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Computer-Based Resistance, Capacitance and Inductance Measuring and Monitoring System

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Abstract

A computer-based resistance, capacitance and inductance measuring and monitoring system is developed. The variation of the resistance, capacitance and inductance values within a specified period are graphically displayed on the monitor continuously and saved in a file. The stored data from the file can be retrieved and seen as the text document. The Colpitts LC feedback oscillator, SN 74 LS 123 monostable multivibrator and 555 timer astable multivibrator are used in this circuit. The software program is written in Turbo C^{++} Language.

Key words: RLC measuring and Monitoring System, Colpitts LC Feedback Oscillator, SN 74 LS 123 Monostable Multivibrator, 555 Timer Astable Multivibrator.

Introduction

We would like to expand the applications of a personal computer into the area of electronic measuring instrumentation. In one approach of measuring the resistance, it is based on astable multivibrator and its output frequency is related to the resistance of test resistor in the timing network. The personal computer makes the frequency measurements through parallel printer port, and software program provides the necessary calculations and calibration. In measuring the capacitance, the personal computer makes the measurement of output frequency of astable while capacitors having lower capacitance values are being tested and personal computer measures the time period of one shot pulses produced by monostable when higher capacitance values are under test. To measure the inductance, the inductor is connected in the tank circuit of LC feedback oscillator and the sinusoidal output signal of oscillator is converted into square wave form since the resonant frequency of oscillation is related to inductance of the inductor.

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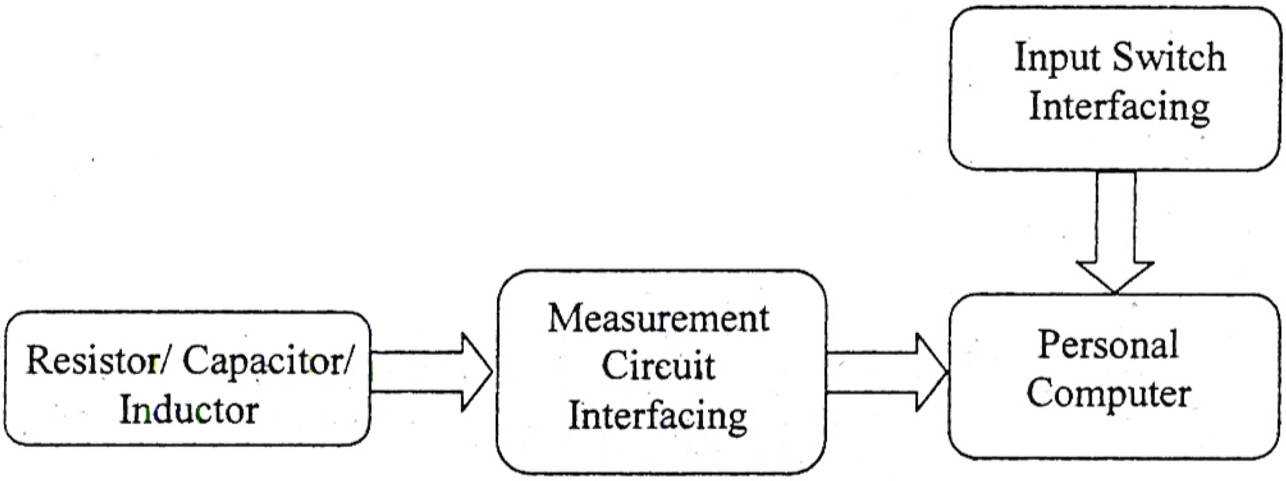

Fig. 1. Block diagram of the whole system

Design and Construction of the Complete Circuit

The interface unit consists of (3) major sections:

(1) circuit arrangement for measuring the resistance,

(2) circuit arrangement for measuring the capacitance and

(3) circuit arrangement for measuring the inductance.

