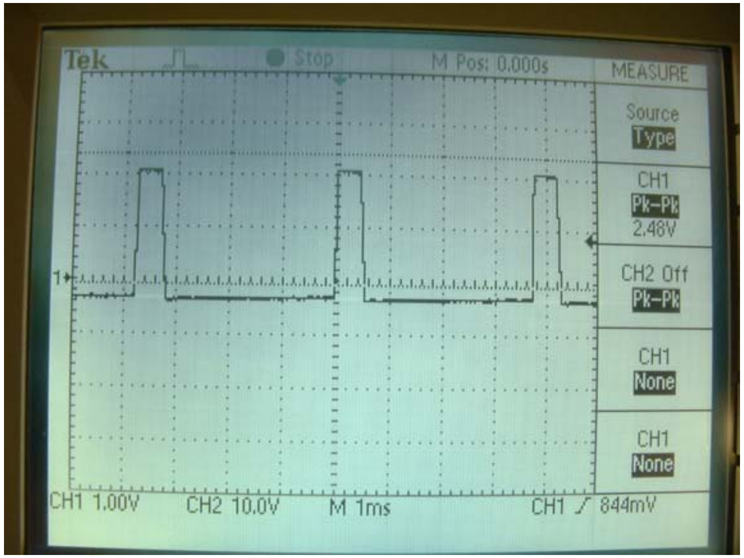
Received Data @ 3.5 m



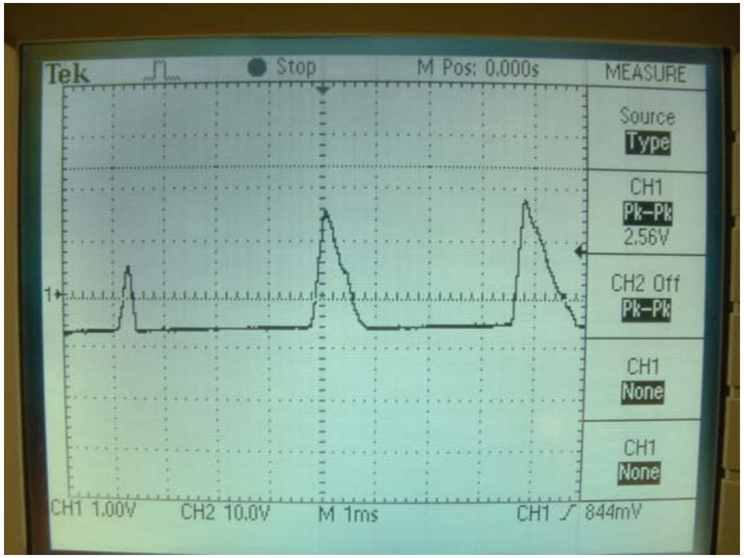
Expected pulse shape

Transmission Range Test Results

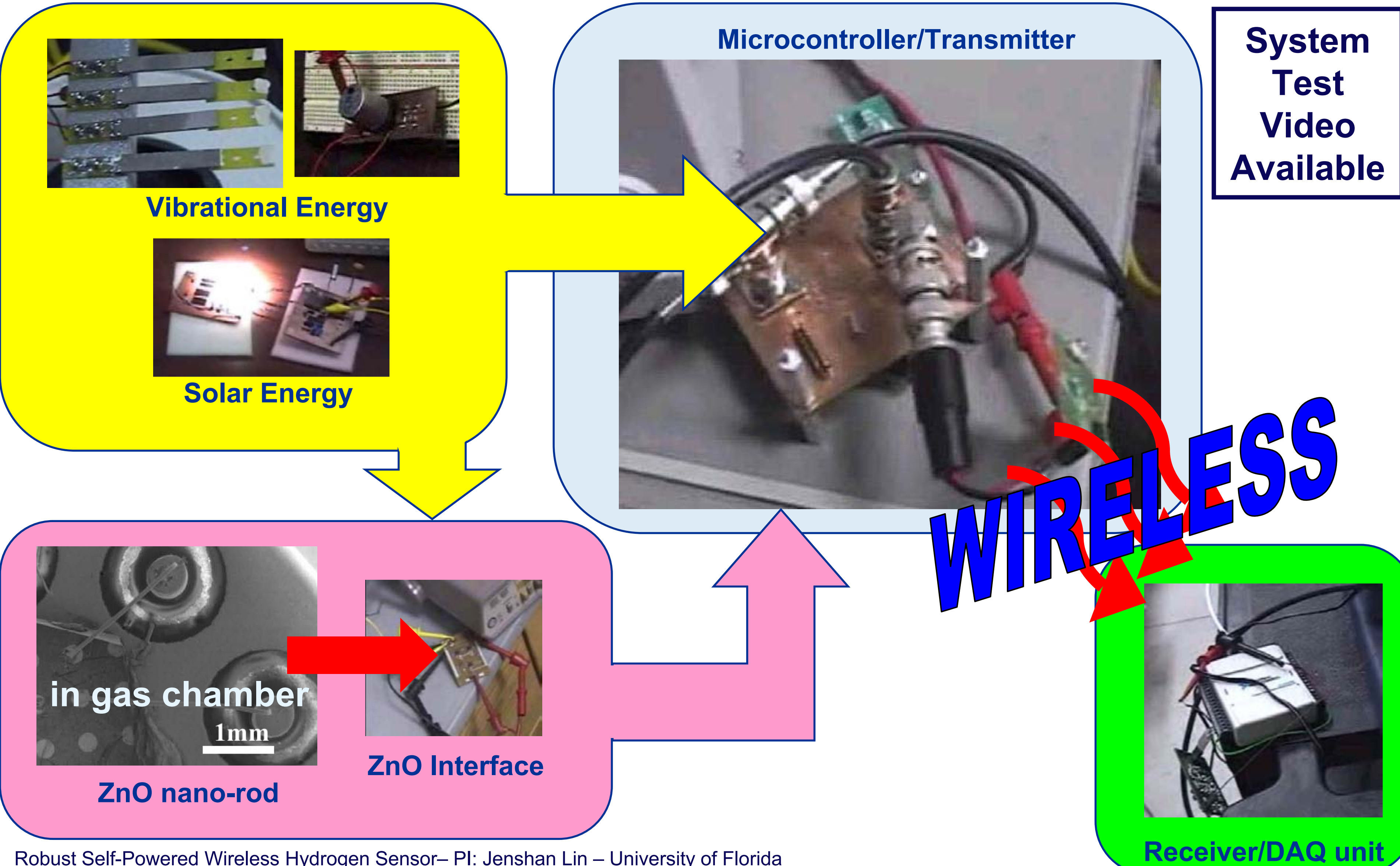
• With External Antenna: Max Distance ~ 14.5 meters



Received Data @ 3.5 m



Received Data @ 14.5 m


Vibrational Energy
Solar Energy
Microcontroller/Transmitter
System Test Video Available
WIRELESS
in gas chamber
1mm
ZnO nano-rod
ZnO Interface
Receiver/DAQ unit

Future Plans

- Further test of transmission range, hardware and software operation.
- Test of concentration level detection using hydrogen chamber.
- Perform testing in various scenarios.
- Field test in NASA GRC facility.
- Improve the design with software configurable low power RF transceiver to have higher level security.
- Collaborate with NASA GRC to fine tune the design for future missions.