Setting the Standard for Automation™

Solar Powered Wireless Sensors & Instrumentation:
Energy Harvesting Technology Reduces Operating Cost at Remote Sites

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Presenter

- Michael A. Macchiarelli, President
  Imagine Instruments LLC
  Stratford, Connecticut

- Electronic Engineering, Community College of USAF
- 23 Years Experience Designing Sensors, Process Controls and Instrumentation
- - 5 awarded and 6 pending U.S. and International Patents
- Recent Project
  - Line of Solar Power Systems for Sensors and Instrumentation operated in remote locations
- Employment History
  - Imagine Instruments LLC (6 Months)
  - Omega Engineering Inc. (23 Years, Product Development Manager, Electronic Design Engineer)
  - Norden Systems, United Technologies (2 Years, Engineering Assistant) Military Electronics
  - USAF (6 Years, Aircraft Electrician, Avionic Sensors Systems Technician)

Presentation Outline

- Wireless Sensor System Overview
- Energy Harvesting & Storage
- Solar Power System Components
- Example Application
- Benefits & Cost Savings
- Conclusion
- Questions & Discussion

Wireless Sensor System

- A wireless sensor system uses sensors to monitor physical or environmental conditions

- A typical system consist of one or more transmitter nodes sending measurement date to a receiver or base connected to a host PC that monitors or records the data.

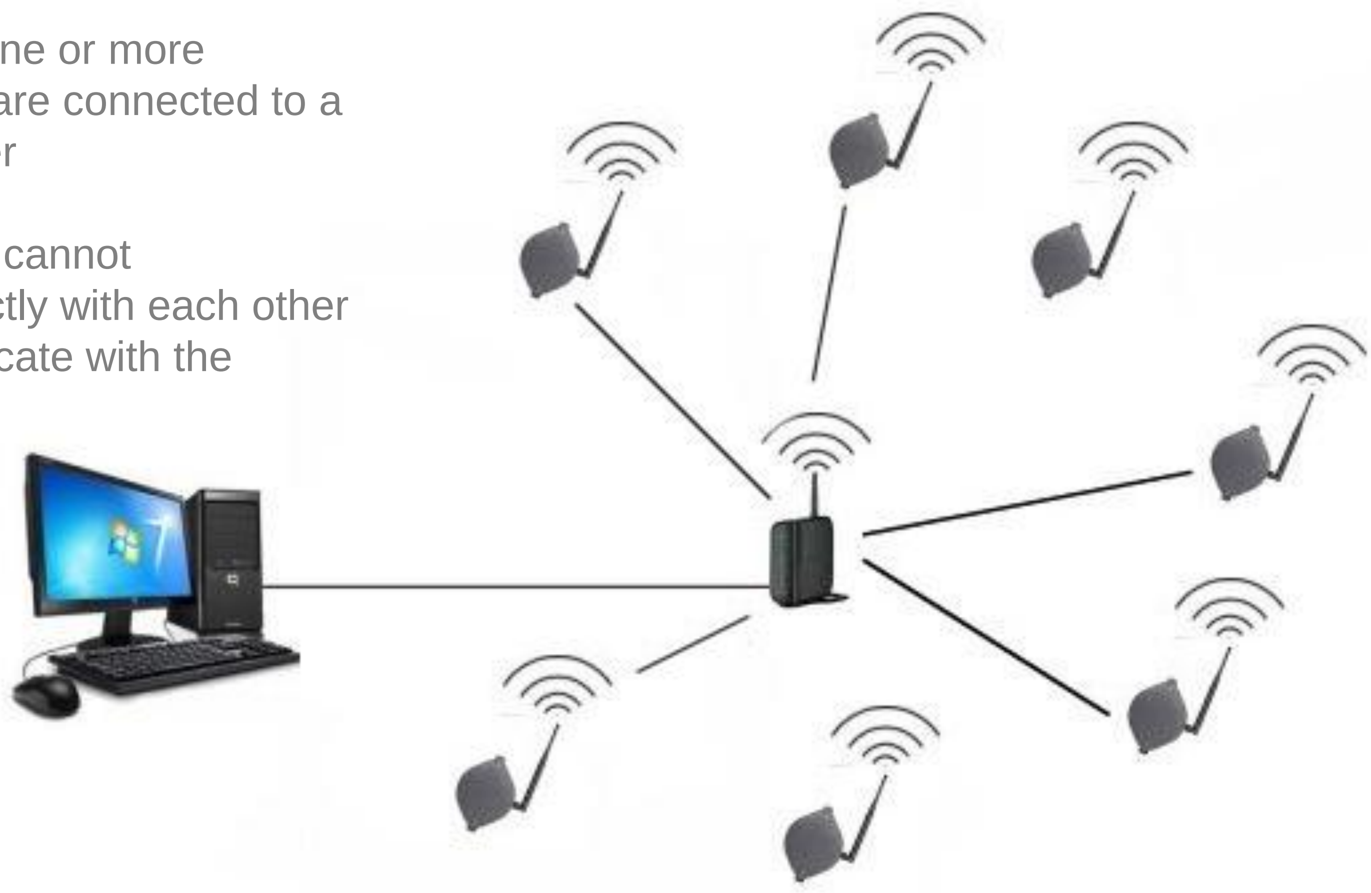
- The predominant wireless sensor standards being deployed in the field currently are ISA100.11a, WirelessHart and Zigbee

