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DESIGN AND CONSTRUCTION OF BATTERY POWERED DIGITAL AMMETER WITH LCD DISPLAY

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ABSTRACT

Most ammeter installed in equipment panels such as distribution substations in Nigeria are mainly analogue meters of which many of them are currently in a state of disrepair. Noteworthy, also is that most of the ammeters are foreign made and thus huge foreign exchange is needed to replace them. Thus, there is need to develop locally made alternatives for the meters. The aim of this project is to design and construct a battery powered digital ammeter with liquid crystal display (LCD). The ammeter designed in this work named "JP AMMETER", implemented using embedded system design. PIC16F876A microcontroller was used as embedded system control unit. The ZMCT103C current transformer with a range of 0 10 amps, was used as the current sensor which produces the analogue voltage signal representing the current being measured. The output of the current sensor is connected to the analogue to digital (ADC) pin of the microcontroller. The ammeter was designed to work with a 9v battery The ADC converts the analogue voltage to its digital equivalent. The microcontroller was programmed to use the digital value of the analogue voltage to compute the actual current being measured, based on the characteristic equation of the current sensor. The current value computed by the microcontroller in amps is then outputted via a liquid crystal display (LCD). Four experiments were carried out in the course of this project. The first was used to verify the linearity property of the current sensor. The other three experiments were used to evaluate the performance of the ammeter with two foreign made meters used as control. The result obtained for the three ammeters (JP ammeter, control ammeter and 2), which gave R value equal to I in each case which signified that the meter has comparable accuracy with the foreign made counterpart. Thus, ammeter designed in this work can be reliably used to replace analogue ammeters in equipment panels in process equipment such as in the distribution substations in the country. The ammeter is therefore recommended to be locally produced so as to save foreign exchange spent on importation of panel meters.

KEYWORDS: PIC Microcontroller, ZMCT103C Current Transformer, Liquid Crystal Display (LCD), Analog Digital Converter ADC, JP Ammeter

INTRODUCTION

Nowadays many measurement instruments have been used in all laboratories throughout the world. Unfortunately, their accuracies are mostly proportional to the time period. As time passes, they may function incorrectly and generate some errors. The mistaken results from such instruments can cause serious problems in economic system and life safety since they will be used for validating product standards in the importing and exporting industries. In order to ensure that they work perfectly, the calibration process is required. In the past, the calibration has to be performed manually and this process usually takes long time. Presently, fully automatic calibration systems have been used worldwide and they play an important role in the calibration of measurement instruments. A digital ammeter is not an exception.

Digital ammeters are instruments that measure current flow in amperes and display current values on a digital display (liquid crystal display (LCD), Dot matrix or seven segment display). These devices provide information about current draw and current continuity in order to enable the user to troubleshoot erratic loads and trends. They have both positive and negative leads and feature extremely low internal resistance.

Digital ammeters are connected in series with a circuit (and never parallel) so that current flow passes through the digital ammeter. High current flow may indicate a short circuit, unintentional ground, or defective component. Low current flow may indicate high resistance or poor current flow within the circuit.
In this project however a digital ammeter for measuring alternating current is developed.

Problem Statement
Most of the panel ammeters in power distribution substations and other equipment panel are prone to errors due to parallax which is common with analogue instruments; this could lead to wrong records of measured current data. Thus, there is need to develop digital equivalents for replacement of panel analogue ammeter.

Aim and Objectives
The aim of this project is to design and construct a battery powered digital panel Ammeter with liquid crystal display (LCD)
The specific objectives include;

i. To select a suitable current sensor for the ammeter.
ii. To characterize the current senor using a suitable experimental procedure.
iii. To design and construct hardware circuitry for the ammeter.
iv. To program the micro-controller selected for ammeter design using Proteus software.
v. To test and evaluate the performance of the ammeter.

Scope of Work
The digital ammeter designed in this project is limited to measurement of current values between the ranges of 0A to 10A.

