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Design and simulation of electronic Instruments for Solar Energy measurement systems

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1 Introduction

WITH expansion of urbanization and population the energy requirement is increasing day by day which leads to extraction of renewable resources of energy, like sun and wind among these sun energy has a vast potential to fulfill the energy needs.

The terrestrial solar radiation is very important data for evaluating the performance of solar energy conversion system. One can use the electronic integrator for total radiation measurement. The principle of the electronic integrator is based on the use of voltage and current consumption of solar cell . A typical solar radiation measuring station usually installs the pyranometer quite far from the integrator. Since the EMF output signal from the pyranometer is very small. The signal is in microvolt level ,which results more noise coupling. The insolation value is also printed out locally. To make the insolation data base for wide area, we have to install many stations. This makes difficulty to collect data. The proposed work describes the alternative method by connecting the Solar cell to the high-resolution analog to digital converter and the use of computer software along with the memory card for computing the insolation including the use of internet server for sending the everyday data to the receiver.

From the latest researches it would appear that solar, wind or biomass would be sufficient to supply all of our energy needs, however, the increased use of biomass has had a negative effect on global warming and dramatically increased food prices by diverting forests and crops into biofuel production. As intermittent resources, solar and wind raise other issues.

Development of suitable solar irradiance measurement system with additional features such as remote monitoring , real time capture and facility to backup and store the data is thus essential.

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2 System Model

2.1 Overview

As seen from the figure above our measurement unit consist of PIN photodiode as a SENSOR whose readings are converted digitally using a 10 bit delta to sigma analog to digital converter unit which is inbuilt in AVR ATMega16 microcontroller, unit takes the sample and convert the digital data into energy per unit distance from the formulae as describe in section 2.3.3, energy unit is then passed to tcp/ip stack by ENC28j60 Ethernet module. Microcontroller unit here acts as a data acquisition device which is converting the analog reading into meaning data to be transferred to the Ethernet gateway.

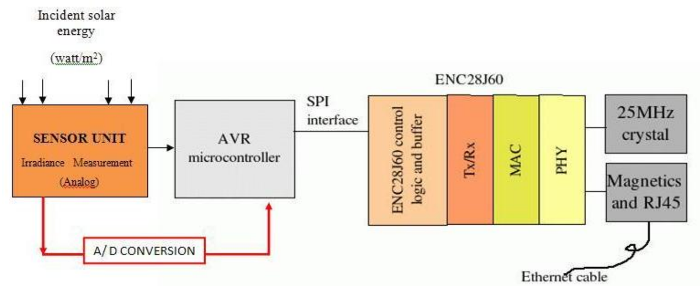

Fig 2.1 SCHEMATIC BLOCK DAIGRAM

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2.2 Microcontroller unit as a DAQ (Data acquisition System)

Transducers, a common component of any data acquisition system, convert physical phenomena, such as strain or pressure, into electrical signals that can be acquired by a data ac-

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quisition (DAQ) device. Common examples of transducers include microphones, thermometers, thermocouples, and strain gauges. When selecting a transducer for use with a DAQ device, it is important to consider the input and output range of the transducer and whether it outputs voltage or current. Often, the sensor and DAQ device require signal conditioning components to be added to the system to acquire a signal from the sensor or to take full advantage of the resolution of the DAQ device. However, the transducer's output impedance is commonly overlooked as a vital consideration when building a DAQ system.

Impedance is a combination of resistance, inductance, and capacitance across the input or output terminals of a circuit. Figure 1 models the resistive output impedance of a transducer and the resistive input impedance of a DAQ device. Realistically, capacitance and inductance are also present in all DAQ systems. It is important that the input impendence of the DAQ device is much higher relative to the output impedance of the selected transducer. In general, the higher the input impedance of the DAQ device the less the measured signal will be disturbed by the DAQ device. It is also important to select a transducer with as low an output impedance as possible to achieve the most accurate analog input (AI) readings by the DAQ device. The following sections address how high output (source) impedance affects a measurement system and how to use a unity gain buffer or voltage follower to decrease the output impedance of a sensor.