Circuit Arrangement for Measuring the Resistance

In Fig (2), the circuit is quite simple and 555 timer IC 4 and IC 5 are used for measuring the resistance. Each 555 timer is configured as astable multivibrators, and the 0.01 μF capacitor is connected to the control input for decoupling and it has no effect on the astable operation. The external components R_1, R_2 and C_{ext} form the timing circuit that sets the frequency of oscillation. The 555 timer IC4 is used for measuring the lower resistance values ranging from ($100\,\Omega$) up to (80K) and the fixed values of R_2 and C_{ext} are chosen as $100\,\Omega$ and $0.33\,\mu F$ respectively. The resistor whose resistance is to be measured must be connected in place of timing resistor R_1 between DISCHARGE input and supply rail. For higher resistance, values range from 80 K up to some megaohms. In the 555 timer IC_5, resistor R_2 and capacitor C_{ext} are chosen as 1K and 0.003 μF respectively. It is arranged in such a way that the resistor to be measured is connected to proper astable multivibrator circuit by using range selector switch SW_1 as shown in the figure, and square-wave output signal is selected by the switch SW_2 and applied to the (In 4) input of PC's printer port through a female 25 way D type connector to measure the frequency of oscillation which is given by

$$f = \frac{1.44}{(R_1 + 2R_2)C_{ext}} \qquad [1]$$

where R_1 is the resistance of resistor to be measured. The software program written in Turbo C^{++} language provides the frequency measurement, necessary calculation and calibration.

Circuit Arrangement for Measuring the Capacitance

Astable multivibrator configured with IC_1 is used for measuring the lowest range capacitance values and the astable multivibrator implemented with IC_2 is for middle range capacitance values. The capacitor under test connected across the THRESHOLD input of 555 timer and ground. The square-wave output signals are applied to the (In 4) input of PC's printer port to measure its frequency.

The frequencies of oscillation produced by the astable multivibrator for the high capacitance values are too low to be measured with a PC. For higher capacitance values, it is based on monostable multivibrator implemented with a 74LS123IC. In this case, the test capacitor must be connected across pin 14 and pin 15 of monostable multivibrator IC and it is also done by the switch SW1. One-shot pulse width of monostable is related to RC time constant and given by $T = 0.45R_{ext}C_{ext}$,[1] where C_{ext} is the capacitor under test. An additional astable circuit implemented by a 555 timer is used for the purpose of triggering the monostable. The one-shot pulse train output of monostable is applied to the (In 4) input of PC's printer port to measure the pulse width which is proportional to capacitance of test capacitor.

Circuit Arrangement for Measuring the Inductance

A BJT transistor of the type C828 is used as the gain element of the Colpitts oscillator and the inductor under test must be connected in the LC feedback circuit. The approximate frequency of oscillation is the resonant frequency of LC circuit and governed by the values of C_1, C_2 and L according to the following relation.

$$f_r = \frac{1}{2\pi\sqrt{LC_T}}\text{, where total capacitance } C_T = \frac{C_1C_2}{C_1+C_2}. \qquad [2]$$

The sinusoidal output signal of Colpitts oscillator appeared at the collector of transistor is applied to the input of level comparator (LM 339) to be converted to square waveform. The software provides the frequency measurement, necessary calculation and calibration.

