Analysis of Transient Response of First & Second Order System using EXPEYES

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Abstract— Time response analysis has key role in most of control systems to study satisfactory performance of system.The system require certain finite time to reach its steady state value and till then it increases exponentially in first order and oscillates in second order system. Such transients are observed on dedicated instruments viz. Digital Storage Oscilloscope which is costly. The main contribution of this work reflects replacement of such instruments by portable EXPEYES hardware. In this paper, transient responses of electrical circuits are analyzed. Python is used as programming language to show output on GUI. Performance parameters like time constant of circuit, damping factor and resonant frequencies are calculated. The results are validated with theoretical readings and existing system.

Keywords— Damping Factor, EXPEYES, GUI, Python, Transient Response.

I. INTRODUCTION

Time response of any system has two parts viz. transient response and steady state response. Transient response of system is the portion of total time response during which output changes from one value to another value. Output reaches to steady state value in steady state response. Transient response of first order system gives information about speed of response depending on system time constant. Similarly, transient response of second order system gives the nature of response like underdamped or overdamped. In practice, transient of electrical circuits maintain for few milliseconds. To capture accurate response and measure relevant parameters, some dedicated instruments are required which are costly and bulky. Therefore to overcome this issue, small, handheld and less weighty hardware called 'EXPEYES' is used.

EXPEYES stands for EXPEriments for Young Engineers & Scientists. This is a part of PHOENIX (Physics with Home-made Equipment & Innovative Experiments) project which was started in 2004 by Inter-University Accelerator Centre. This hardware consists of PIC microcontroller of 16 MHz; 2 kB RAM, inbuilt waveform generator, CMOS power supply, frequency counter and quadruple operational amplifiers. EXPEYES hardware is interfaced with computer with the help of USB connection. EXPEYES software is open access and programming is done in Python Language [1], [2].

This paper is organized as follows: Section II discussed relevant and related work. In Section III, block diagram of proposed work is described. The concept of transient response of first and second order system is explained in Section IV. Experimental setup and its results are reported in Section V. Finally, paper is concluded in Section VI.

II. LITERATURE SURVEY

Many researchers showed contribution to capture transient responses for different standard test inputs. Most of them are based on simulation of competent software like MATLAB, POWEReSIM etc.

Matthew Younget. al. designed data acquisition system of MEMS structure in [3]. The impulse response of system is captured using underdamped second order system. It uses Field Programmable Gate Array (FPGA), Analog-to-Digital Converter (ADC), buffer amplifier, and a computer interface.

Graphical User Interface (GUI) is developed using MATLAB Mex Function which gives user a high degree of control over various device operations.

In [4], the fibre optic sensor technology is used for measuring the parameters like pressure, temperature, humidity in industrial environment. Fibre optics is the medium for measuring the information in optical sensor which measure the physical parameter with very high performance, simplicity, small size, wide frequency capability. By changing the distance of the phototransistor from the optical fibre the intensity of light can be changed. EXPEYES hardware is used for measuring the distance between the source and detector. If it is increased, then response time increased and decay time decreased.

Melvin Chelli in [5] used an opto interrupter technology for sensing the speed of DC motor. EXPEYES is used to generate High frequency variable PWM. If the reference speed is more than actual speed then applied voltage to the motor is increased which will increase actual speed of motor in feedback path. In opto interrupter technology, slotted disc is used with shaft of DC motor. The slots are used between LED and phototransistor. If light is blocked then transistor gives low pulse and if light reaches on transistor it gets high pulse, then the actual rotating speed of the shaft is obtained.

G.T. Haldankaret. al. used EXPEYES hardware with Raspberry Pi to analyse classical audio signal "Bhoop Rag" [6]. Fourier Transform is observed on GUI of EXPEYES which evaluates frequency coefficients of audio signal. By doing this, costly spectrum analysers can be replaced by this low cost hardware.

Authors in [7] implemented simple analog circuits like half wave rectifier, full wave rectifier with its waveforms as well as V-I characteristics of BJT CE amplifier with the help of EXPEYES hardware with Raspberry pi. Furthermore, authors focused work on simple electrical circuits and analyse its transient response.

III. PROPOSED SYSTEM

Fig. 1 shows block diagram of proposed system. The analog circuits are connected with dedicated microcontroller through inbuilt ADC and sensor or control elements. The interconnection is bidirectional for data transmission. The microcontroller performs the action which is to be controlled or measured as per user program. The result is sent to computer through USB cable. User Program uses Python interpreter and Python module to access serial port. The program is written in C and assembler. Python code is used to represent GUI for real time measurement and displaying the data.