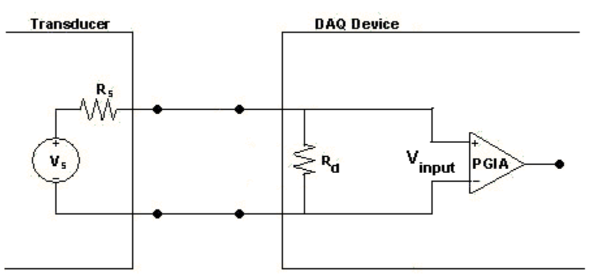


Figure 1.-Model of a Typical Transducer and DAQ Device

2.3 Using a Unity Gain Buffer to Decrease Source Impedance

When you can neither use a transducer with a low output impedance nor reduce the sampling rate of the DAQ device, you must use a voltage follower that employs operational amplifiers (op-amps) with unity gain (gain = 1) for each high-impedance source before connecting to the DAQ device. This configuration is commonly referred to as a unity gain buffer, and it decreases the impedance of the source connected to the DAQ device. A power supply is required to provide +/- 5 V to the op-amp, and the power supply should be referenced to the analog input ground (AIGND) of the DAQ device.

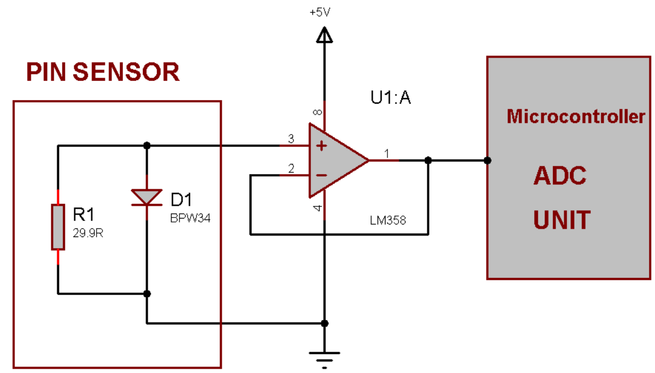


Figure: Unity gain Buffer for the ADC to decrease the source impedance here LM358 is used as a unity gain buffer , PIN photodiode BPW34 solar irradiance sensor, R1 as shunt resistor

3 Measurement And Readings

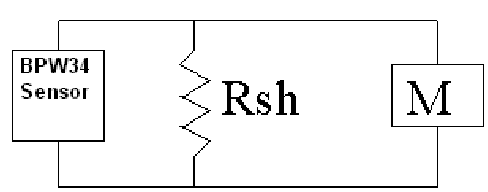
Silicon PIN photodiode is used as a irradiance transducer .Photodiode used has a photosensitive area of 7.5mm2. Below is the characteristics' table of BPW34 photodiode.

BASIC CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)						
PARAMETER	TEST CONDITION	SYMBOL	MIN.	TYP.	MAX.	UNIT
Breakdown voltage	I_R = 100 μA, E = 0	$V_{(BR)}$	60			V
Reverse dark current	V_R = 10 V, E = 0	I_{ro}		2	30	nA
Diode capacitance	V_R = 0 V, f = 1 MHz, E = 0	C_D		70		pF
	V_R = 3 V, f = 1 MHz, E = 0	C_D		25	40	pF
Open circuit voltage	E_e = 1 mW/cm², λ = 950 nm	V_o		350		mV
Temperature coefficient of V_o	E_e = 1 mW/cm², λ = 950 nm	TK_{Vo}		- 2.6		mV/K
Short circuit current	E_A = 1 klx	I_k		70		μA
	E_e = 1 mW/cm², λ = 950 nm	I_k		47		μA
Temperature coefficient of I_k	E_e = 1 mW/cm², λ = 950 nm	TK_{Ik}		0.1		%/K
Reverse light current	E_A = 1 klx, V_R = 5 V	I_{ra}		75		μA
	E_e = 1 mW/cm², λ = 950 nm, V_R = 5 V	I_{ra}	40	50		μA
Angle of half sensitivity		φ		± 65		deg
Wavelength of peak sensitivity		λ_p		900		nm
Range of spectral bandwidth		$\lambda_{0.1}$		430 to 1100		nm
Noise equivalent power	V_R = 10 V, λ = 950 nm	NEP		4×10^{-14}		W/√Hz
Rise time	V_R = 10 V, R_L = 1 kΩ, λ = 820 nm	t_r		100		ns
Fall time	V_R = 10 V, R_L = 1 kΩ, λ = 820 nm	t_f		100		ns

Readings taken by a standard ammeter

Photodiode 3.337 +/- 0.116 mA at an ambient temperature of 25ºC when exposed to a solar irradiance of 1000 W/m2.In order to keep the readings in a voltage range a shunt resistance is used to calibrate the circuit . Our goal is to make full sunlight give a 100 mvolts reading on the digital meter (full sunlight is about 1000 watts per square meter), so our meter will read 1 mvolts per 10 Watts/m2.

