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Design, Construction and Implementation of an Inductance-Meter, Capacitance-Meter with I-V Characteristics Plotter Instrumentation System

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Abstract: This paper presents a practical design and construction of an instrumentation system that incorporates three sections of different measuring and characterizing instruments on a single apparatus. These sections include an inductance-meter, a capacitance-meter and an I-V characteristics plotter used for testing, measuring and monitoring electronics components. This instrumentation system was constructed using a PIC 18F452 microcontroller, GLCD, LC oscillator, A/D converter, timer1 module, and a source of power. In operation, the CCP module was configured as the PWM module to generate the graded voltage used for the I-V characteristics plotting. The instrument has been successfully tested and it was able to give the I-V characteristics curve of components like resistors, light dependable resistors and diode of different kinds. In addition, the instrument was able to give the capacitance value of any capacitor and the inductance value of any inductor inserted in it for measurement or calibration. With this instrument, it is easy to measure, calibrate and evaluate I-V characteristics of capacitors, inductors, resistors and diodes before use.
Keywords: I-V characteristics, Inductance-meter, Capacitance-meter, Microcontroller, LC Oscillator.

I. INTRODUCTION

An instrumentation system is collection of instruments used to measure, monitor, and control a process (HalitEren and Chun Che Fung). Developing and building instrumentation system involves numerous scientific and technical disciplines, such as electronic, electrical, control, mechanical and industrial engineering. Modern instruments and instrumentation systems are largely based on digital technology. Digital instruments are developed by using dedicated ICs, microcontrollers and microprocessors that give them flexibility in information handling, networking and data communications. An Inductance-meter is an electronics measuring device that can measure and give the inductance value of an inductor. Faraday and Joseph Henry (1797-1878) independently discovered mutual inductance in 1831 and self-inductance in 1832 with Faraday getting most of the credit for the former and Henry for the latter. A capacitance meter is a piece of electronic test equipment used for measuring the value of a capacitor. A capacitor is an electrical device that can store energy in the electric field between a pair of closely spaced conducting plates. Capacitance value means the measure of how much charge a capacitor can store at a certain voltage. Characteristics plotter is an electronics device measurement apparatus used for measuring and characterizing of electronics and electrical devices such as transistors, diodes, batteries, electrical circuit, MOSFET etc. This measuring apparatus trace out the characteristics relationship of the device under test, hence it is refers to as curve tracer. I-V curve tracer is a type of characteristics plotter that measures in particular the I-V relationship of the device under test. In construction, it is majorly made up of the data processor or microprocessor, memory address, counters, load circuit, switch control, user control, device under test (DUT) etc depending on the method of construction.

II. PRINCIPLES OF OPERATION

Figure 1 shows the schematic diagram of the whole system.

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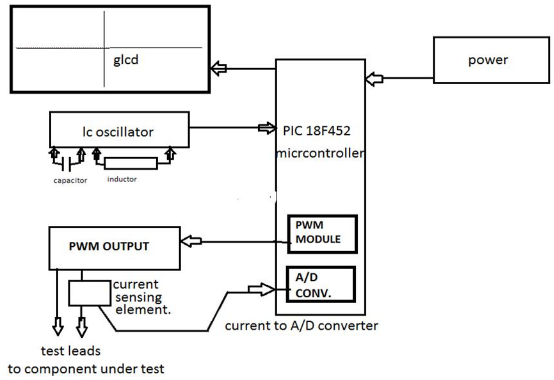

Fig.1 Overall of the system schematic diagram

A. Electronics Design Of Power Supply Circuit

An alternating current source of 240V was stepped down to 15V by an AC transformer which is then connected to a bridge rectifier (KBU808) to convert the AC to full wave DC. The full wave DC generated after connecting a capacitor (4700µF) which filters the DC generated and eliminates the ripples is 17V. A voltage regulator (LM7812) was used to regulate and give a stable output of 12V which was used to charge the battery. The output from the battery was connected to a voltage regulator (LM7805) which generates a stable supply of 5V which was used to power the PIC.

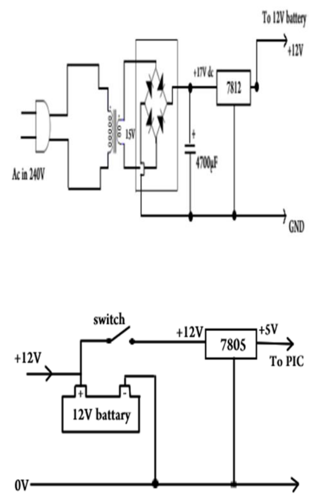

Fig.2 Power supply circuit diagrams

B. Pic 18 Microcontrollers

PIC 18 microcontrollers are family of devices which include PIC 18F2455, PIC 18 2550, PIC 18F4455, PIC 18F4550, PIC 18LF2455, PIC 18LF2550, PIC18LF4455 and PIC 18LF4550. These family devices incorporate a range of features that can significantly reduce power consumption during operation and a fully featured Universal Serial Bus communications module that is compliant with the USB specification. These features include Memory Endurance, Self-Programmability, Extended Instruction Set, Enhanced CCP Module, Enhanced Addressable USART, 10-But A/D Converter and Dedicated ICD/ICSD Port.

