An Intelligent Characteristics Analyzer of PV Module

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Abstract

This paper describes construction, development and testing of a low cost PV module characteristics analyzer. A computer-based, fully automatic characteristic analyzer has been designed and developed using locally available components. The system is capable of acquiring current and voltage of PV module by varying the operating point to draw the IV curve and to analyze the module characteristics. In this system, a Pico ADC-16 has been used to convert the analog data into digital. The module current and voltage is changed by using a transistor active load. The operating point of the active load has been changed by the analog output of a DAC and the DAC is driven by a digital counter. A driver program has been developed for the system using C language. Finally, the system was assembled and the characteristics of some PV modules of different power capacity have been studied. It is found that, the system is capable of finding characteristics of PV modules up to the capacity of 75Watt.

I. Introduction

Nowadays, the problem of energy crisis is well known to all in Bangladesh. Almost 70% people of Bangladesh have no access to electricity. Even the amount of electricity generated now is not sufficient for 40% people [1]. It is difficult to solve this problem by establishing new power plants due to the scarcity of primary energy. Consequently, renewable energy specially, solar photovoltaic system, is getting popular day by day in our country. The rural people, having no access to national grid, have no choice except PV system to lit their minimum amount of light.

The Government of Bangladesh is trying to promote solar energy by giving incentives and by making rules. As a result, a large number of PV systems are being sold every month in the rural area as well as in urban area [2]. To construct these systems, a huge number of PV modules are being imported from abroad by many companies. But in our country there is no facility to study the performance of these PV modules. In this point of view, this data logger system has been developed to study the characteristics of PV module.

Although, some works have been done to construct the characteristics analyzer [3], none of them is for PV modules. Those systems were made for only solar cells. But the newly developed system is capable of determining the characteristics of both solar cells and solar modules. All other problems of the previous systems have been addressed in this new system.

II. Block Diagram of the System

A simplified block diagram of the system is given in Fig. 1. The complete system consists of mainly five blocks and a microcomputer. These are 1) Counter, 2) DAC, 3) Active load, 4) Pico ADC-16 data logger and 5) A power supply.

The function of the counter unit is to get signal from the computer and change its output count. Actually this unit works as a memory unit whose data can be changed step by step by the computer.

The DAC unit has been used to convert the digital output of the counter into analog data. The active load works only by the analog signal but the output of the counter is digital. To convert this digital data into analog signal DAC has been used.
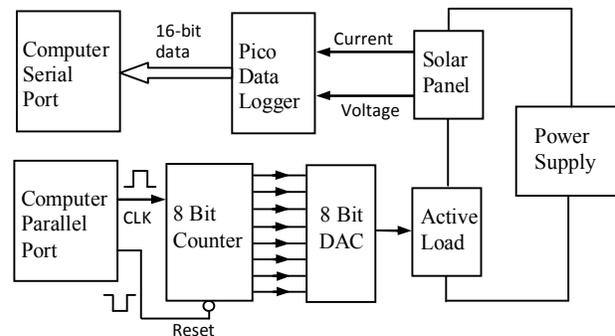

Fig. 1. Block diagram of the system

To make the system fully automatic, a variable load is necessary. It is not easy to change current and voltage level of a simple variable load like potentiometer, rheostat by computer signal. Hence, a transistor active load has been used so that its current and voltage level can be changed easily by the computer.

The purpose of the Pico ADC-16 data logger is to sample the current and voltage level of the PV module and convert it into digital data and send them to the computer. The computer will control the entire system i.e. increase the current of the PV module step by step with the help of the counter, DAC and active load and read them with the help of Pico ADC16.

III. Design and Description of Each Unit

A. Counter

The active load is driven by an 8-bit DAC. Hence, an 8-bit counter is necessary. Since the counter is connected to the

parallel port of the computer, it could be replaced by an 8-bit buffer. However, the 8-bit counter has been constructed using two 74LS93 ICs. The select inputs of the ICs are properly enabled and the output of the MSB of the first counter (where the clock is applied) is connected to the CLOCK input of the second counter.