Calculation of *Rshunt* resistor



At a full sunlight output current of 3.4 mA current is obtained by the sensor. Thus by applying ohms law.
V=IR
We want 0.1V or 100mv at the output so equation becomes
R=(0.1V)/(0.0034)=29.41 ohms
We are using variable resistance to calibrate the shunt.

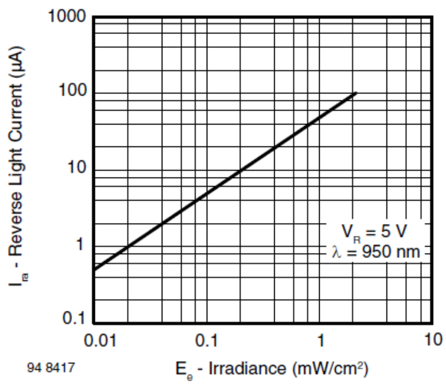


Fig. 3 - Reverse Light Current vs. Irradiance

Spectral Sensitivity

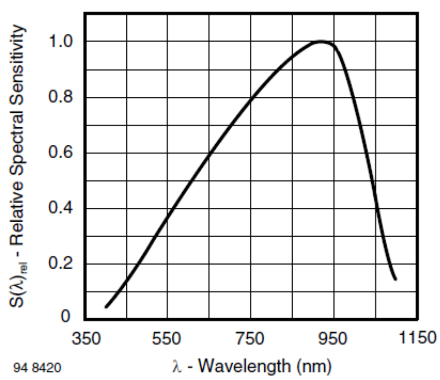


Fig. 7 - Relative Spectral Sensitivity vs. Wavelength

As the figure shows sensor has a unity spectral density at 950nm wavelength which makes it ideal for using in a standard measurement equipmentary.

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4. Web Connectivity

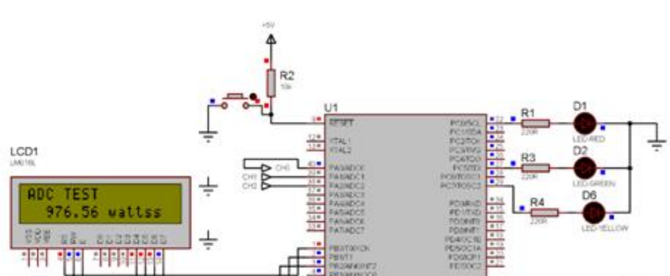
An **embedded WEB server** is a component of a embedded system that implements the TCP/IP protocol, by which one can able to talk to the gadgets using internet .This measurement Unit makes use of LAN/WAN network acting as a carrier and uses TCP/IP protocol.Microcontroller when recieves any commands from internet passes the commands to electrical equipment. Real reason for building the project is to provide a unlimited control of any device which will be economic to be used in household as well as industries. Since our measuring device itself act as a small server it meets under the need of the industry.

ENC28J60 ETHERNET CONTROLLER CHIP

The ENC28J60 is a stand-alone Ethernet controller with an industry standard Serial Peripheral Interface (SPI). It is designed to serve as an Ethernet network interface for any controller equipped with SPI. The ENC28J60 meets all of the IEEE 802.3 specifications. It incorporates a number of packet filtering schemes to limit incoming packets. It also provides an internal DMA module for fast data throughput and hardware assisted checksum calculation, which is used in various network protocols. Communication with the host controller is implemented via an interrupt pin and the SPI, with clock rates of up to 20 MHz. Two dedicated pins are used for LED link and network activity indication.

5 SIMULATION

Simulation with Proteus design envoirnment:
AVR microcontroller is tested with inbuilt 10 bit ADC , performance is computed
And displayed on a regular 16X2 liquid crystal display unit .By reading a 5V and 2.5V voltage reading from channel 0 of adc .
Generalize formulae for solar irradiance.
As from above we get digital reading with a precision of 10bit
Hence ADC reads= (5V/1024) =4.88millivolts per bit
But for 0.1 V of photodiode current it must show 1000watt / sq m energy.
For 1 Volt solar irradiance=10000watts
Readings=value of adc X (5/1024)X(10000)
Readings =(20)X (5/1024)X10000=976.54watts
This shows results having a tolerance of 2.3%error due to adc conversion and floating point arithmetic problem.
Simulations' test carried out



6 Conclusion

Solar radiation measurement is carried out with 2.3% error. Reading data is buffered and viewed over Ethernet connection over a Public Local area LAN system.Authors feel's that remote sensing used over public LAN will be a innovative approach to collect the data globally.It is the authors original contribution.The work extended to enhance the capabilities to read more parameters such as temperature, humidity And pressure and is continued further.

Acknowledgment

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