Inductance-Capacitance Meter using Microcontroller

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Abstract: *The Inductance-Capacitance (LC) meter is an electronic instrument that can be used for the measurement of the value of unknown inductor or capacitor of a simple coil. This paper aims to discuss the concept and the technique of measuring the unknown inductance and capacitance with the help of a microcontroller board. This meter makes use of the resonance frequency of a tank circuit which consists of a capacitor and an inductor and an unknown inductor or capacitor value connected in parallel. This changes the natural frequency at which the tank circuit resonates. The new frequency depends on the value of inductance or capacitance. The new frequency is determined and the value is calculated with the help of simple mathematical equations. AVR Microcontroller Board has been used to develop this instrument. It consists of an ATmega328p micro-controller chip that facilitates the operation.*

Keywords: LC meter, Microcontroller, ATmega328p, Tank Circuit

1. Introduction

LC meter is basically a frequency meter which measures the resonating frequency of a tank circuit. The tank circuit is a general term representing an inductor and a capacitor connected in parallel. This circuit is also called parallel LC circuit, in which the 'L' denotes the inductance and the 'C' denotes the capacitor.

A typical LC meter is a wide range LC oscillator. When measuring an inductor or capacitor, the output frequency changes because of the added capacitor and inductor. Thus, we can calculate capacitance or inductance depending on the requirement by calculating the frequency change. [1]

2. Working of LC meter

The tank circuit is made to oscillate at its resonating frequency by suddenly discharging it after a period of constant charging. Once it starts discharging, the tank circuit will oscillate at its resonating frequency, or it will resonate while discharging. The amplitude of the oscillation keeps on decreasing each time it oscillates and finally the oscillation dies out at the point of time when the tank circuit is completely discharged. This type of oscillation is called damped oscillation. [3]

LC meter has two modes of operation: LC mode and frequency mode. Measurement can be switched from LC mode to frequency mode and vice versa using a reed relay. Frequency measurement can be made more accurate by using a second comparator to condition the input signal. This second comparator acts as a Schmitt trigger. When the meter is in the LC mode, the frequency output from the first comparator is simply feed through the Schmitt trigger.

The output frequency is determined by the following equation:

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad (1)$$

where $L=L_0+L_{measured}$ and $C=C_0+C_{measured}$

The oscillation of a LC tank circuit will always be in the form of a sine wave. Since, the Arduino is a digital device, some circuitry is required which helps in reading the frequency of the damped oscillation of the LC circuit. This is achieved with the help of a zero crossing detector made with a comparator IC, LM339 [8]. The output of the zero crossing detector is high when the sine wave starts the positive half cycle and will remain high till the time sine wave starts the negative half cycle. Thus for one cycle of a sine wave the output of the Zero crossing detector will generate a square wave which is having a time period exactly half of that of the sine wave.
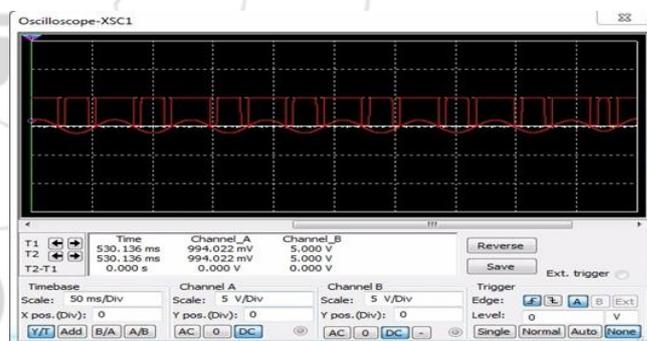
Figure 1: Mutlisim output of LM 339

The time period of all the square waves will be same since for the damped oscillation, only the amplitude keeps on decreasing with each cycle but the frequency remains the same. The Arduino board measures the time period of the first square wave after the tank circuit is discharged and takes the time period 'T' of the oscillation as double that value. The frequency of the oscillation is then calculated by taking the inverse of that value as shown in the below equation: [2]

$$F = \frac{1}{2T} \qquad (2)$$

Calculating the time period of the square wave gives the frequency. This is easily achieved using the Arduino code. The newly developed library helps to count number of

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pulses. The library function returns the time period of a pulse which appears at the specified pin. [4]

The designed circuit can measure inductance from a few nH to a few Henrys.For capacitance measurement, it is most suitable for measurement from a few pF to tens of nF.

3. Calculation of Inductance and/or Capacitance

3.1 Calibration of the meter

Before the LC meter is used of calculation of inductance or capacitance, it needs to be calibrated like any other measuring instrument. In capacitance measurement mode, the none-load reading is used to calculate stray inductance (assuming C_0 is accurate) which is then used to compensate capacitance measurements. And similarly, in inductance measurement mode, we assuming L_0 is accurate and the none-load reading (by shorting the test leads) is used to calculate stray capacitance which is then used to compensate inductance measurements.

