DIGITAL CURRENT INTEGRATOR

M PANDIAMMAL, K R RAMAKRISHNAN and HN VENKOBA RAO
Central Electrochemical Research Institute, Karaikudi 623006

ABSTRACT

Current integration into coulombs is an important method in many instrumentation applications like coulometry, thickness measurement etc. Various circuit configurations have been published so far [1, 2]. Here a VFC (Voltage to frequency converter) using NE 566 and a Counter I.C. 7217 A, have been used to achieve current integration that can be rigged up in any laboratory with minimum effort. The theory and operation of the circuit are discussed in this paper.

INTRODUCTION

Digital techniques are finding applications exclusively in analogue electronics. In the handling of complicated chemical processes, sophisticated electronic equipments are used. In electrochemical and electroanalytical experiments and their studies, techniques like coulostat and digital coulometer etc. are in use. The digital integrator, which has been developed, in our laboratory is a very versatile one for these purposes. It can be easily built up in any laboratory using simple solid state components, like single chip VCO 566 and Counter 7217 A. It is also having the advantage for direct digital read out of the charge in coloums. The coulomb represents the charge taken for deposition of a metal or paint on a surface for a particular interval of time.

The digital integrator described here is successfully used for measurement of total charge consumed in a reaction on a surface. This works by the principle of voltage to frequency conversion and yields a direct read out on a 5 digit LED display. The maximum counts possible here is $1 \times 10^4$. A schematic diagram of the current integrator is shown in Figure 1. Figure 2 explains how to couple the digital integrator circuit to a potentiostat.

CIRCUIT DESCRIPTION

The full circuit diagram is as shown in Figure 3. This is so designed that input of either polarity can be given. The current from a potentiostat is converted into voltage by a current to voltage converter A 1. Input to the current to voltage converter is directly fed as a summing mode through a resistor $R_1$ and the output will be the corresponding voltage drop through the resistor $R_2$. $R_2$ is the scaling factor.

Then this output is fed to a combination of unipolar generator (UPG) comprising of two stages of operational amplifiers $A_2$ and $A_3$. This UPG operates in such a way that the output of the UPG will always be positive.
The NE 566 is one of the few integrated devices which can really claim the superiority of VCO. The frequency of the oscillator is determined by an external resistance \( R_1 \), the capacitance combination of \( C_y \) and \( C_4 \) and the voltage \( E_o \) applied to the control terminal. The oscillator can be programmed over a ten to one frequency range by proper selection of an external resistance and modulated over a ten to one range by the control voltage with exception linearity. The function of capacitor \( C_y \) is to prevent parasitic oscillations that may creep in during VCO operations.

The time period is governed by the RCK value where

\[
K = (V_{ce} - E_o)
\]

In NE, 566, we have used here

\[
F_0 = 2 \left( \frac{V_{ce} - E_o}{R_y V_{ce}} \right)
\]

\[
= \frac{K_0}{K_1} F_0
\]

where \( E_o \) is the voltage output of UPG proportional to the current.

\[
K_0 = 2 \frac{R_y V_{ce}}{R_1 V_{ce}} + K_1
\]

No. of counts of the counter 7217A = \( N = \int f dt \)

But \( f = E_o / R_y \)

where \( R_y \) is the feed back resistance which is the scale factor \( R_2 \). In other words

\[
f = \frac{E_o}{K}
\]

where \( K \) is the time constant

Therefore \( f = \left( \frac{R_1}{K} \right) t \)

\[
N = \int f dt = \text{charge } Q
\]

By properly calibrating and scaling the input current, it is possible to get the corresponding digital output of the counter to read out directly in coulombs. In this circuit the resistance \( R_2 \), the scale factor is the calibration resistor. The accuracy of the circuit could be further improved by making the resistance \( R_2 \) adjustable.

**Counter**

The output frequency of the VCO is fed to the input of the counter. The counter used here is 7217 A which is having the capacity of maximum counts 9999. In 7217 A there are two outputs such as zero and carry/borrow. The zero o/p will give one negative pulse at the end of maximum counts 9999. Similarly the carry/borrow will give a positive pulse at the end of maximum counts 9999. Outputs are fed to an exponential counter, by using 7490 and 7448 chips and a single digit seven segment LED display to enable counting up to \( 1 \times 10^9 \) counts. The carry output is given to the B input of 7490. The BCD output of 7490 is fed to the BCD-to seven segment converter, 7448. The segment output from 7448 drives the single digit LED.

The counter 7217 A is reset at 1000 by selecting at the BCD inputs of 7217 A with the help of thumb wheel switches. By using the zero output of 7217 A, the same is reset to 1000 after the first maximum counts of 9999. The NE 555 is included for giving a small delay pulse for resetting the 7217 A at 1000.

**Display**

The display here used is the 5 digit 7 segment LED display using the 7 segment LEDs TIL 313. The counter has been set to maximum capacity of \( 1 \times 10^9 \) counts.

**The specifications of the digital integrator**

- **Input** From potentiostat or Galvanostat 100 mA max
- **Range** 0 - 100 mA
- **Input impedance** 10 meg ohms
- **Output** Direct read out of the counter

**Display**

- **Type** 7 segments LEDs TIL 313
- **No. of digits** 5
- **Max no. of counts** \( 1 \times 10^9 \)

**REFERENCES**