In this circuit although LEDs are connected at the outputs to test it, in the complete system these LEDs are not been used.
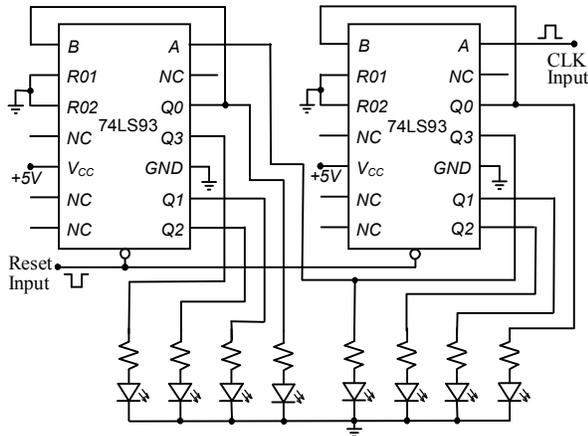

Fig. 2. Schematic diagram of 8-bit counter

B. **DAC unit**

The purpose of the digital-to-analog converter (DAC) is to produce variable voltage for the active load. Since an eight bit counter has been chosen, the capacity of the DAC must be eight bit. For this purpose an IC AD558 has been used. Output of eight bit counter is connected to the digital inputs of AD558. To get output range 0 V to 2.56 V from AD558, it has to be operated with 5V and the V_{out}, $V_{out}Source$ and $V_{out}Select$ have to be connected all together. Two control inputs (CS, CE) are connected to ground. Analog output is taken from V_{out} pin.
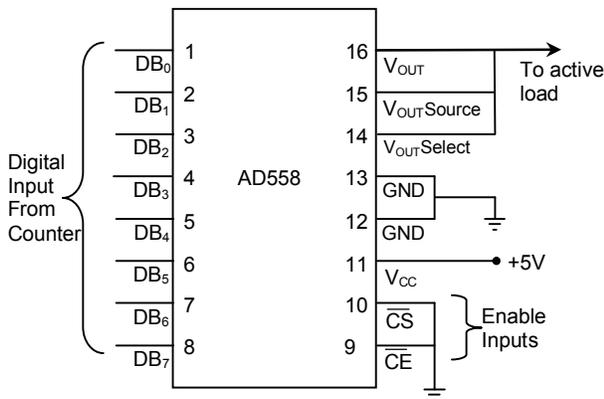

Fig. 3. Wiring diagram of DAC

C. **Active Load**

The active load has been constructed using a Darlington pair. Although Darlington Pair consists of two transistors, in this work five power transistors (TIP3055) have been connected in parallel. The bases of these transistors are driven by a normal transistor D400. Here, five power transistors have been used to share the power of the PV module so that they do not damage with heat.

D. **Pico Data logger**

The Pico ADC-16 is a high resolution (16 bits) self-contained data logger. It is capable of measuring voltage within the range of 0V to +2.5V. It is capable of measuring signal as small as 40μV and its sampling rate is 1.5Hz. It has 8 input channels which can be used for measuring eight common mode signals or four differential signals. In our developed system two differential input channels have been used to measure the output current and terminal voltage of the PV module.
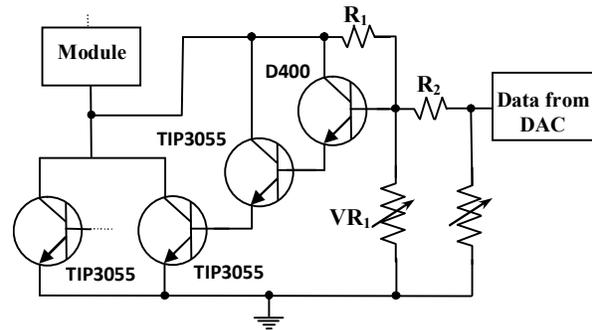

Fig. 4. Schematic diagram of the active load

E. **Power Supply**

The power source (PS) required for the system is a little bit complicated. As the PS and the PV module will be connected in series, the current capacity of the PS should be equal or greater than the short circuit current (Isc) of the PV module. Since the system has been designed to study up to 75 Watt module the current capacity of the PS should be at least 9A.