3.2 Measuring L or C

Determining the values of lot of inductors and capacitors can be a cumbersome process. Therefore, Arduino board comes handy for such purposes. It uses Atmega 328 microcontroller. It is a very flexible microcontroller as the pins can be configured as inputs and outputs. It is powered using computer and coded in C language. The code is sent to the board from the computer. Thus, users can program the microcontroller to execute specific set of instructions or perform calculations.[7]

4. Results

LC meter with the following ranges was designed [5]:

LC Meter's Inductance Measurement Ranges:

1. 10nH – 1000nH
2. 1uH – 1000uH
3. 1mH – 100mH

LC Meter's Capacitance Measurement Ranges:

1. 0.1pF – 1000pF
2. 1nF – 900nF

The LC meter was designed and simulated in Multisim software [6]. The design and output waveforms observed in Multisim are shown below. They were verified with the ideal waveforms. The same design was then implemented using Proteus software and was verified for different values of inductors and capacitors.
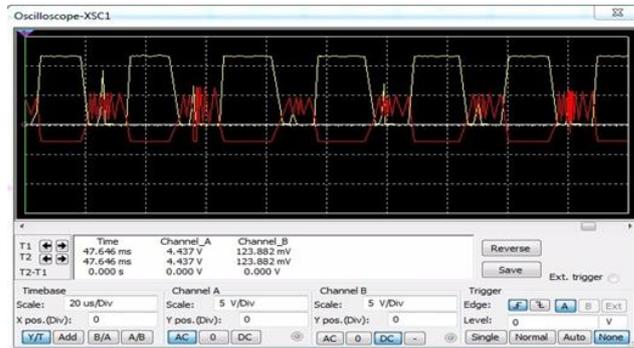

Figure 2: Mutlisim output signal of LC meter signal conditioning circuit to be sent to Atmega microcontroller
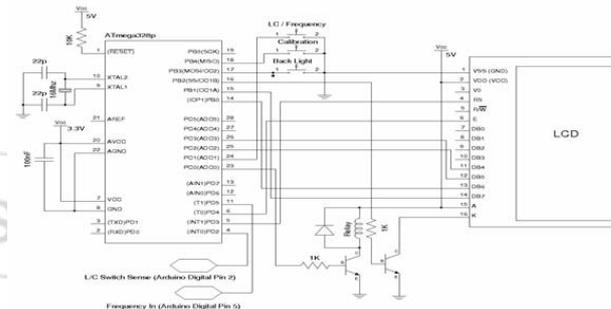

Figure 3: Interfacing with Atmega microcontroller (Proteus simulation).

After successful implementation and verification of functionality in Multisim and Proteus, the design was tested using Atmega microcontroller. The output waveforms from microcontroller were tested using cathode ray oscilloscope (CRO).
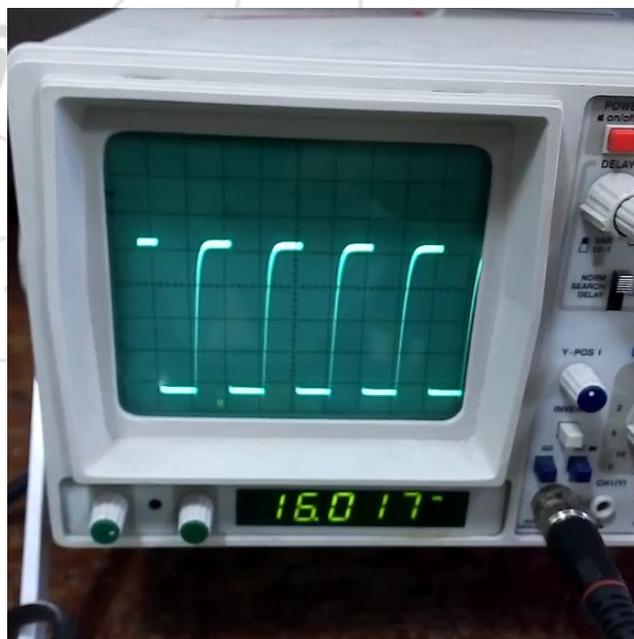

Figure 4 (a): Output frequency as observed in CRO in Inductor mode.

Figure 4 (b): Output frequency as observed in CRO in Capacitor mode.

Structure applications.

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5. Conclusions

The LC meter is first designed in Multisim and then Proteus where its functionality is tested. A new library is developed in Arduino IDE to count the number of pulses. The library returns the time period of oscillation. The LC meter is coded and programmed such that it satisfies all the ranges for whichit is designed. Upon successful realization, the meter is calibrated and tested for different values of capacitors and inductors. LCD is interfaced with the microcontroller and used for display. The LC meter was accurate with an error of 10%. This LC meter can also be used as frequency meter.

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