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A CIRCUIT DESIGN OF A CYCLIC VOLTAGE GENERATOR

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Abstract. The present paper describes a simple circuit for construction of a cyclic voltage generator, which can be used in electrochemical synthesis of conducting polymer films like polyaniline(PANI), polythiophene, polypyrrol *etc*. The circuit consists of a clock generator; its frequency is converted into digital voltage which is further converted to analog form using digital to analog converter (DAC). This analog voltage, after boosting, is used as a source of voltage in the synthesis of conducting polymer. Since the oxidation potential for a polymer is unknown, the circuit developed has a facility to change output in cyclic fashion from initial to final value at a rate of 45 mV/s and return back to the initial position. The designed circuit can also hold the potential at any desired value and hence can also be used in the potentiostatic configuration as a potentiostat for synthesizing a conducting polymer.

Key words: circuit, cyclic voltage generator, potential, polymer films, synthesis.

1. Introduction

In a cyclic voltammeter the voltage linearly varies from an initial to final potential and returns back to the initial position at the same rate. Since the oxidation potential for a polymer is unknown cyclic voltage generators are required for the formation of polymers. For many years a number of researches has been using cyclic voltammetry for synthesizing conjugated conducting polymers electrochemically. J. Bacon and R. Adams [1] have synthesized PANI using electro-oxidation of aniline by cyclic voltammeter which produces an even and smoother film which adheres strongly to the electrode surface. On the other hand PANI synthesized electrochemically at constant potential adheres badly to the electrode [2].

But commercially available, cyclic voltammeter is very costly and hence, the attempt has been made to design a cyclic voltage generator in a laboratory with the components that are available in almost every laboratory. Such a circuit has already been reported by U. Sinha *et al*. [3]. However the circuit described has certain drawbacks such as (i) a dual power supply of 5V is required, (ii) the current capacity of the circuit is limited to 1 amp., (iii) null offset voltage has to be adjusted each time while using the circuit. To overcome these problems and to raise the current handling capacity of the circuit, a modified circuit has been designed and described in the present paper.

2. Results and Discussion

2.1. Circuit details

Figure 1 shows the circuit diagram of the cyclic voltage generator. The circuit consists of IC-555, used in ustable mode as a clock generator. The frequency generated can be varied from 30 Hz to 51 Hz with the help of a potentiometer R_3. The selected frequency is further reduced using IC 7490 configured in symmetric divide by ten mode. The reduced frequency acts as a clock for up-down counter. The output of up-down counter is fed to a digital-to-analog converter (DAC, IC 1408) which converts the digitized count into the analog form. The DAC and an op-amp convert the 8-bit input data to the analog form [4]. The potentiometer (R_{18}) in the feedback is used to set maximum in the voltage cycle manually. The next part described in the circuit is the potentiostat arrangement designed using op-amp, one input of which is from the reference calomel electrode and the other input is from DAC through a buffer to avoid loading effect. The current handling capacity of the instrument is increased by power booster that follows the potentiostat. Power boosting is required because the final output voltage of the circuit is applied to conducting electrode kept in liquid. During formation of polymer film, due to chemical reactions the resistance of liquid/solution continuously changes which results in voltage drop of the final output. The power booster consists of power transistor BU-3055 and MJ-2955 connected in complementary symmetry class B push-pull amplifier [5]. The power transistors boost the current due to which voltage drop in liquid is prevented to some extent. Using the said circuit, voltage varies in cyclic form from –0.8 V to +5 V in the open circuit configuration and it drops to –0.15 V to +2.39 V in liquid at rate of 45 mV/s. The same circuit can be used as a potentiostatic arrangement