F. **Power Tolerance of the transistor**

As shown in fig. 4 a 0.25Ω resistance is connected in series in the system. It is made by connecting four 1Ω 12Watt resistors. Hence the voltage of the PS should be at least 3 V (=9×.25 + 0.5V). In this system the PS voltage has been kept 5V. If a 75Watt module is connected in the system, total power supplied by the sources will be 110Watt (75W + 5V×9A). Among them about 10Watt will be dissipated by the resistor. Hence 100Watt power will be dissipated by the five power transistors. Hence, large heat sink has been used with the transistor to protect thermal runaway.

IV. Software

A program has been developed to run the system automatically by modifying the original driver of the Pico ADC16 driver. A source code in C of the Pico ADC16 has been collected and necessary functions have been added in this code to increment the counter and collect current and voltage of the PV module. Functions have also been added to process the data to find out the characteristics of the PV module. The flowchart of the developed program is given in fig. 5.

V. User Port

Windows XP/NT/2000 or higher version does not allow user programs to access I/O ports directly for security purpose [5]. So, the ports of the PC were enabled for data acquisition using third party software – UserPort. UserPort.SYS is a kernel mode driver for Windows XP/NT/2000 that gives user mode programs access to I/O ports. This makes it possible to access hardware directly from a normal executable program in the same wary as under Windows 95/98/ME. The I/O ports 0x378, 0x379 and 0x37A have been made user accessible using the UserPort in order to proceed with data acquisition.
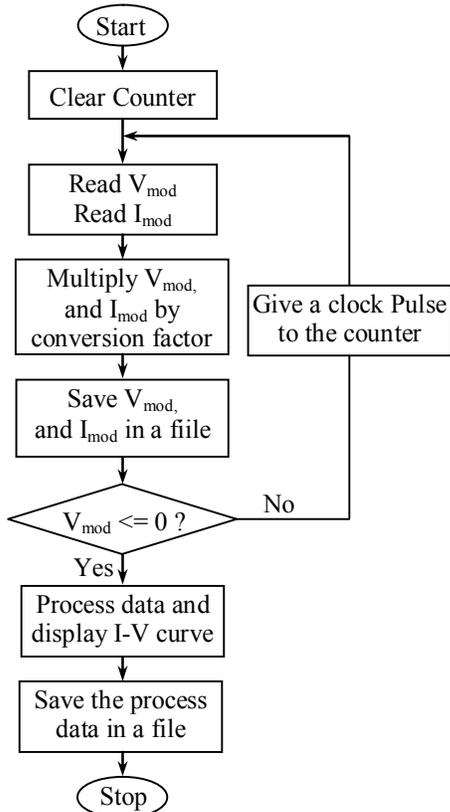
VI. Operation of the System