Wireless Sensor System

Typical Star Network

In a star network one or more transmitter nodes are connected to a centralized receiver

Transmitter nodes cannot communicate directly with each other and only communicate with the receiver



Wireless Sensor System

Typical Mesh Network

Mesh network transmitter nodes are all able to communicate with each other.

Transmitter nodes can move data between themselves until the data reaches the intended location

Mesh networks are self healing.

Best choice when setting up a short to moderate distance, non line-of-sight application

Wireless Sensor System

Transmitter (Node) Operation

Typically measures temperature, humidity, voltage or current

Radio transmit power, transmit cycle time and ambient conditions effect the power consumption.

Short range radio consumes most power

Radio wakes periodically from sleep mode and transmit measurement data to the receiving base.

During each transmit ion of data the current drain placed on the battery usually spikes to levels in the hundreds of milliamps.

Wireless Sensor System

Powering the Transmitter (Node)

Most wireless transmitters are currently powered by limited-life (non-rechargeable) Lithium or Alkaline batteries.

The Lithium Thionyl Chloride battery technology provides the highest energy density, three times higher than Alkaline (Zinc Manganese Dioxide) batteries. A standard 3.6V C size cell on average has a capacity of 8500 mAh

Generally have the widest operating temperature range of -76F to + 185 F, ideal for industrial and field applications

Alkaline batteries are sometimes used in wireless transmitter design but they lack the same length of performance and reliability.

Wireless Sensor System

Powering the Receiver (Base Unit)

Usually the receiver, or base unit is not powered by limited-life batteries.

Most often the receiver is connected to a permanent, continuous source of power.

Examples would be…

- ✓ Through the USB connection to a host computer
- ✓ Standard AC/DC power supply
- ✓ Large capacity solar power system

Wireless Sensor System

Selecting Wireless System Components For Your Application

Radio Strength Over Distance

The higher the frequency of the radio (i.e. 2.4GHz is > 900MHz) the quicker the wave loses its strength.

A 900MHz signal will transmit almost 2.5 times further than a 2.4GHz signal.

Obstructions to the RF Signal

2.4GHz radios tend to propagate poorly through walls, trees and other obstructions.

A 900Mhz (and 868MHz) frequency has a 12 inch radio wave (from peak to valley) and can penetrate obstacles more efficiently.

Radio Frequency

An advantage of the 900MHz frequency is that it is not nearly as crowded as higher frequency bands.