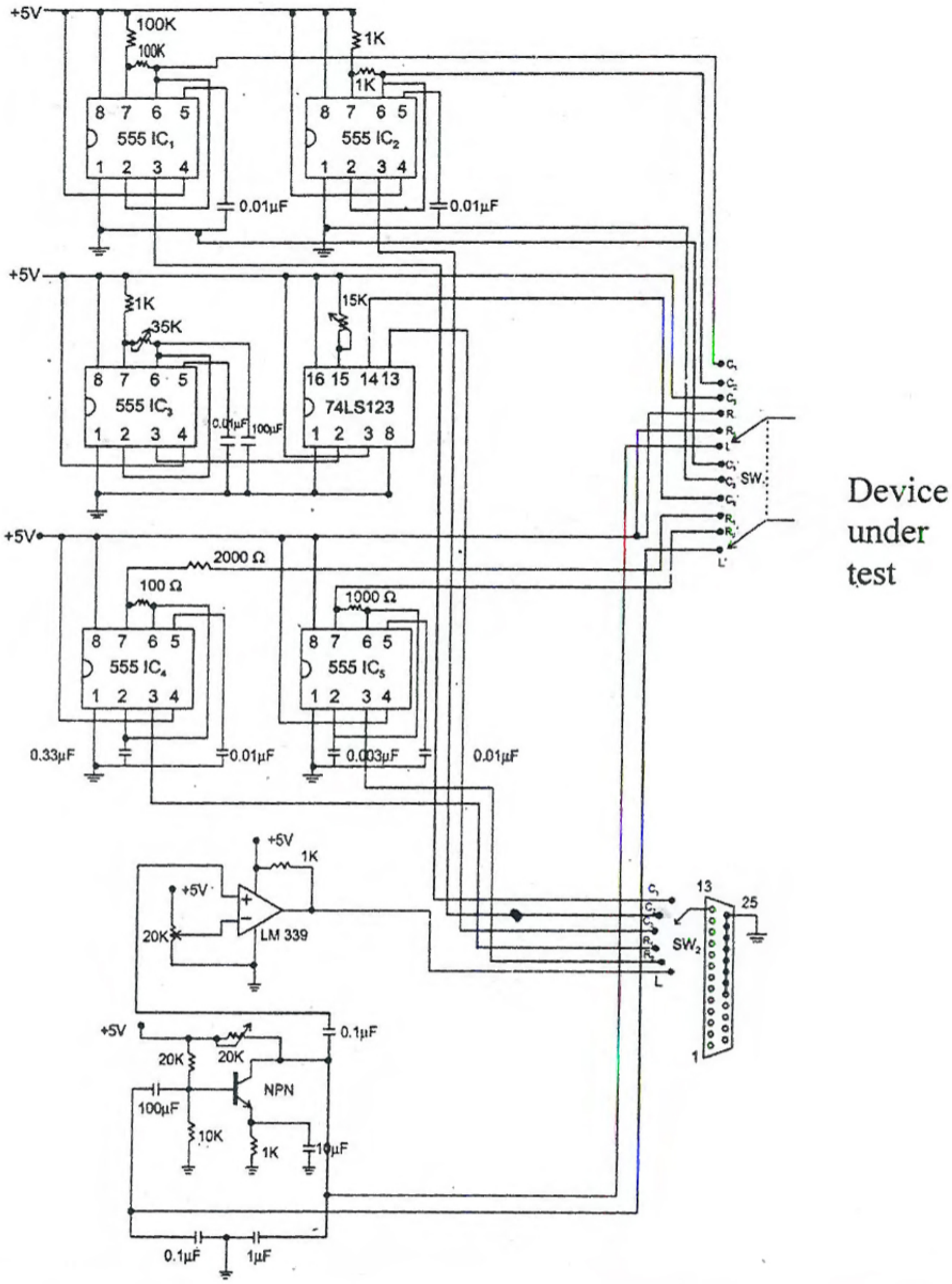

Fig. 2. Complete circuit for capacitance resistance and inductance measurement with PC