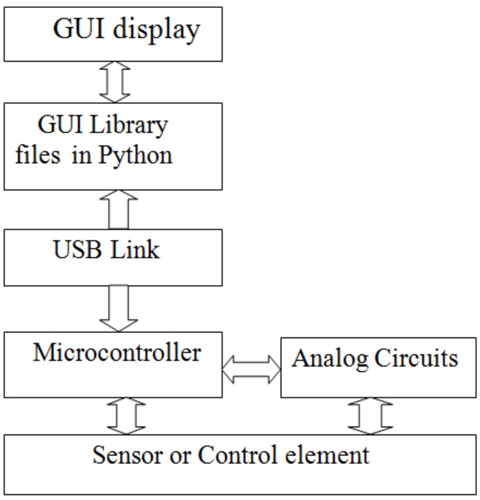

Fig. 1 Block Diagram of Proposed Work

Hardware Design

The hardware part of EXPEYES is shown in Fig. 2.

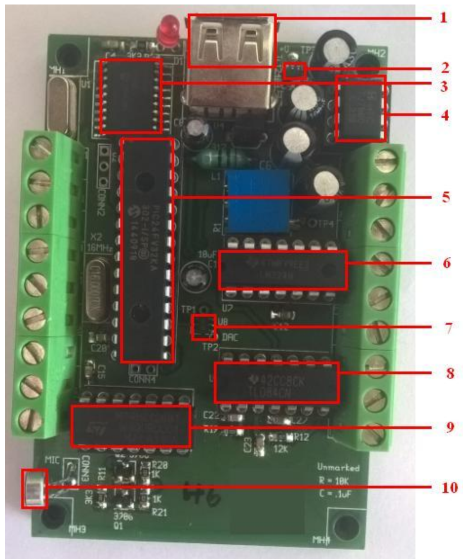

Fig. 2Hardware Design of Proposed Work

The parts of hardware are describes as follows:Part 1 indicates USB connector that is used to connect hardware with computer. Part 2 is IC TC1240A used for positive doubling charge pumps with shutdown. Part 3 is IC MCP2200 used to convert the USB to UART protocol converter for communicating with PIC24FV32KA302 IC. Part 4 is IC 7660 which is used to convert the positive voltage into negative voltage. It is switch capacitor voltage converter IC. PIC24FV32KA302 IC is 5th part which has general purpose 16 bit and having 12 bit resolution. Part 6 is LM324 low power quad OP_AMP IC used for obtaining analog outputs. IC 4727 is memory IC shown by number 7. Part 8 is IC 8024 general purpose Quad OPAMP IC which is used to obtain sine wave output. Part 9 indicates IC74HC126 quadruple 3-state buffer used for getting digital output. Microphone is shown at Part 10.

IV. TRANSIENT RESPONSE OF ELECTRICAL CIRCUITS

First Order System

Consider a simple system shown in Fig. 3.

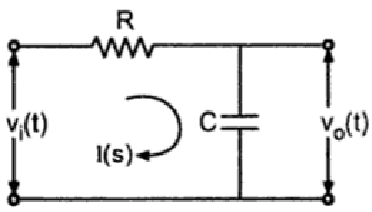

Fig. 3 First Order R-C Network

If input is excited by unit step input, then the transfer function is given in equation (1):

$$T.F. = \frac{1}{1+sRC} = \frac{1}{1+Ts} \quad ; \quad \text{where } T = RC \qquad (1)$$

Now transient term is totally dependent on the values of R & C and its rate of exponential decay is controlled by -1/RC.

Second Order System

Consider second order RLC Circuit as shown in Fig. 4.

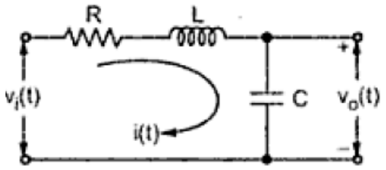

Fig. 4 Basic RLC Circuit

For second order system the denominator of closed loop transfer function is quadratic and the coefficients of this equation are directly related to ξ and ω_n which is given in equation (2).

$$T.F. = \frac{\omega_n^{\ 2}}{s^2 + 2\xi\omega_n s + \omega_n^{\ 2}} \quad (2)$$

Where, ξ is damping factor which explain how much opposition imposed to the oscillatory behaviour of system. Also, $\omega_n$is natural frequency of oscillation when there is no damping.