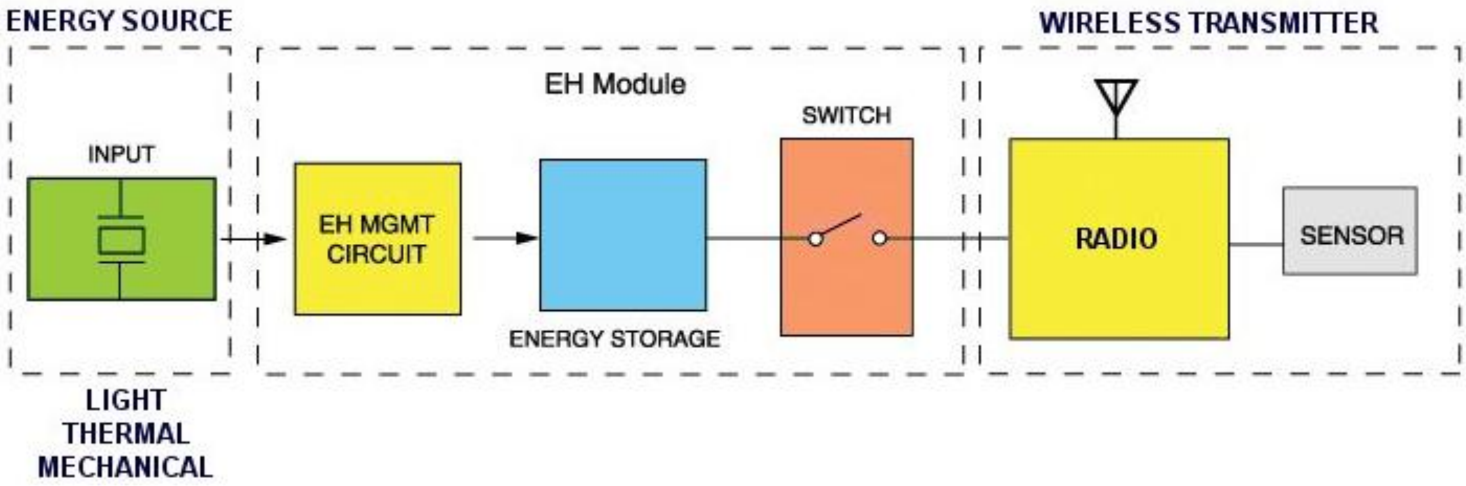
Blue Tooth devices, standard WiFi networks (802.11.x), Zigbee and other 802.15.4 devices all share the 2.4GHz frequency band.

Energy Harvesting & Storage

What is Energy Harvesting?

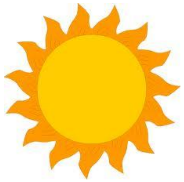
Energy Harvesting, or energy scavenging, is the process by which energy is derived from ambient external sources that would otherwise be lost as heat, light, sound, vibration or movement. This free energy is captured, and stored.

The process, also known as energy scavenging, captures residual energy as a byproduct of a natural environmental phenomenon or industrial process and is therefore considered "free energy." More often than not, this residual energy is released into the environment as waste.



Energy Harvesting & Storage

Examples of Ambient Energy Sources



light

- ✓ Captured from sunlight or ambient room light
- ✓ photovoltaic cells are used to capture light energy

Thermal

- ✓ Waste energy from friction and sources of heat
- ✓ Furnaces and engines can be used to capture thermal energy

Mechanical

- ✓ Resulting from mechanical stress, strain and vibration
- ✓ Wind and water flow can be used to capture mechanical energy

Energy Harvesting & Storage

Types of Storage Devices Used In Solar Power Systems

Ultracapacitor Bank (Supercapacitors)

- ✓ Energy density hundreds of times greater than electrolytic capacitors
- ✓ Long life, with little degradation over hundreds of thousands of charge cycles
- ✓ Very high rate of charge and discharge
- ✓ No full charge detection needed, no overcharge danger

.ead Acid, Deep-cycle Batteries

- ✓ Can be consistently deeply discharged using most of its capacity
- ✓ Life depends on number of charge cycles and depth of discharge
- ✓ Rated capacity decreases in cold ambient temperatures

Solar Power System

Remote Location, “Off-grid” System for Wireless Sensors and Instrumentation

An off-grid solar power system is where there is no connection to the utility company’s power grid.