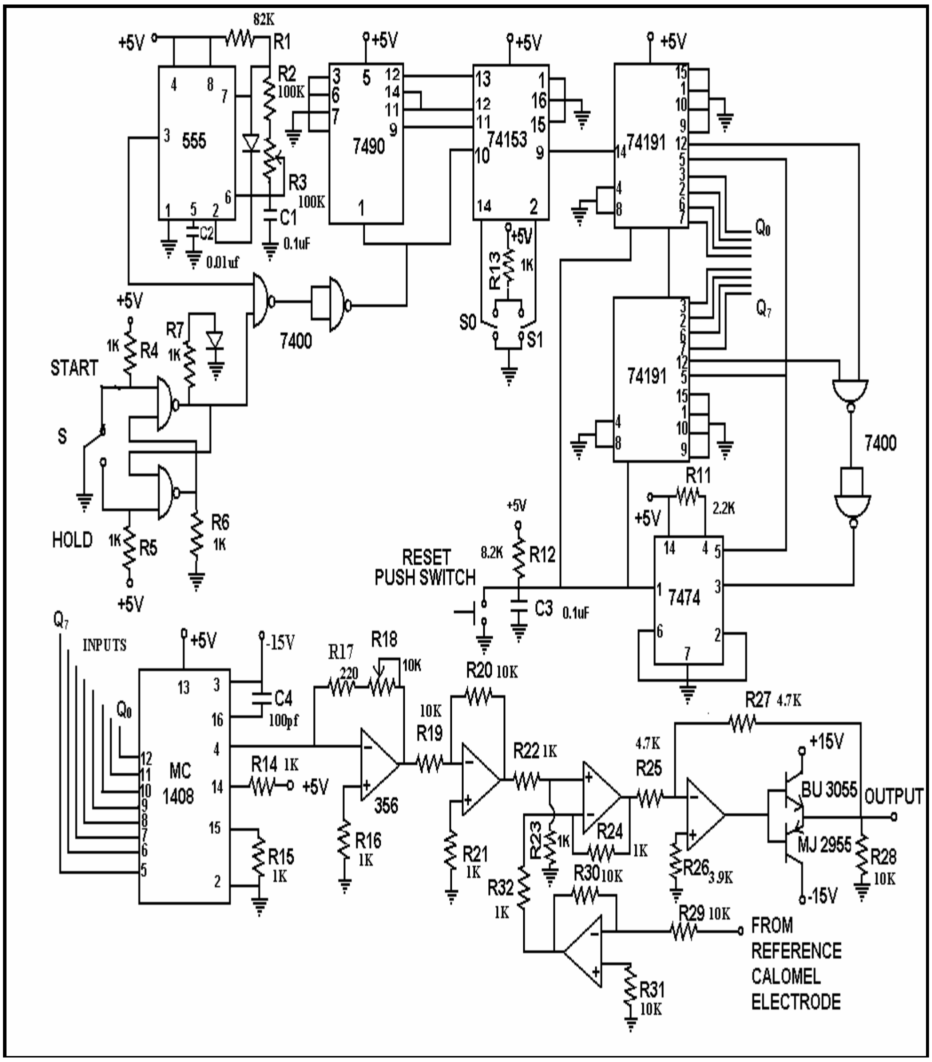

Fig. 1. Circuit diagram of a cyclic voltage generator

since it has facility to hold a voltage at a particular value between –0.15 V to +2.39 V in liquid. For this purpose the switch *S*, as shown in Fig. 1, is kept at hold position. In this position clock for the counter stops and hence the output voltage is maintained at a particular/desired value.

2.2. Applications

The designed apparatus has been used for electrochemical synthesis [6] of various polymers such as polyaniline, polypyrrole *etc*.

The method used for synthesis of polyaniline is described below.