According to RLC circuit shown in Fig. 4, the transfer function is given by:

$$T.F. = \frac{1}{s^2 LC + sRC + 1} \quad (3)$$

Equation (2) is compared with (3) and that gives eq. (4) as:

$$\omega_n = \frac{1}{\sqrt{LC}} \quad \& \quad 2\xi\omega_n = \frac{R}{L} \quad (4)$$

V. EXPERIMENTAL SETUP

The electrical circuits are implemented using EXPEYES hardware and its transient response is observed on GUI. The input applied is 0-5 V step signal.

A. Transient Response of RC circuit

The circuit is build having Resistance of 1 kΩ and capacitance of 1 µF as shown in Fig. 5.

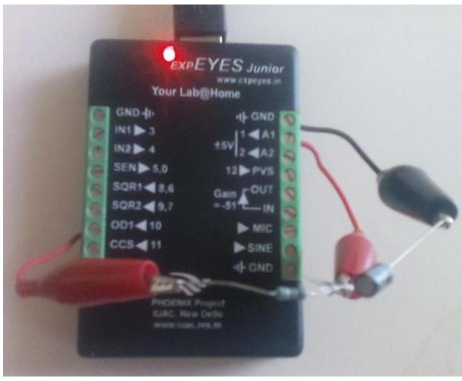

Fig. 5 Hardware Setup of RC Circuit

Input is given from Pin A1 which is step signal of 5 V. The output is taken at Pin OD1. The output is voltage across capacitor when step signal applied to resistor. The response is shown (Fig. 6) on GUI. The black line curve shows input from 0 to 5 V step signal and red line curve shows from 5 V to 0 step signal. By clicking discharge curve $V(t) = V_0 e^{-\frac{t}{RC}}$, time constant value is extracted. It is observed that as time constant increases, speed of response is sluggish and vice-versa.

TABLE 1 : COMPARISON OF TIME CONSTANT READING

Sr. No.	Time Constant (mS)		
	Theoretical	Proposed Method	Existing System
1.	1 mS	1.04 mS	1 mS

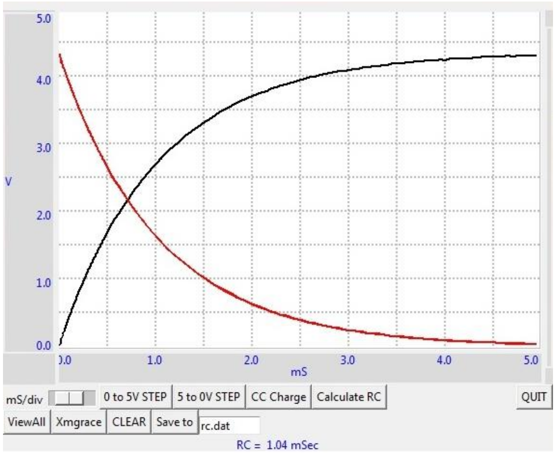

Fig. 6 Transient Response of RC Circuit

As shown in Table 1, time constant is compared which tell the speed of response.

Fig. 7 shows output of existing system using Control System Toolbox of MATLAB software platform. But existing system works totally on virtual electrical circuitry.

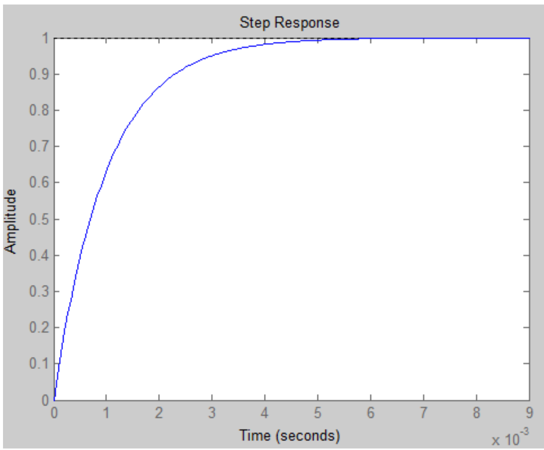

Fig. 7 Transient Response of RC Circuit (Existing System)

B. Transient Response of RLC circuit

Second order system is built with resistance of 600 Ω, capacitor of 0.1 µF and inductor coil of 3000 turns, 150 mH and is shown in Fig. 8.