The complete schematic diagram of the system is given in fig. 6. The complete system works with the help of the developed program. By connecting the module and the power supply with the system and placing the module in sunlight the program has to be run. At first the program will send a Reset signal to the counter through the parallel port of the computer. So, the output of the counter and the DAC will be zero. This will produce the open circuit condition of the module. The module voltage (V_{mod}) and the module current (I_{mod}) will be read by the PICO ADC-16. Then the program will send a pulse to the clock (CLK) input of the counter. Thus the output of the counter and hence the output of the DAC will increase by a very small voltage. So the active load will start to draw current form the module and the module voltage will gradually decrease. Again, V_{mod} and I_{mod} will be read by the data logger. This process will be continued until the module voltage V_{mod} becomes zero or negative. The acquired data will be saved in file at first and then will be processed to determine the characteristics of the module and I-V characteristics will also be drawn.
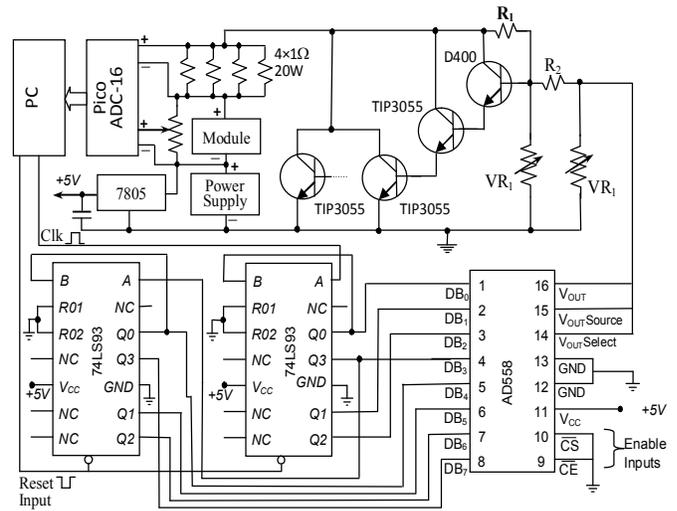

Fig. 6. Schematic diagram of the complete system

VII. Results

To study the performance of the system, I-V characteristics of some PV modules of different power ratings have been studied. The incident solar radiation has also been recorded using a pyranometer. The obtained data of some modules are given here. As there was no sun-simulator in laboratory, the data were taken in sun light. For this reason, the insolation levels for different data table are different.

Fig. 5. Flowchart of the program

The data given in the Table 1 were taken from a 30 watt module at a solar insolation of 773Watt/m^2. Fig. 7 represents the graph of this data. From this, it is clear that the system is quite accurate to measure the I-V characteristics of PV module. The I-V characteristics depicts that the performance of the 30Watt module is not so good, as the current falls rapidly with the increase of voltage near the I_{SC} and the voltage falls rapidly with the increase of current near the V_{OC}. These problems occur due to the effect of series and shunt resistance.

The data given in the Table 2 were taken from a 50 watt module at a solar insolation of 731 Watt/m^2. Fig. 8 represents the graph of this data. The performance of this module is better compared to that of Fig. 7, as the current decrease less rapidly with voltage near I_{SC} and also the voltage near the V_{OC}.

Finally, Table 3 shows the data taken from a 75Watt module at a solar radiation level of 916 Watt/m^2. Fig. 8 gives the I-V characteristics of this module. The performance of this module is even better than the 50 watt module.

Table. 1. Data Recorded from a 30WP Module at Solar Insolation 773W/M^2

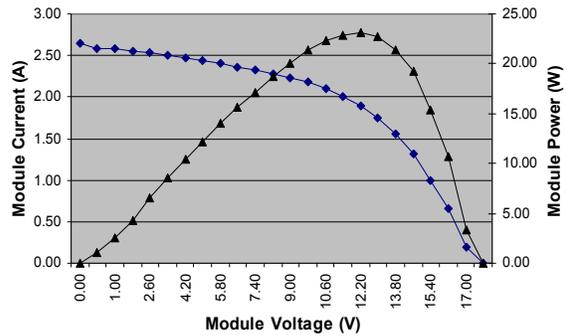| Module Voltage (V)	Module Current (A)	Module Power (W)
0.00	2.65	0.00
0.40	2.59	1.04
1.00	2.58	2.58
1.70	2.55	4.34
2.60	2.54	6.60
3.40	2.51	8.53
4.20	2.47	10.37
5.00	2.44	12.20
5.80	2.41	13.98
6.60	2.36	15.58
7.40	2.32	17.17
8.20	2.28	18.70
9.00	2.23	20.07
9.80	2.18	21.36
10.60	2.10	22.26
11.40	2.00	22.80
12.20	1.90	23.18
13.00	1.75	22.75
13.80	1.55	21.39
14.60	1.32	19.27
15.40	1.00	15.40
16.20	0.66	10.69
17.00	0.20	3.40
17.80	0.00	0.00