System requires the following components…

- ✓ Solar panel
- ✓ Charge Controller
- ✓ Deep-cycle Battery
- ✓ Low Voltage Disconnect
- ✓ Ether a Step-up, Step-down Power Conditioner or Inverter
- ✓ Equipment Enclosure & Mounting Accessories

Additional monitoring equipment can be added

Solar Power System

Solar Panel

- ✓ Solar panels use light energy to generate electricity
- ✓ Most are wafer-based crystalline silicon cells or thin-film cells made from cadmium telluride or silicon.
- ✓ A single cell can generate around 0.5 Volts
- ✓ Multiple cells are typically connected in series together to provide higher voltages and increased capacity.
- ✓ Solar panels are rated in watts per hour
- ✓ Most panels under 135 watts are designed for 12 Volt systems
- ✓ Generally panels over 135 watts provide 21 to 40 Volts

Solar Power System

Solar Charge Controller

- ✓ Solar charge controller s are connected between the solar panel and the battery
- ✓ Regulate the charge from a solar panel to a single battery or battery bank.
- ✓ Charge controllers are rated based on the amount of amperage they can process
- ✓ Protect the battery from over charging
- ✓ Usually handles up to 30 amps of array current and up to 450 watts of solar power
- ✓ Connecting a solar panel to a battery without a regulator can damage the battery.

Solar Power System

Low Voltage Disconnect (LVD)

- ✓ Prevents damage to the battery due to excessive deep discharge.
- ✓ Is installed between the battery and load.
- ✓ Disconnect usually occurs between 10.5 to 12 Volts.
- ✓ You should use a model with a very low “on” resistance.

Solar Power System

Lead Acid Deep-cycle Battery

- ✓ Designed to absorb and give up electricity by using a reversible chemical reaction.
- ✓ A cycle on a battery occurs when you discharge your battery and then charge it
- ✓ Deep-cycle batteries are designed to discharge between 50% and 80%.
- ✓ Best lifespan vs cost method is to keep the average cycle at ab
- ✓ Can be consistently deeply discharged using most of its capaci
- ✓ Life depends on number of charge cycles and depth of dischar
- ✓ Rated capacity decreases in cold ambient temperatures

Solar Power System

Power Conditioner / Inverter

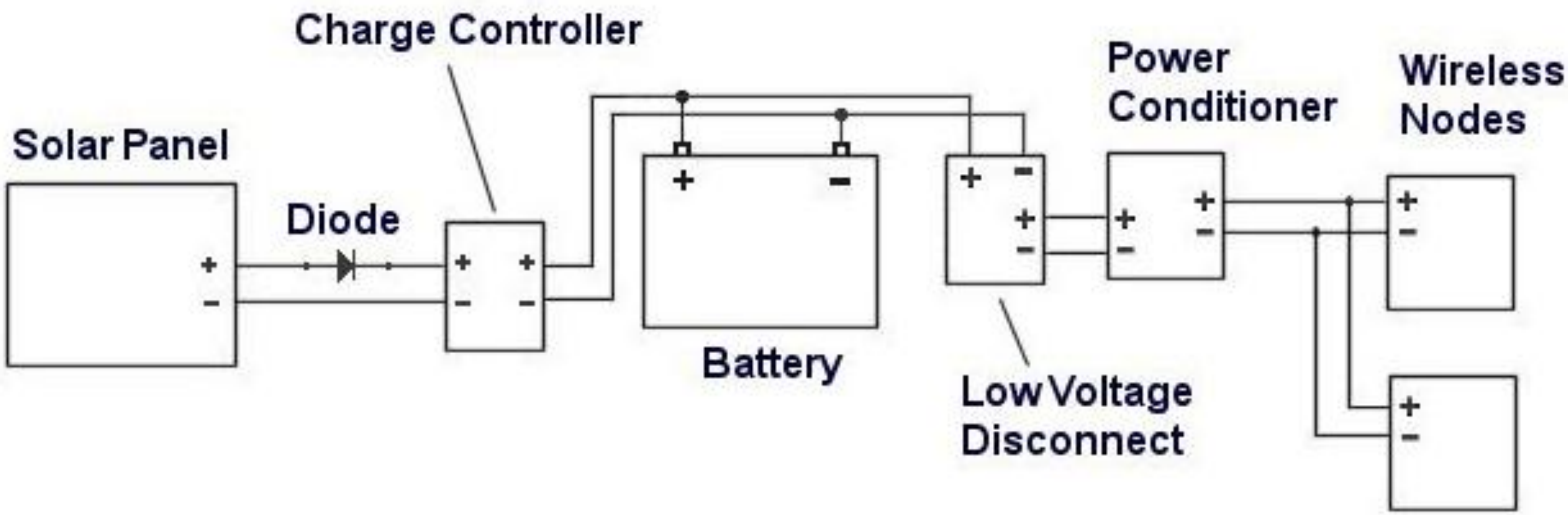
- ✓ For powering wireless sensors, transmitters and Instrumentation
- ✓ Regulates the battery voltage to a lower or higher voltage.
- ✓ A dc-dc switching supply is recommended over a linear regulator.
- ✓ A switching regulator offers higher efficiency and less heat in the design.
- ✓ A “step-down” power conditioning module typically provides between 3 to 5 Vdc
- ✓ A “step-up” power conditioning module typically provides up to 24 Volts
- ✓ Additionally, a DC to AC inverter can be added should you need 120VAC 50/60 Hz