C. Generation Of Graded Voltage By The Pic

This is done by using the capture compare pulse (CCP) module in the PIC. This module is configured to the pulse width modulation (PWM) mode by using the CCPC0W1 and CCPC0W2 registers. The pulse width to be generated is written to the CCP1 register and it is immediately processed and output at the designated pin (port c, pin2).

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D. Pulse Width Modulation

A pulse is composed of the "ON" period or "Mark" and the "OFF" period or space.

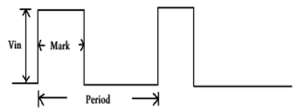

Fig.3 Pulse width modulation waveform

The addition of the "Mark" and "Space" gives the period. The duty cycle is given as

$$Duty\ Cycle = \frac{mark}{period} x\ 100$$

In PWM, the mark to space ratio changes, this changes generated on appropriate analog voltage equivalent when the PWM signal is filtered.
The R-C network forms a low pass filter for removing the high frequency of the PWM signal and allowing the analog signal to pass.

$$\text{The Output analog voltage} = \text{Vin (amplitude of the wave)}\ X \frac{mark}{period}$$

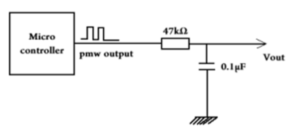

Fig.4 R-C network for low pass filter

Note: The low pass filter allows frequency below$f = \frac{1}{2\pi RC}$to pass and blocks those above it. This is called low pass filter.

III. INDUCTANCE-METER

An LC circuit oscillates at a resonant frequency of $f_0 = \frac{1}{2\pi\sqrt{LC}}$, this circuit was used to generate a pulse of frequency (f) which is counted in the microcontroller for one second. The capacitance has being fixed to 1nF with the inductance$(L) = \frac{1}{4\pi^2 f^2 C}$. The frequency counted in the controller is substituted for the R and the inductance is calculated in Henry (H).

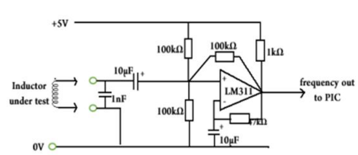

Fig.5 LC Oscillator circuit diagram

IV. CAPACITANCE MEASUREMENT

The capacitor charges exponentially through a resistor. The time taken for the voltage across the capacitor to reach 0.6v is t or time constant.

$$t = RC$$

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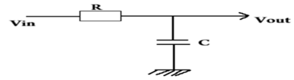

Fig.6 R-C network circuit

Fig.7. Exponential curve showing capacitor charges

This property was being exploited in measuring capacitance, a fixed resistance of 100KΩ was used and the capacitance to be measured was introduced. The capacitor was charged through pin2 of port C. A timer (Timer1) in the microcontroller was started and the microcontroller monitors the voltage of the capacitor through port C, pin1 till it gets to 0.6v before stopping the timer. The time was read and relation, t= RC was then used to calculate the capacitance in Farads (F).

$$C = \frac{t}{R}$$

Where R is the resistance in series with the capacitor and t is the time captured by the controller.

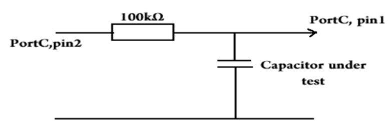

Fig.8. Circuit showing capacitor under test

The microcontroller then makes port C, pin2 logic low to discharge the capacitor; clears the timer and then restarts the process again.

V. I-VCHARACTERISTICS MEASUREMENT

I-V characteristic was gotten by generating a stepwise voltage into the test component and measuring the current flowing.

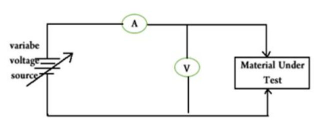

Fig.9 I-V characteristics circuit for device under test

To measure this process, the PIC generates the variable voltage and it then measures the current for each of the voltages till the max voltage is reached. The current is then scaled into the height of the cycle and the voltage to the width of the GLCD by dividing the new current value by the height (64 pixels) and width (128 pixels) and then the current with its corresponding voltages are drawn. The polarity of the voltage is reversed by a relay and the same test carried out again to carry out the test in reverse biased mode.