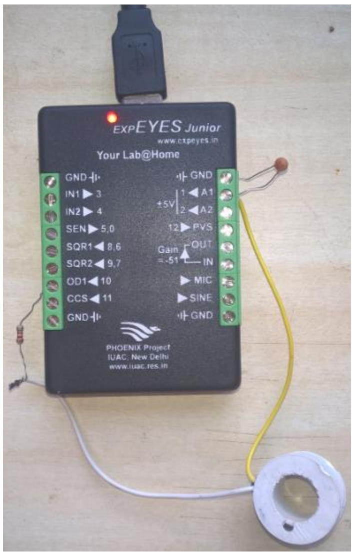

Fig.8 Hardware Setup for RLC Circuit

Depending upon value of R, L & C, and response can be classified as underdamped, overdamped and critically damped. Fig. 9 shows underdamped transient response.

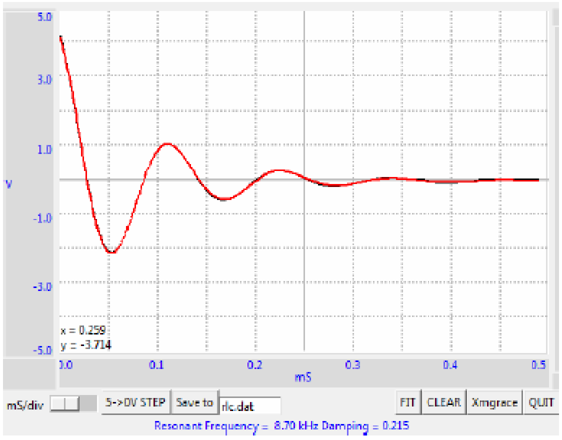

Fig. 9 Underdamped Transient Response of RLC Circuit

From GUI, damping factor & resonant frequency is measured. The resonant frequency is given by eq. (5):

$$\omega_0 = \omega_n \sqrt{(1-2\xi^2)} \qquad (5)$$

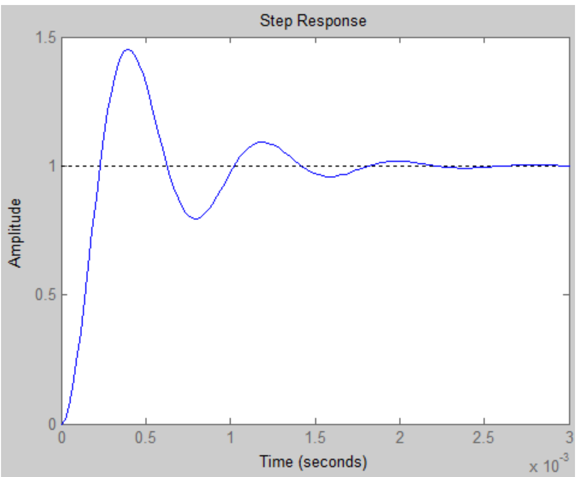

Fig. 10 Underdamped Transient Response of RLC Circuit

(Existing System)

Fig. 10 shows MATLAB simulated transient response using step input of RLC circuit.

TABLE 2 : COMPARISON OF SECOND ORDER PARAMETERS

Sr. No.	Parameters	Techniques implemented		
		Theoretical	**Proposed Method**	**Existing System**
1.	**Damping Factor (ξ)**	0.244	0.215	0.245
2.	**Resonant Frequency (ω_r)**	7.663 kHz	8.7 kHz	8.16 kHz

Table 2 gives validation of theoretical reading with practical values and existing system. The value of damping factor is always in between 0 & 1. If additional resistance is connected in series with inductor, then it gives overdamped response.

VI. CONCLUSION

The proposed method utilized EXPEYES hardware to analyse transient response of first and second order system. The main advantage of proposed system is that it is portable and less costly. The hardware is interfaced with computer through USB link and output is observed on GUI. Performance parameters like time constant, damping factor & resonant frequency is obtained and compared with theoretical results and existing system. Control System Toolbox of MATLAB is used in existing system for evaluating results. It is observed that as time constant value is increased, speed of response became slow. From second order system, it is observed that for underdamped system damping factor must be in between 0 & 1.

In future, all other transient specifications like rise time, peak time, settling time, delay time can be calculated. The proposed system can be configured with Raspberry pi which enhance compactness.

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