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LOGARITHMIC I-V PLOTTER FOR SOLAR CELL CHARACTERIZATION

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ABSTRACT

Hitherto a number of circuits for current (I) - voltage (V) characterization of solar cells have been developed. But these circuits do not have the frequency stability and versatility for carrying out I-V studies in dark as well as under illumination of solar cells. A circuit for logarithmic current versus voltage has been developed which makes use of IC 8038 oscillator and 3573 power amplifier for best frequency and power performance. Also a Teledyne Phillbrick 4362 precision logarithmic operator has been made use of for conversion to log I accurately. The circuit has been successfully tested. The functional parameters of a standard silicon solar cell such as reverse saturation current (I_0), the diode factor (n), the open circuit voltage (V_{oc}), the short circuit current (I_{sc}) have been recorded.

Key Words: Solar cells, log I-V plotter

INTRODUCTION

The fast improving non-conventional energy projects need, fast, accurate and less expensive measuring instruments. Perfect solar cells are to be chosen from a whole lot to make solar modules for efficient conversion of available sunlight into power. To match the cells, each of them should be tested for the fundamental parameters like open circuit voltage V_{oc}, short circuit current I_{sc}, reverse saturation current I_0, the diode quality factor n, etc. Attempts have been made to plot automatically the characteristic curves of solar cells using relays and FETs [1].

An instrument to measure the I-V, log I-V (dark) and log $(I+I_L)$-V under illumination using high performance ICs for accurate measurements, and which is easy to fabricate in any laboratory, has been developed. The operational characteristics of the various stages are dealt with in detail in this paper. Measurements have been made using a 0.12 cm^2 area silicon solar cell.

CIRCUIT DESIGN PRINCIPLES

Figure 1 shows the block diagram and figure 2 shows the schematic diagram of the instrument. The plotter as shown in figure 2 is a compact system made up of four main units-power oscillator, differential amplifier, a unity gain preamplifier and a logarithmic operator.

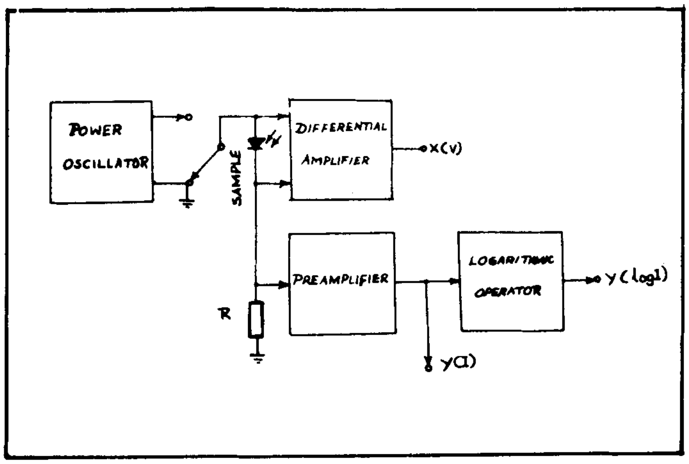

Fig.1 : Block diagram of logarithmic I-V plotter

Power oscillator

IC 1 and IC 2 depict the circuit of the power oscillator. The waveform generated (IC 1-8038) [2] and its associated components constitute the sine wave oscillator. Its operating frequency can be selected over nine decades of frequency from 0.001 Hz to 1 MHz, by the choice of external RC components. In our case, the RC components were selected, a 10 mfd and 50 k for varying the frequency from 0.3 Hz to 150 Hz, and calculated as F = 0.15/RC. The frequency of oscillation is highly stable over a wide temperature and supply voltage range. The output is fed to the trimmer potentiometer RV 1 so that the input amplitude to the high power operational amplifier (IC 2-3573) [3] can be adjusted, using trimmer potentiometer RV 2 fine adjustment of the output voltage. This amplifier is internally frequency compensated and is used to improve the signal strength to make the unit capable of handling currents upto 1A.

Differential amplifier

Operational amplifier IC 3 [4] constitutes a standard differential amplifier to amplify the voltage V across the sample. It has a gain with respect to differential signals of R_2/R_1.