Aniline (1 gm) is purified by distillation. In a single compartment cell using steel as a working electrode, glassy carbon as a counter electrode and SCE as a reference electrode and using 0.5M H_2SO_2 (50 ml) as solvent and LiCl as an electrolyte, polyaniline is synthesized. The film is generated by sweeping the voltage applied to electrode between –0.14 V to + 2.39 V at the rate of 45 mV/s. A very smooth film strongly adhering to electrode is obtained. The infrared (IR) spectrum of the film thus obtained is shown in Fig. 2. Polyaniline obtained using electrochemical method is in the salt form. The IR spectrum of PANI synthesized using designed circuit shows bands at 1600 cm^{-1} and 1500 cm^{-1} corresponding to quinoid and benzoid vibration respectively. The band at 1300 cm^{-1} corresponds to C–N stretching vibration. These bands are observed at the nearly same position as that in the IR spectrum of chemically synthesized PANI using standard electrochemical method by Potentiostat/Galvanostat. The C–H in plane stretching band is observed at 1100 cm^{-1} for PANI obtained using designed circuit. The band at 800 cm^{-1} and 490 cm^{-1} is due to out of plane vibrations of PANI. All these bands confirm the formation of PANI by electrochemical polymerization process using designed circuit. Thus the absorption peaks observed are similar to those obtained in IR of PANI prepared using potentiostatic method (Princeton Applied Research Potentiostat/ Galvanostat, Model 363) with the same chemical composition and the same cell arrangement.

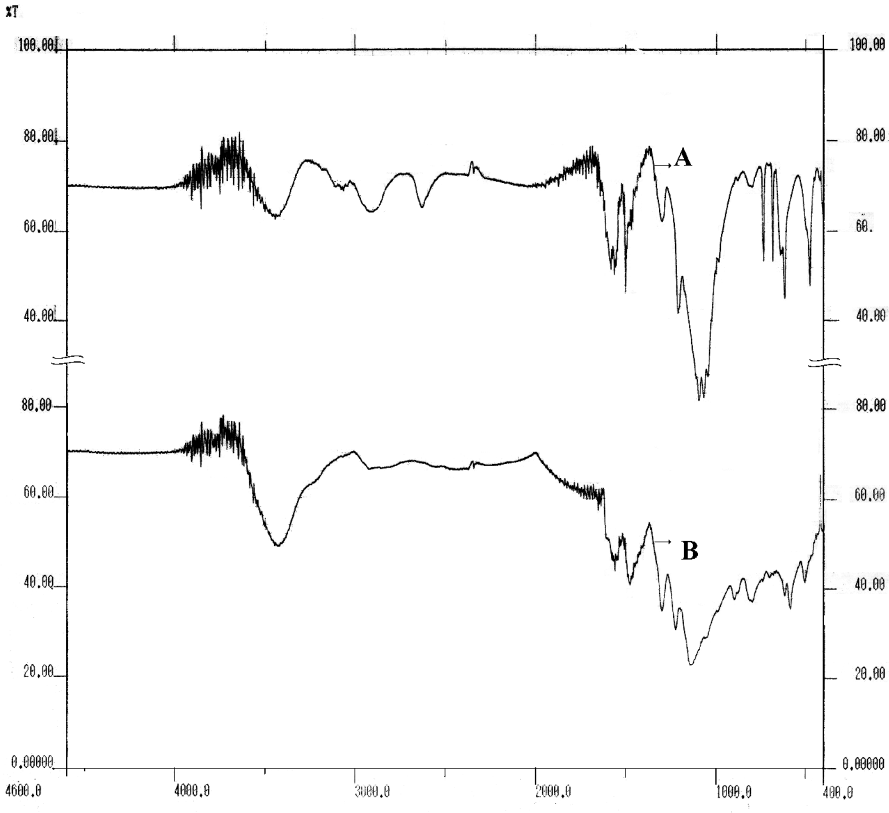

Fig. 2. FTIR spectra of polyaniline synthesized using designed circuit described above (A) and synthesized using standard electrochemical method by Pontentiostat/Galvanostat (Princeton Applied Research Potentiostat/Galvanostat Model 363) (B)