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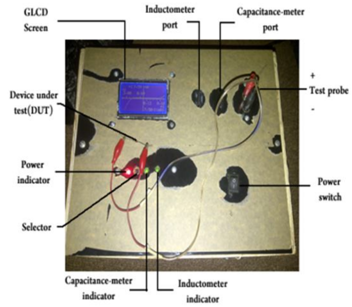

Fig.10.Diagram of the constructed Instrumentation system

VI. RESULTS

I-V characteristics curve of different components

Fig.11 I-V characteristics curve of a tested Zener diode

Fig.12 I-V characteristics curve of a typical LED

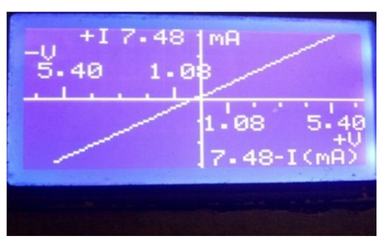

Fig.13 I-V characteristics curve of a Resistor

Fig.14 Result of a tested inductor

Fig.15 Result of a tested capacitor

VII. CONCLUSION

During the implementation of this instrument, it was observed that the instrument was able to give the I-V characteristics of components like resistors, light dependable resistors and diode of different kinds. In addition, the instrument was able to give the capacitance value of any capacitor and the inductance value of any inductor measure through it. With this instrument, the manufacturer ratings can be verified easily before use to avoid trial and error which usually results into malfunctioning of electronics circuits. The availability of the three measuring instrumentation systems (multipurpose system) on a single chip is an added advantage in this instrumentation system.

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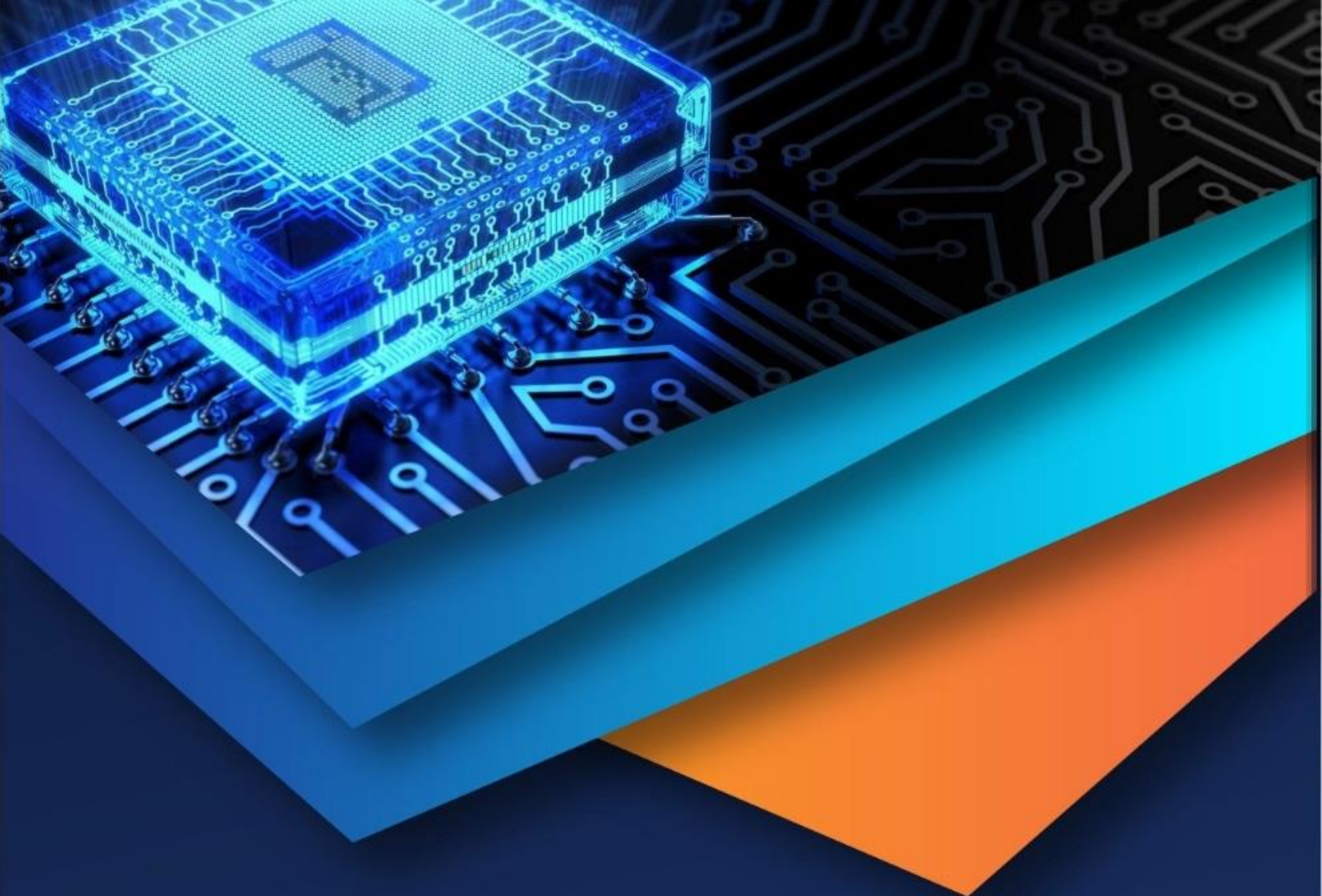

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