Preamplifier

The sinusoidal signal from the power oscillator is applied to the solar cell (Si) through a series resistance R, which can be selected from 10, 30 or 100 ohms. The voltage developed across the resistor is proportional to the current passing through the solar cell. This voltage is buffered by the operational amplifier IC 4 [4] and an offset network is provided at the noninverting mode of OP 5 to adjust the DC offset of the operational amplifier as well as to compensate for the light generated I_L on the solar cell. The output of IC 5 is a measure of the current, I.

Logarithmic amplifier

Philbrick's model 4362 [5] forms the logarithmic amplifier. The log amplifier

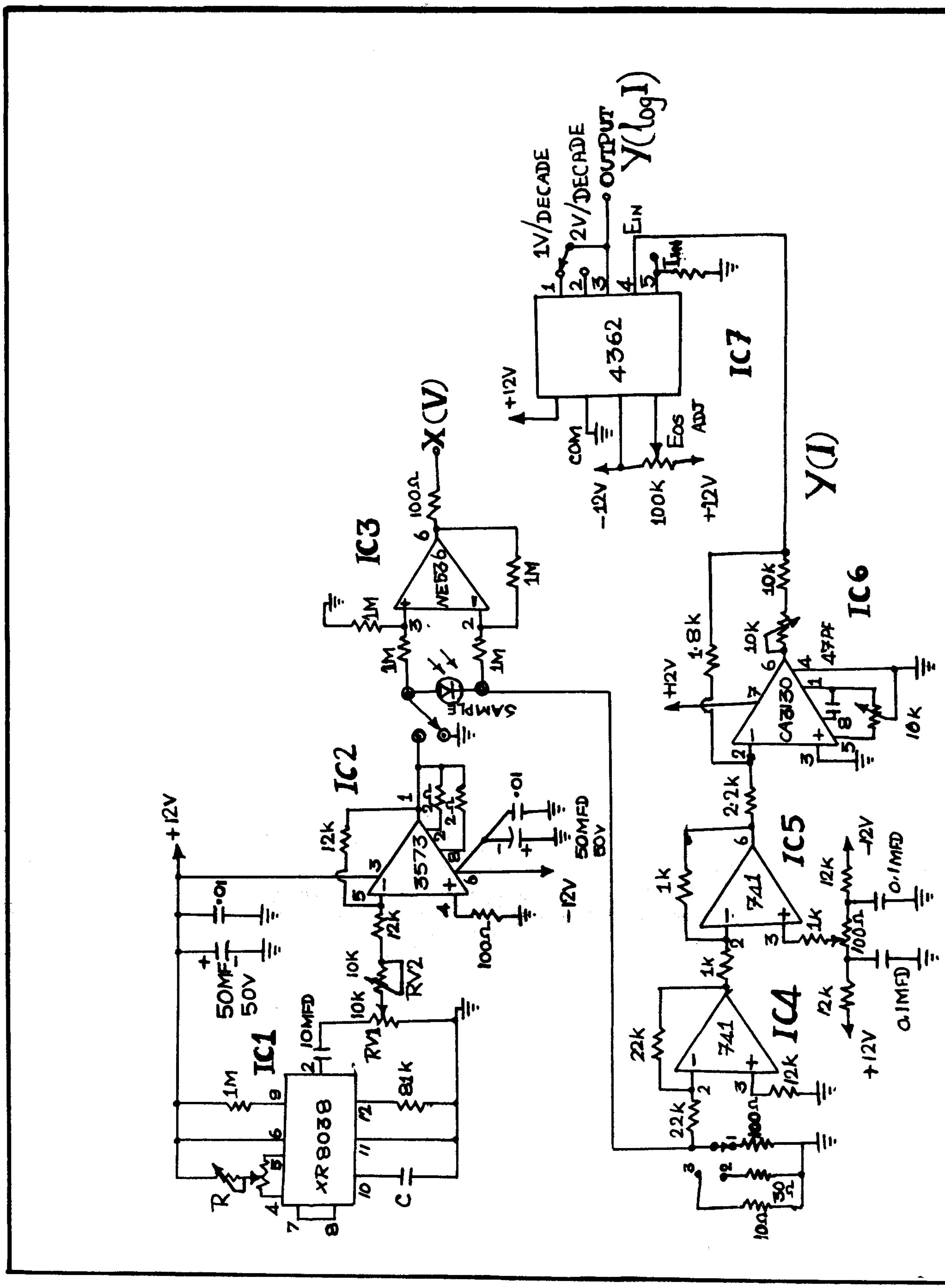

Fig. 2 Schematic diagram of the logarithmic I-V plotter

computes the logarithm of the ratio of the input current to the reference current and it handles only the positive input currents and operates in the inverting mode. Hence the output of the preamplifier is fed through an active rectifier (to allow only the positive input current), using an operational amplifier CA 3130 (IC 6) that its output cannot become negative if its power supply is asymmetrical. For log I operation, the input current I_{in} is appplied to the summing point. The input current lies between 10^{-9} and 10^{-3}A. To improve useful accuracy, the output is designed to swing each side of zero. Since the log of unity is zero, it makes good sense to choose a reference current I_{ref} such that when its ratio to the input current I_{in} is unity the output is zero. The value chosen for I_{ref} is 10^{-5}A. The output is connected to terminal 1 (for 1V per decade), terminal 2 (for 2V per decade), or to both terminals, 1 and 2 tied together (for 2/3 V per decade).

The transfer function of the logarithmic amplifier when connected for the logarithmic current equals