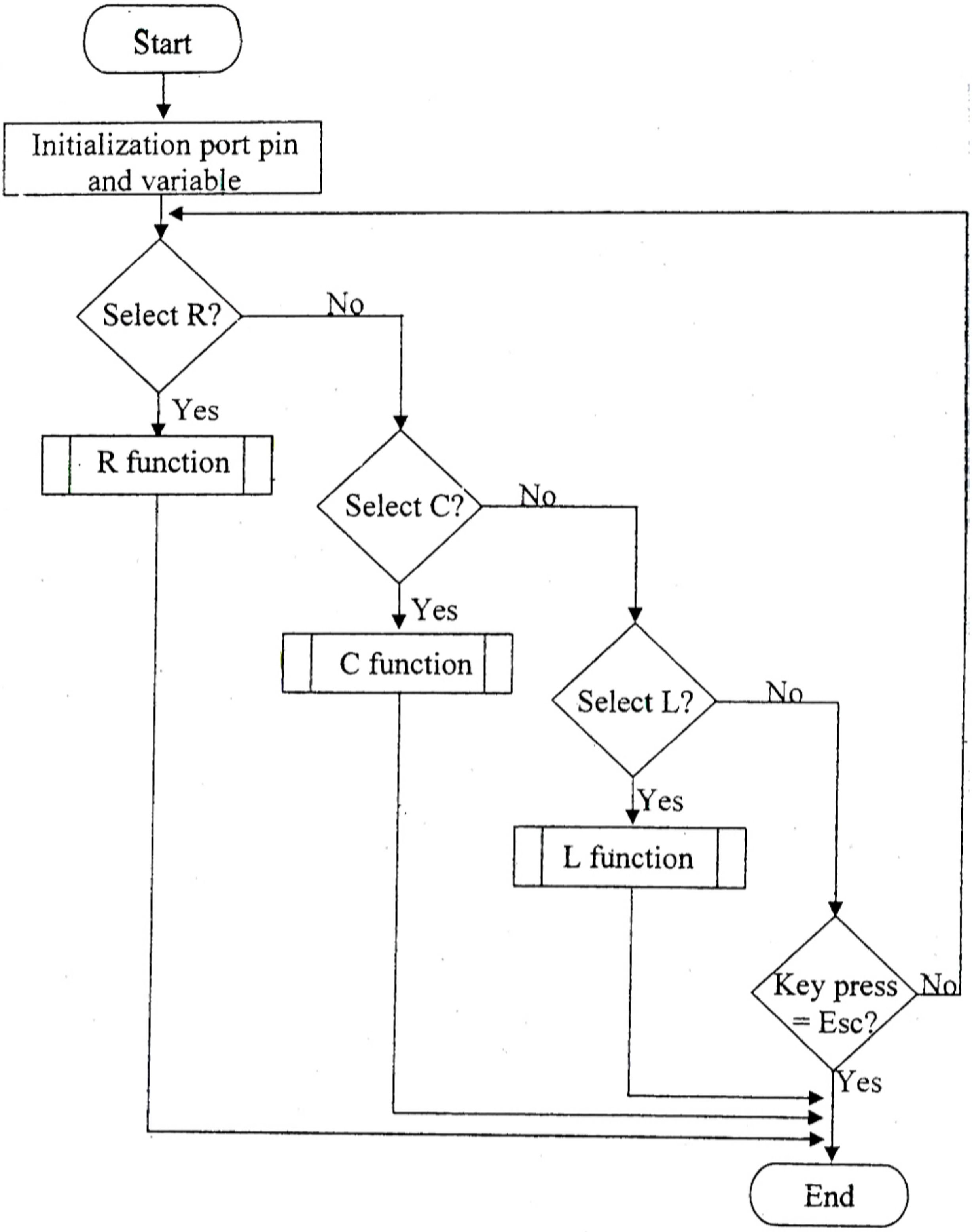

Fig. 3. Flowchart of the program

Results and Discussion

The personal computer based system functions as desired. The 555 timer is the choice for astable multivibrator because of its capability of wide range oscillation frequency adjustment for a given set of resistance and capacitance values in its timing network. To cover the whole usable range of resistance from a hundred ohm to a few mega ohm, it needs two sets of RC network arrangement even though the 555 timer has wider adjustable frequency range among other types of relaxation oscillator. A remarkable advantage of our approach of developing a PC-based RCL measuring system is that the circuit design is very simple and reliable. The PC-based system can measure the capacitance values as large as $4700\mu F$ but the digital LCR meter (model No. 9073) cannot make measurements for capacitors having capacitances of $1000\mu F$ and above. Measured values with LCR digital meter and measured values with our constructed meter and their discrepancies (%) are shown in Table (1), (2) and (3). The frequencies are produced by 555 timer IC and then resistances are calculated with the aid of calibration curves and these are shown in Fig (4), (5) and (6). Fig (7) and (8) are calibration curves for measured capacitances and output frequencies of 555 timers. Large capacitances are measured by using calibration curve of output periods of monostable multivibrator shown in Fig (9). Fig (10) and (11) show the calibration curves for inductances to be measured and output frequencies from LC oscillator. The graphs of the variations of resistances, capacitances and inductances with time are seen in Fig (13), (14) and (16) and variation of capacitances with time in the form of text file is shown in Fig (15). The resistance, capacitance and inductance values are graphically displayed on the monitor. The stored data from the file can be seen in the form of the text document. The complete program will do the job of data acquisition for the minimum 1 minute to the maximum 12 hours. The measurable resistance range lies between 100Ω and $5.65\ M\Omega$ within accuracy better than 10%. The measurable capacitance range lies between $0.001\mu F$ and $4700\ \mu F$ within accuracy better than 3%. The measurable inductance range lies between 0.75 mH and 1090 mH within accuracy better than 7%.