Solar Power System

Typical Installation Setup

Solar Power System

Typical Wiring Block Diagram



Incorporates a blocking diode you would need to install one.

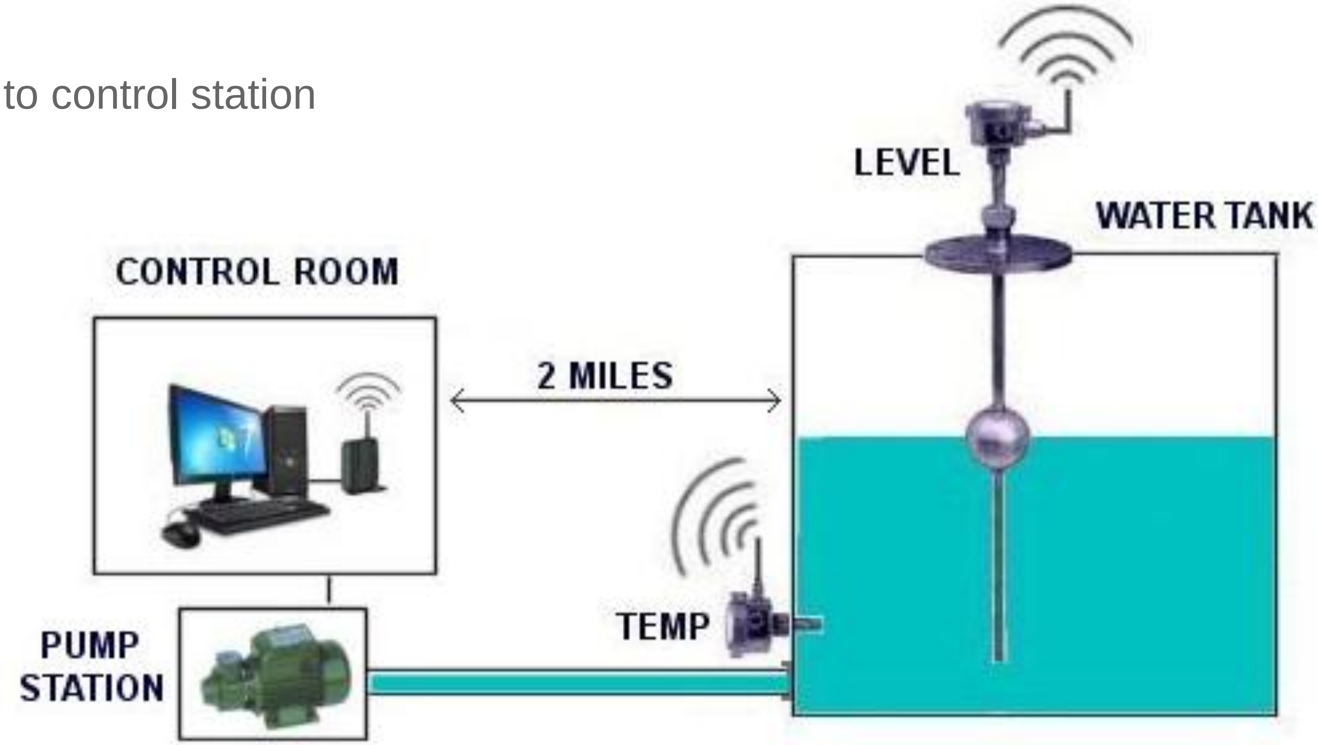
When there is no voltage being produced by the panels (at night), the voltage of the battery would cause a current to flow in the opposite direction through the panels, causing a discharging the battery