Fig. 7. I-V characteristic curve of a 30 Watt module

Table. 2. Data Recorded from a 50WP Module at Solar Insolation 731W/M^2

Module Voltage (V)	Module Current (A)	Module Power (W)
0.00	3.6	0.00
0.40	3.58	1.43
1.00	3.56	3.56
1.70	3.52	5.98
2.50	3.5	8.75
3.30	3.49	11.52
4.20	3.47	14.57
5.00	3.44	17.20
5.80	3.41	19.78
6.60	3.36	22.18
7.40	3.32	24.57
8.20	3.28	26.90
9.00	3.23	29.07
9.80	3.18	31.16
10.60	3.1	32.86
11.40	3	34.20
12.20	2.9	35.38
13.00	2.8	36.40
13.80	2.65	36.57
14.60	2.45	35.77
15.40	2.18	33.57
16.20	1.7	27.54
17.00	1	17.00
17.80	0	0.00
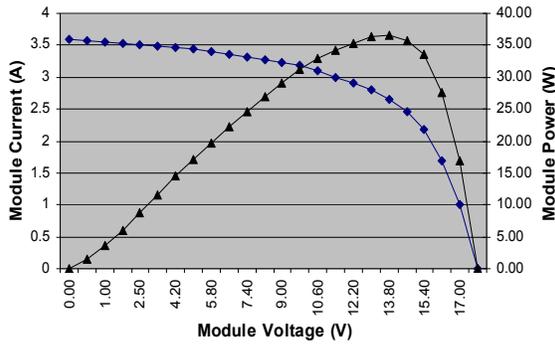
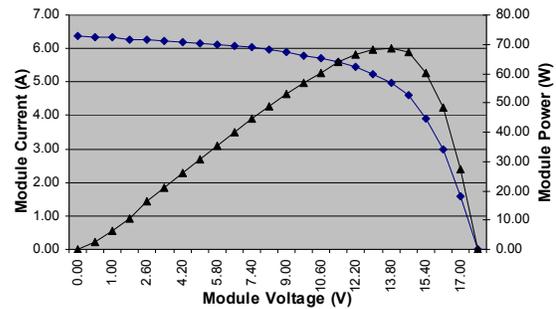**Fig. 8.** I-V characteristic curve of a 50 Watt module

Table. 3. Data Recorded from a 37WP Module at Solar Insolation 916W/M^2

Module Voltage (V)	Module Current (A)	Module Power (W)
0.00	5.18	0
0.40	5.15	2.06
1.00	5.12	5.12
1.70	5.08	8.63
2.60	5.07	13.18
3.40	5.04	17.14
4.20	4.98	20.92
5.00	4.96	24.8
5.80	4.92	24.54
6.60	4.88	32.21
7.40	4.83	35.74
8.20	4.78	39.2
9.00	4.70	42.3
9.80	4.60	45.08
10.60	4.50	47.7
11.40	4.40	50.16
12.20	4.25	51.85
13.00	4.05	52.65
13.80	3.78	52.16
14.60	3.40	49.64
15.40	2.70	41.58
16.20	1.80	29.16
17.00	0.40	6.8
17.80	0.00	0

Fig. 9. I-V characteristic curve of a 75 Watt module

VIII. Discussion

In this work a low cost computer-based PV module characteristics analyzer has been designed and developed. The system is capable of taking current and voltage from PV module using a data acquisition card. It is also able to change the current taken from the module step by step. Using this data, I-V characteristics can be drawn and some other parameters, like I_{SC}, V_{OC}, efficiency, fill factor etc., can be calculated. Here, the module current has been changed using a counter and a transistor based active load. The main challenge of this design is the power capacity of the transistor, as all of the power generated by the PV module will be dissipated by the transistor. Here, a system has been developed that is able to study PV module of 75Watt maximum. But this capacity can be increase by increasing the number of power transistor in parallel. The performance of the system has been studied by determining the characteristics of PV modules of various wattage capacities. The characteristics are presented in this paper. From these data it is clear that within the power capacity limit, the system works very well.

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