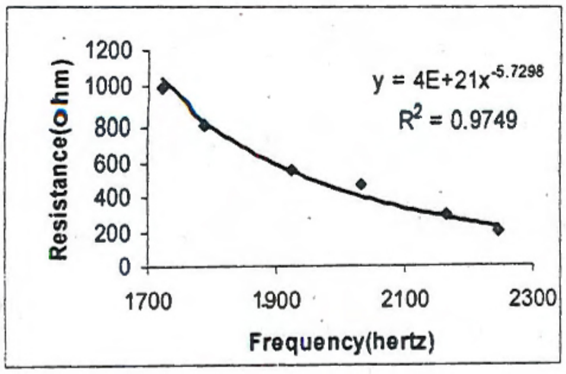

Fig. 4. Calibration curve for small resistance in range 1 (R≤ 1000Ω)

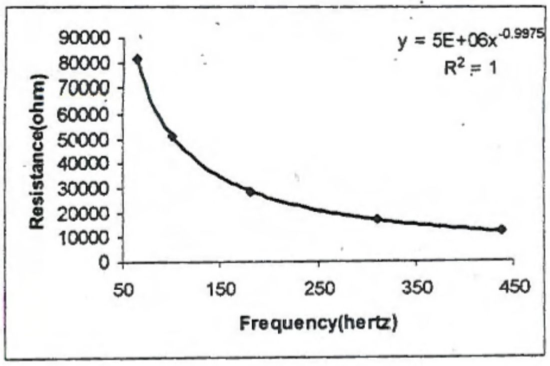

Fig. 5. Calibration curve for small resistance in range 1 (1000 Ω > R > 80 K)

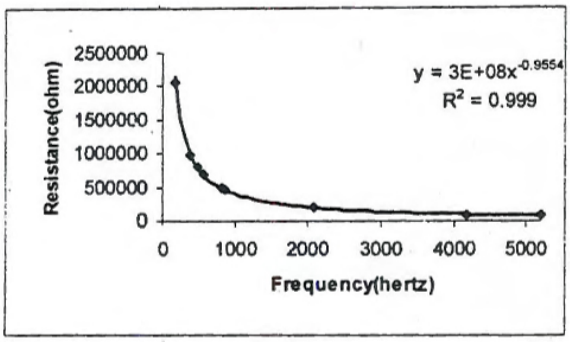

Fig. 6. Calibration curve for large resistance in range 2 (R ≥ 80 K)

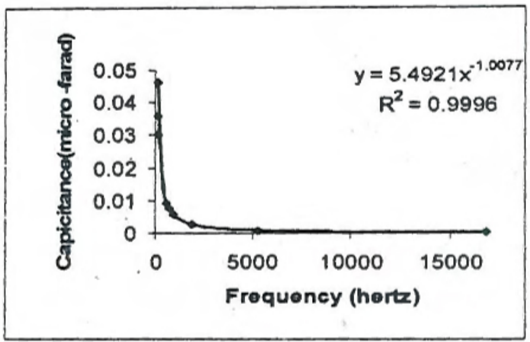

Fig. 7. Calibration curve for small capacitance in range 1 (C≤ 0.05 μF)

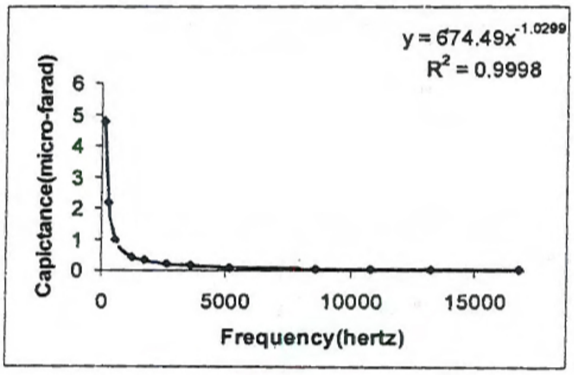

Fig. 8. Calibration curve for small capacitance in range 2 (0.05 μF < C < 5μF)

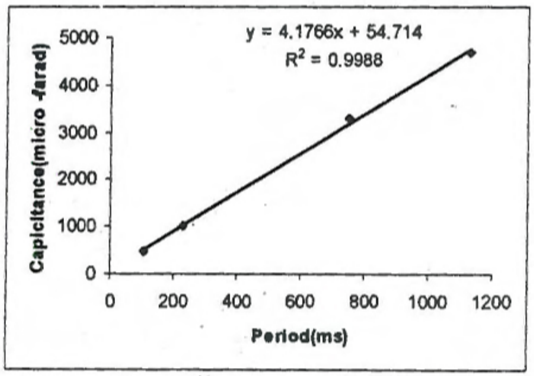

Fig. 9. Calibration curve for large capacitance (C ≥ 5 μF)