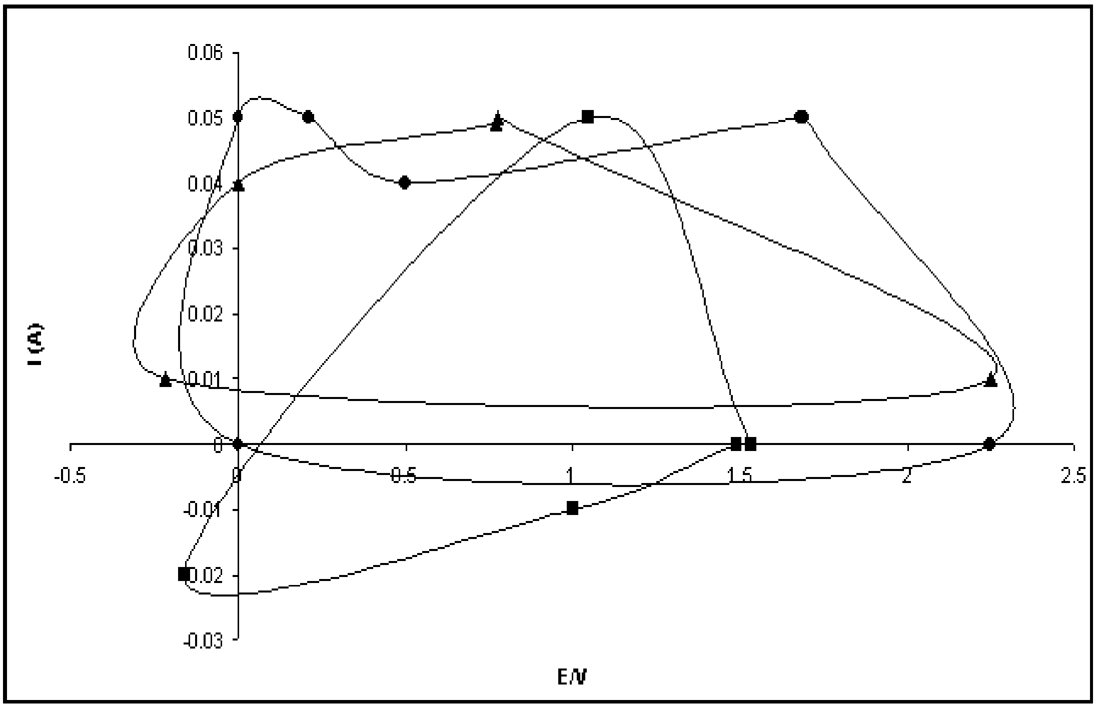

Fig. 3. Voltammograms of polyaniline during the synthesis

The infrared spectra of synthesized PANI matches also very well with already reported one [7].

This confirms that the synthesized polymer is polyaniline. Hence it is concluded that the circuit can be used for synthesis of such conducting polymers. The voltammogram recorded during electropolymerization of aniline are shown in Fig. 3.

3. Conclusion

A low cost circuit has been designed and it can be used for synthesis of conducting polymers.

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РОЗРАХУНОК СХЕМИ ЦИКЛІЧНОГО ГЕНЕРАТОРА НАПРУГИ

Анотація. *Описано просту схему для створення циклічного генератора напруги, який може бути використаний в електрохімічному синтезі струмо-провідних полімерних плівок на основі поліаніліну (PANI), політіофену, поліпіролу та ін. Схема складається з генератора тактових імпульсів, частота якого за допомогою цифрово-аналогового конвертора перетворюється в цифрову напругу з подальшим перетворенням в аналогову форму (DAC). Така аналогова напруга є джерелом напруги при синтезі струмопровідних полімерів. Розроблена схема дозволяє змінювати вихідний сигнал з початкової до кінцевої величини із швидкістю 45 мВ/с і повертатись у вихідне положення. Запропонована схема може утримувати потенціал будь-якої величини, а тому може знайти застосування як регулятор напруги при синтезі струмопровідних полімерів.*

Ключові слова: *схема, циклічний генератор напруги, потенціал, полімер, синтез.*