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DIGITAL CURRENT INTEGRATOR

M PANDIAMMAL, K R RAMAKRISHNAN and H N 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 coloumbs. 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 1×10^9. 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.

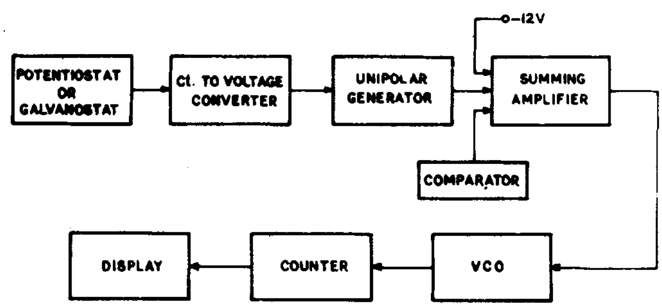


Fig. 1 : Schematic diagram of current integrator

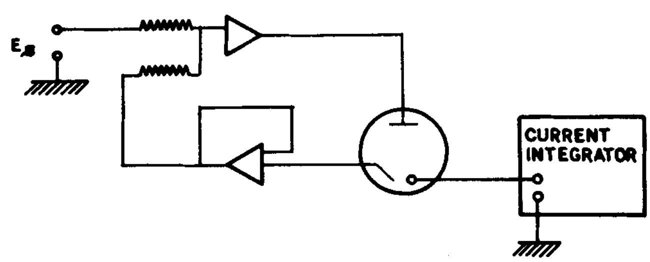
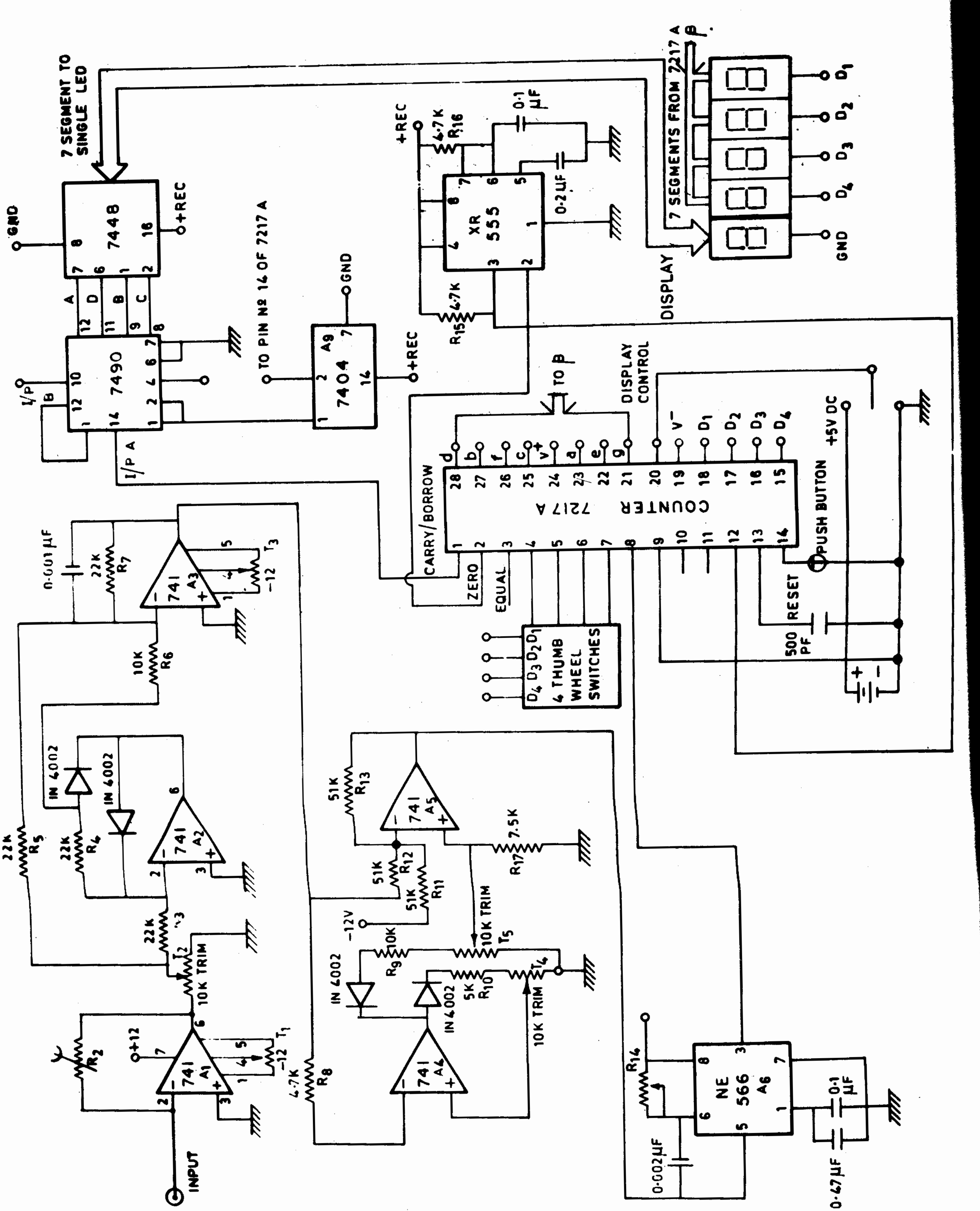