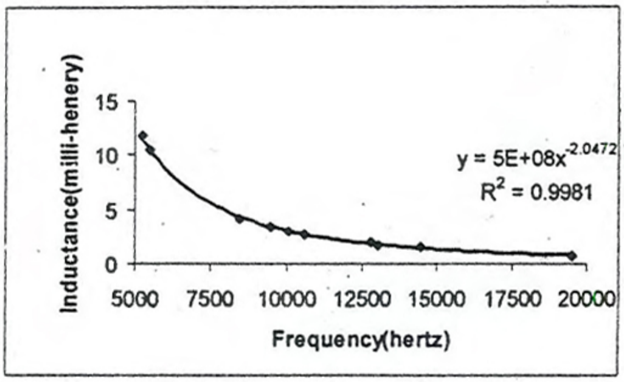

Fig. 10. Calibration curve for small inductance (L ≤ 11 m H)

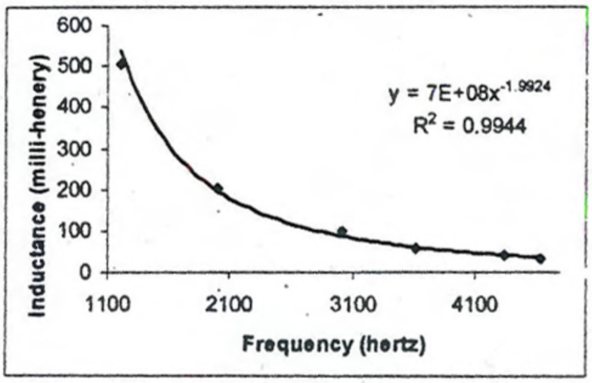

Fig. 11. Calibration curve for large inductance (L > 11 m H)

Table 1. Comparison of Measured Resistances

R	R'	Discrepancy (%)
98.00 Ω	97.00 Ω	1.02
384.00 Ω	386.00 Ω	0.52
549.00 Ω	543.00 Ω	1.09
674.00 Ω	671.00 Ω	0.45
813.00 Ω	820.00 Ω	0.86
0.99 K	1.05 K	6.06
2.19 K	2.15 K	1.83
9.86 K	9.72 K	1.42
14.50 K	14.00 K	3.45
26.40 K	25.50 K	3.41
49.20 K	48.90 K	0.61
98.40 K	100.60 K	2.24
463.00 K	464.00 K	0.22
692.00 K	690.00 K	0.28
807.00 K	803.00 K	0.5
0.97 M	0.94 M	3.1
2.05 M	2.00 M	2.44
5.60 M	5.1 M	8.9

R = Measured Resistance with LCR digital meter
R'=Measured Resistance with Constructed meter

Table 2. Comparison of Measured Capacitances

C(μF)	C'(μF)	**Discrepancy (%)**
0.0009	0.0009	0
0.0028	0.0028	0
0.0057	0.0056	1.75
0.0090	0.009	0
0.2100	0.2040	2.86
0.4400	0.4400	0
2.1500	2.1600	0.47
4.7600	4.7800	0.42
9.4600	9.5000	0.42
33.1000	33.1500	0.15
93.4000	92.4000	1.07
335.0000	333.0000	0.6
468.0000	465.0000	0.64
-	1021.0000	-
-	3275.0000	-
-	4625.0000	-

C= Measured capacitance with LCR digital meter (μ F)
C'=Measured capacitance with constructed meter (μ F)

Table 3. Comparison of Measured Inductances

L (mH)	L' (mH)	**Discrepancy(%)**
0.75	0.74	1.33
1.52	1.42	6.57
1.96	1.94	1.02
2.72	2.72	0
3.04	3.04	0
3.40	3.37	0.88
11.70	11.70	0
68.30	68.10	0.29
450.00	445.00	1.11
1090.00	1098.00	0.73

L= Measured Inductance with LCR meter (mH)
L'=Measured Inductance with personal computer (mH)