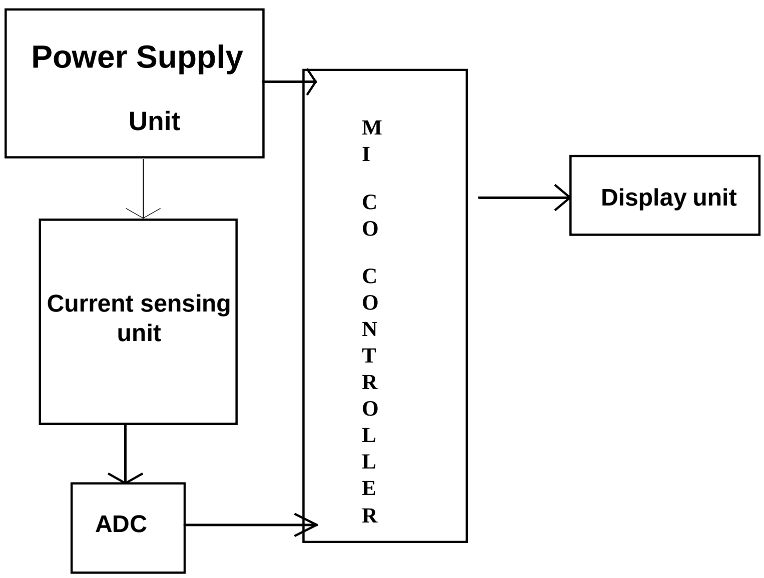
Limitations of the Study
The key limitation of this project is the deviation noticed between the current sensor behavior during the initial experiment used to characterize it and its behavior when connected to the rest of the ammeter circuitry. To deal with this limitation, a secondary ammeter was used to standardize the ammeter’s performance.

MATERIALS AND METHODS
Materials
The materials used in this project include;

- PIC16F876A Micro-controller IC
- Crystal oscillator (11.0592MHZ)
- ZMCT103C current sensor
- Liquid Crystal Display(LCD)
- 9v battery

- Regulator IC(LM7805)
- IC sockets (40pins)
- Top 360 series programmer
- Printed circuit board(PCB)
- Resistors
- Capacitor
- Load board
- 16 filament bulbs
- Kits like (copper-clad board, etching materials vero board and drilling tools)
- Proteus software

3.2 Methods



System Block Diagram

In line with the objectives of the project, the following procedures were adopted to realize the objectives.

A. Selection of a suitable current sensor.
B. Experimental characterization of the current sensor.
C. Design of the hardware circuitry.
D. Construction of the hardware circuitry.
E. Programming of the micro-controller.
F. Testing and evaluation of the ammeter.

Selection of suitable current sensor

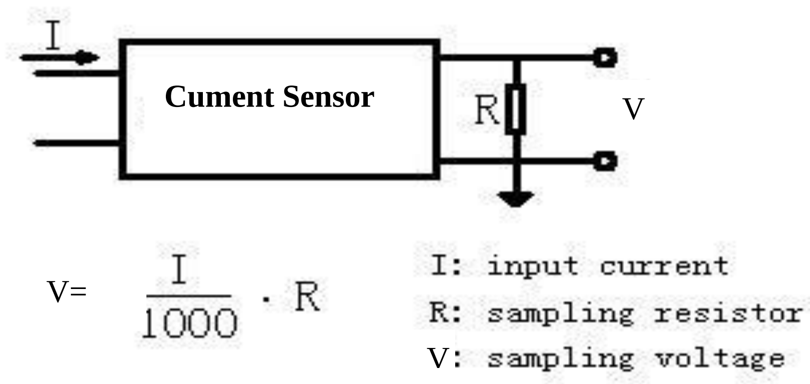
The ZMCT103C current transformer was selected due to its attractive features of small size, high accuracy and good consistency for current measurement.

The structural features and technical parameters of the sensor are illustrated in the data sheet presented in Appendix A.

Experimental characterization of the current sensor.

As specified in the data sheet of the current sensor (Appendix A), the equivalent circuit of the sensor is shown in figure 3.2

Figure 3.2 equivalent circuit for the current sensor (Appendix A)



The sensor behavior is governed by the equation in figure (3.2)

Where,)

V is sensors output voltage

I is input current (current flowing through conductor)

R is the sampling resistor. (Shunt resistor)

$$V = \frac{I}{1000} \cdot R$$

An experiment was carried out using a load board of 16 bulbs for varying the current being measured in order to verify the characteristic equation of the sensor

For the equivalent sampling, resistor of 50Ω was used.