$$\text{Log of current, } I_{out} = -A \log_{10} \frac{\text{Input current}}{\text{Reference current}}$$

$$= -A \log_{10} \frac{I_{in} - I_o}{I_{ref}} \quad \text{for } 10^{-9} < I_{in} < 10^{-3}\text{A} \ldots (1)$$

$$\text{Log of voltage } E_{out} = -A \log_{10} \frac{E_{in}-E_{os}}{E_{ref}} \quad \text{for } 10^{-3} < E_{in} < 10^{+1}\text{ V} \ldots (2)$$

where

I_{ref} = 10^{-5}A, ± 4% max; + 0.1%/°C max.

I_o (input error current) = 0, ±3pA max; doubles each + 10°C

A (sensitive multiplier) = Volts/decade

i.e., 1V/decade ± 1% max

2V/decade ± 2% max, + 0.04/°C max

2/3V per decade ± 3%

E_{ref} = I_{ref} x 10k, 10^{-1}V nominal

E_{os} = 0, ± 700 microV max, adjustable to zero, ± 15 microV per °C max

A minus sign is associated with the constant A to comply with the accepted convention denoting reversal of signal polarity through the device.

To calculate the diode factor n, we choose the linear portion of the log I vs V (in dark) or log $(I + I_L)$ vs V (under illumination) characteristics and determine the voltage change, V_1-V_2, corresponding to a decade change in current. Then

$$n = \frac{V_1-V_2}{5.76} \times 10^2$$

SOLAR CELL CHARACTERIZATION

Assuming that the series resistance is neglible and the shunt resistance is very high, the diode equation is

$$I (V) = I_o [\exp(qv/nKT)-1] \ldots (3)$$

where q is the electronic charge

K is the Boltzman constant

T is the temperature

Under illumination, the I-V relation is

$$I (V) = I_o [\exp(qv/nKT)-1] - I_L \ldots (4)$$

where I_L is the light generated current.

From Eq. 3,

$$\ln I = \ln I_o + qv/nKT \ldots (5)$$

From the slope of the log I vs V plot under dark condition, n can be calculated. Also from the slope of the log $(I + I_L)$ vs V plot obtained under illumination, n can be found out and compared. In both cases, I_o can be obtained by the intercept on the ordinate.