Example Application

Water Tank Monitoring & Pump Control

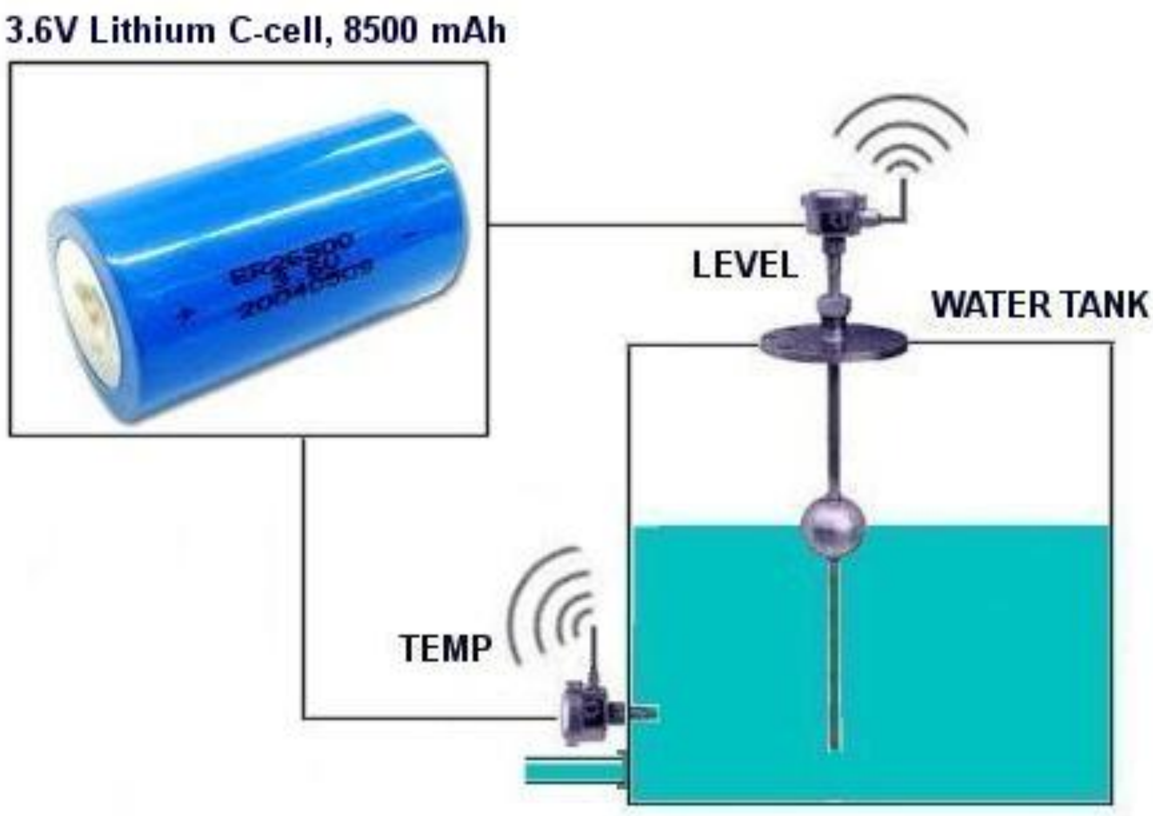
Monitoring both water level and temperature

Sends data 2 miles to control station



Benefits & Cost Savings

Sample Application Running on Limited-life Batteries



Level and Temperature Transmitter nodes sending data ever 30 seconds (explain cycle-time)