Fig. 2 : Potentiostat application

This UPG output is fed to the voltage controlled oscillator, VCO through a comparator A_4 and a summing amplifier A_5. The use of separate comparator boosts the degree of reliability and stability and also reduces hysterisis effects. Comparator output is constantly tracked by the diodes, 1N 4002, and the output is adjusted by the trimmers T_4 and T_5 to give a steady output frequency in VCO. In VCO there is one condition that the bias voltage applied to the control terminal (Pin No. 5 of NE 566) should be in the range $3/4\, V_{cc} \leq E_o \leq V_{cc}$. For getting this range of voltage control, the summing amplifier and the comparator stages are included.


7 SEGMENT TO SINGLE LED
7448
7490
7404
TO PIN No 14 OF 7217 A
XR 555
7 SEGMENTS FROM 7217 A
DISPLAY
DISPLAY CONTROL
COUNTER 7217 A
CARRY/BORROW
ZERO
EQUAL
4 THUMB WHEEL SWITCHES
PUSH BUTTON
RESET
+5V DC
NE 566
INPUT
10K TRIM
1N 4002
741

Voltage controlled oscillator

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 14), the capacitance combination of C_3 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_2 is to prevent parasitic oscillations that may creep in during VCO operations.

The time period is governed by the RCK value where

$$K = (V_{cc} - E_o)$$

In NE, 566, we have used here

$$F_o = 2\,(V_{cc} - E_o) / R_c V_{cc}$$
$$= K_o - K_1 E_0$$

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

$$K_o = 2 / R_c V_{cc} + K_1$$
$$= 2 / R_c V_{cc}$$

No. of counts of the counter 7217A = $N = \int f\,dt$

But $i = E_o / R_F$

where R_F is the feed back resistance which is the scale factor R_2. In other words

$$f_o = E_o / K$$

where K is the time constant

Therefore $f = (R_f / K)\, i$

$$N = \int f\,dt = \text{charge } Q$$

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 1×10^9 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 7217A is reset at 1000 by selecting at the BCD inputs of 7217A with the help of thumb wheel switches. Bu using the zero output of 7217A, 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 7217A 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 1×10^9 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	1×10^9

REFERENCES

1. M Lindstrom and G Sundholm, *J. Chem. Education,* **49** - 12 (1972) 847

2. S Birlasekaran, K R Ramakrishnan and H N Venkoba Rao, *J. Chem. Bio. Med. and Envi. Instrumentation* (USA), **11** - 3 (1981) 1.