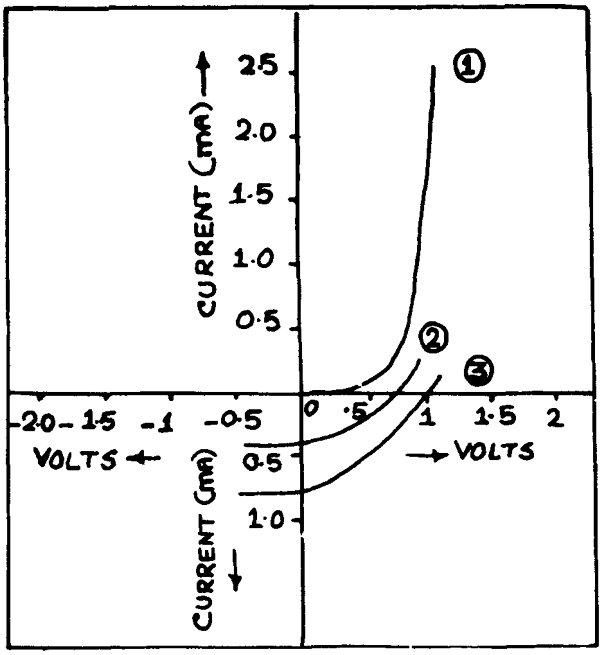

Fig.3 : I-V characteristics : 1) I-V curve in dark 2) I-V curve under 2000 lux 3) I-V curve under 5000 lux

RESULTS

Fig 3 shows the I-V plots of the solar cells in dark and under two differ illuminations. The plotter trace of the log I vs V in dark and log $(I + I_L)$ vs V (under illumination) of the same cell is shown in figure 4. The parameters obtained from I-V curve and log I-V curves and computed values are given in Table I. The values match very closely.

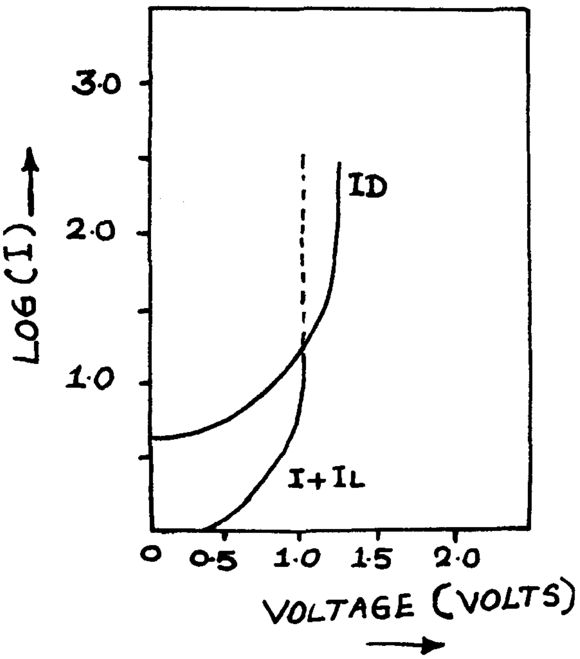

Fig.4 : Log I-V plots of dark and illumination

Table I: Comparison of the parameters of silicon solar cell

	From I-V plot (dark)	From log I-V plot (dark)	From log $(I + I_L)$ – V plot	Computed value
n	5.8	5.85	5.95	5.85
I_o	1.033×10^{-4} mA	0.955×10^{-4} mA	—	1.010×10^{-4} mA

I_L = 0.663 mA
V_{oc} = 0.750 mV
I_{sc} = 0.650 mA

Specifications

Oscillator output V_{rms} = 0 to 5 V
Frequency range = 0.3 Hz to 150 Hz
Current measuring resistors = 10,30 and 100 ohms
Log operator output = 1V max.

CONCLUSION

The designed intrument automatically plots I-V, log I-V curves for rapid analysis of solar cells. The values obtained from the plots agree well with the point-by-point computed values. It is a simple, and low cost instrument which can be used in any laboratory for demonstration of solar cells as well as in solar cell research and manufacture.

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REFERENCES

1. Y W Lam, *J Phys E (Sci Instru)* **14** (1981) 1302

2. Function Generator Data Book, *EXAR* (April 1979),30

3. G E Tobey, J E Greme Cand L P Huelsman, *Operational amplifiers: Design and applications,* McGraw Hill, Kogkusha, Tokyo (1971) 258-266

4. D F Stout and F Kaufman, *Handbook of operational amplifier circuit design,* McGraw Hill, New York, (1976) 17

5. *High performance, low cost logarithmic amplifier,* TELEDYNE PHILBRICK pamphlet 8/78