Battery in the Level transmitter will last an average of 255 days or less

Battery in the Temperature transmitter will last an average of 365 days or less

Benefits & Cost Savings

Sample Application Running on Solar Power

5W 18V Solar Panel

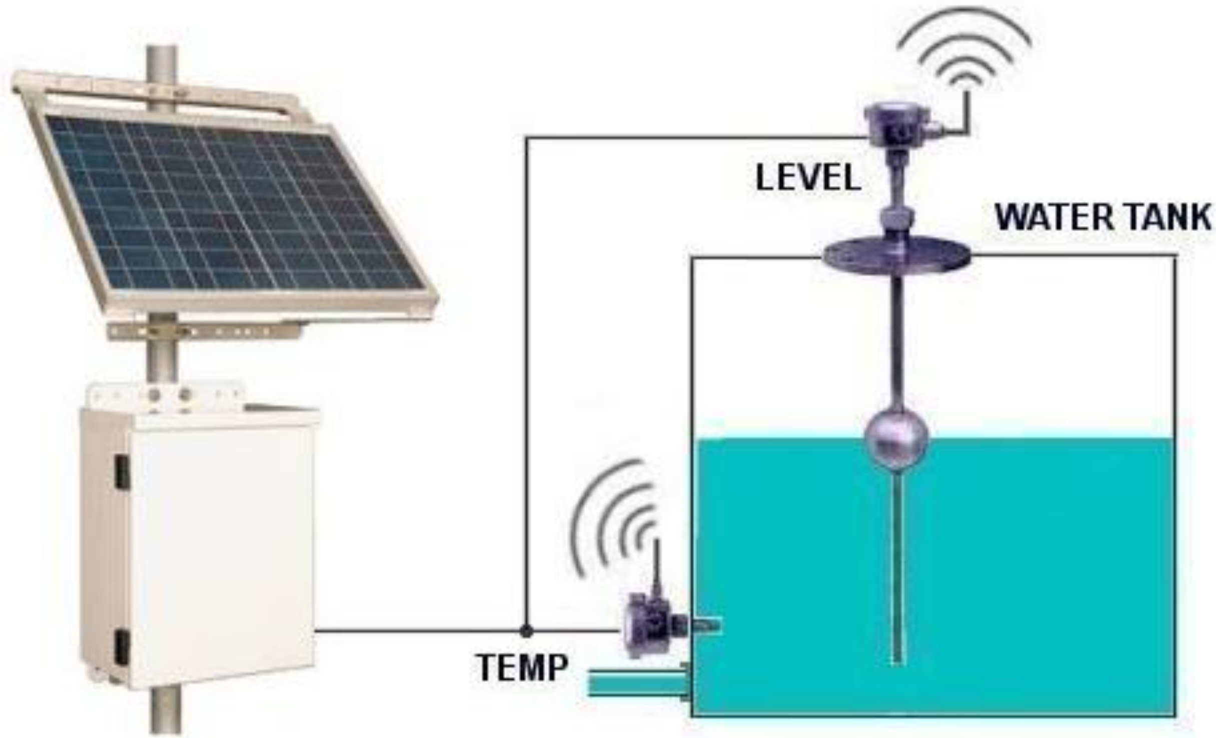
12V, 7Amp Charge Controller

12V 4.5 AH Deep-cycle Battery

Low Voltage Disconnect at 11.5V

Step-down Dc-Dc power conditioner with 3.6V @ 1amp output

NEMA rated enclosure



Benefits & Cost Savings

Cost Comparison & Savings Breakdown Over 6 Years

Both Transmitter Nodes Powered By Limited-life Batteries

Level Transmitter Maintenance - battery ($25) + 1 hr labor ($50) = $75

Requires battery replacement 10 times over 6 years - $750

Temperature Transmitter Maintenance - battery ($25) + 1 hr labor ($40) = $65

Requires battery replacement 6 times over 6 years - $390

Total 6 year cost = $1,140

Powered By Solar Power System (Do it yourself)

10W, 18V Solar Panel $29

12V, 7A Charge Controller $35

Low Voltage Disconnect $40

Mounting Accessories $35

3.6V Power Conditioner $35

12V, 7 ah Battery $26

NEMA Enclosure $30

Installation Labor $100

Total 6 year cost - $330

Conclusion

Wireless Sensor System Overview

- ✓ Uses sensors to monitor physical or environmental conditions
- ✓ Radio transmit cycle time, RF power can greatly effect power requirements

Energy Harvesting & Storage

- ✓ Energy can be collected and stored from light, heat and vibration
- ✓ Energy can be stored in rechargeable batteries or supercapacitors

Solar Power System

- ✓ Requires a solar panel, charge controller, battery, LVD and power conditioner
- ✓ Should be designed to place no more than a 50% depth of drain on the battery

Benefits & Cost Savings

- ✓ Use of limited-life batteries can result in13 or more replacement batteries over 8 years
- ✓ Can reduce overall maintenance cost to “zero” dollars over a 8 year period

Questions / Discussion

Questions?

Thank You!