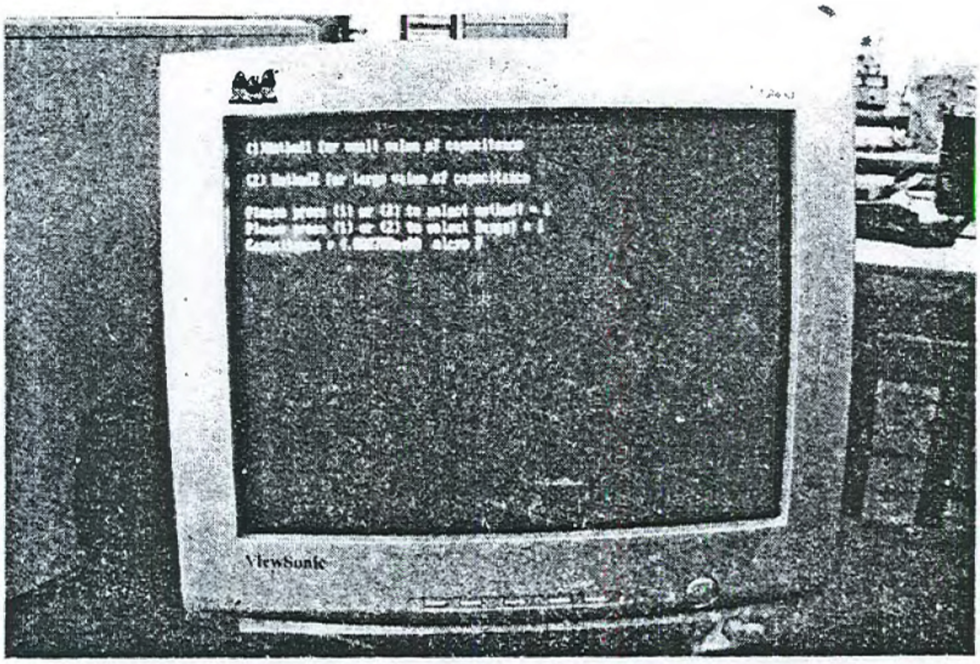

Fig. 12. The measurement result of capacitor displayed on the monitor

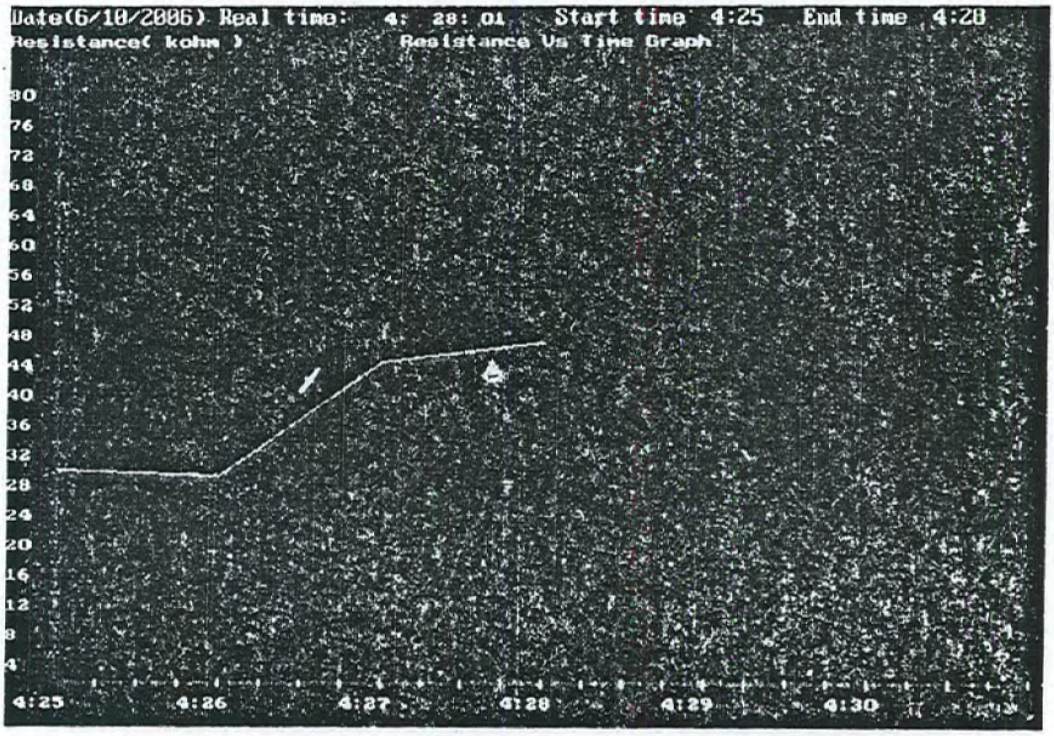

Fig. 13. The output screen of resistance versus time graph

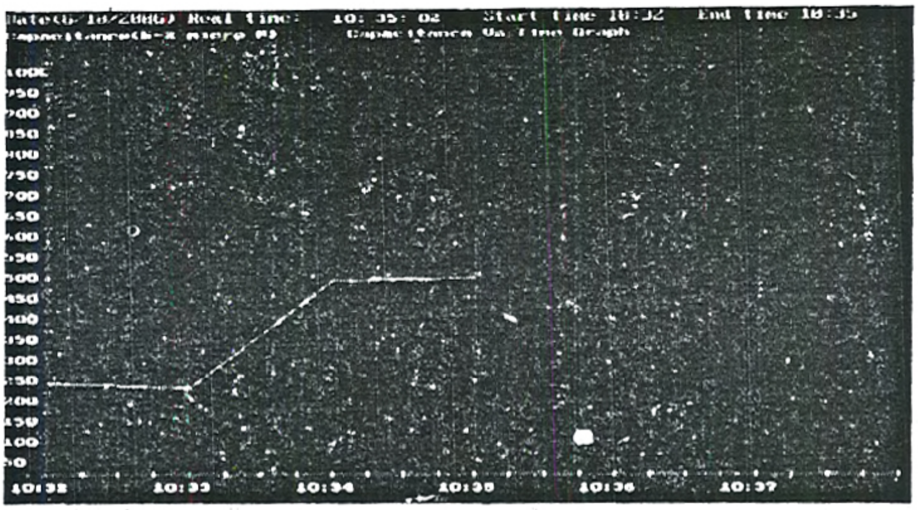

Fig. 14. The output screen of capacitance versus time graph

```
Enter Report File Name with extension to open : = 10321035.txt
                CURRENT RECORD
                =================
Date : 6-10-2006
Start time :    10:32
End time :      10:35
Sampling time (min) :   1
      Time          Capacitance (microF)
    10:32:25             2.188151836
    10:33:00             2.179550886
    10:34:00             4.913259506
    10:35:00             4.871096611
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Fig. 15. The saved data from the file name 10321035.txt

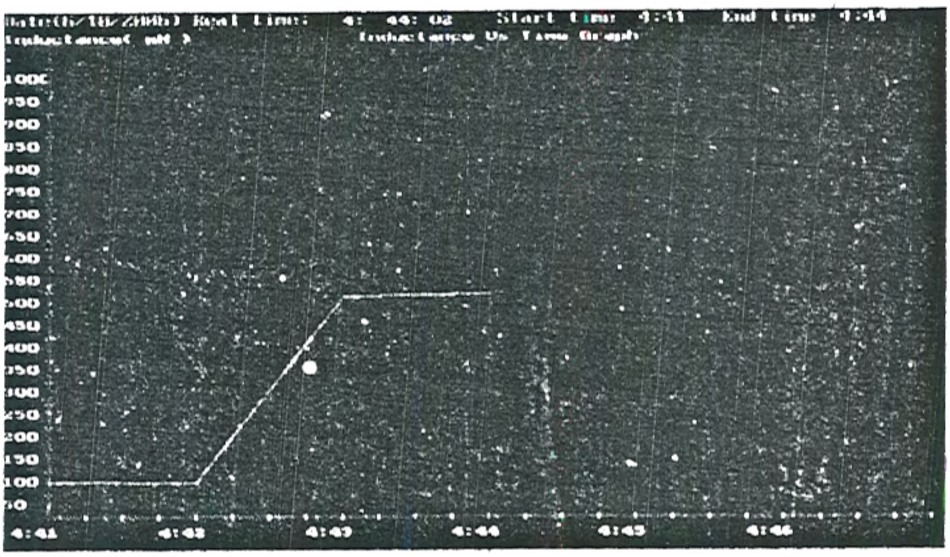

Fig. 16. The output screen of inductance versus time graph

Conclusion

The PC-based resistance, capacitance and inductance measuring and monitoring system is successfully developed in our own way. Our approach of developing a PC- based RCL measuring system is quite straightforward and reliable. It has minimum hardware requirement and simplest circuitry among its counterparts. In practice, calibrating the two parameters with non linear relationship by adjusting hardware is very difficult and the desired degree of accuracy cannot be obtained. Since it is a PC- based system, the calibration can be made at a desired degree of accuracy with the aid of software program. In PC-based instrumentation, the 555-timer astable can be used as resistance to frequency converter or capacitance to frequency converter. The Colpitts oscillator can also be used as inductance to frequency converter. Therefore technicians have been making researches in their own ways with their PC-based measuring instrument all over the world. It is expected that a personal computer may be used as a universal measuring instrument in future.

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