Design of the hardware circuitry.

A. Design specification.

The design of the hardware circuitry of the ammeter was guided by the following specifications:

1. Form factor: panel mount
2. Type of meter: ammeter
3. Measurement type: AC
4. Phase: single phase
5. Current measurement range: 0 – 10A
6. Display type: Liquid crystal display
7. Display digit: 2
8. Micro-controller Input DC voltage: 5V DC
9. System voltage: 220V
10. Maximum power consumption: Less than 2 Watts

Design of power supply unit

Considering the specification of the ammeter,

a) Input voltage for the control circuit-5v was used and LM7805 regulator was selected for that purpose an output of 5v dc to be used by the micro-controller and the display system (LCD)

b) The key devices consuming power in the circuit are the microcontroller and the LCD. Thus the total power consumption of the circuit can be calculated as follows:

$P_T = V(I_{MCU} + I_{LCD})$ from the manufacture data sheets of $I_{MCU} = 80mA$; $I_{LCD} = 100mA$

$P_T = 5VX (80 + 100)\ mA = 5V \times 180\ mA = 5 \times 0.18 = 1W$

To calculate the values of filtering capacitors C_1 and C_2

Vpp at 9V = $\sqrt{2}x9 = 1.414 \times 9 = 12.73$

Therefore to calculate for C_1 using the formula $C = \dfrac{I}{(2xFxVpp)}$

Where Vpp = 12.73, I = 0.1V, F = 50Hz

$$C_1 = \frac{0.1}{2x50x12.73} = \frac{0.1}{1273}$$

$= 7.855 \times 10^{-5}\ F = 7.855x\ 10^{-5} \times 10^{-6} =$ 78.55uf

To calculate for C_2,

Vpp at 5V Regulated = $\sqrt{2}x5 = 1.414 \times 5 = 7.07$

Where Vpp = 7.07, I = 0.18V, F = 50Hz

$$C_2 = \frac{0.18}{(2x50x7.07)} = \frac{0.18}{100x7.07} = 0.000255 \times 10^{6}uf$$

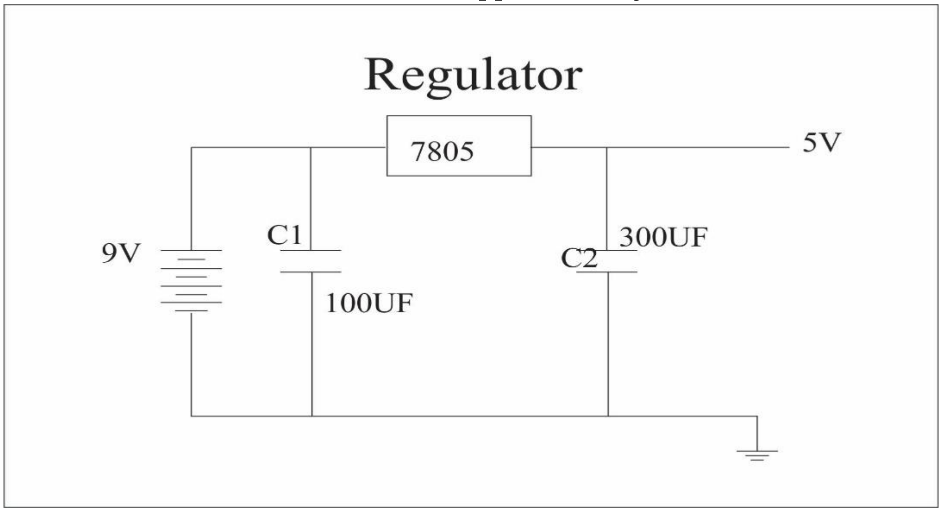
$C_2 = 256uf$

c) Total $P_{MCU} + P_{LCD} = I_{MCR} \times V_{MCU} + I_{LCD} \times V_{LCD}$ – (3.1)

since both the MCU and LCD require 5V to power them,

$P_T = I_{MC} \times V + I_{LCD} \times V = 5V \times 80mA + 5V \times 100mA$ 3.1

$= 5 \times 0.08 + 5 \times 0.1 = 0.9W$ approximately 1W



Power supply unit of digital panel Ammeter Figure 3.3

Design of current sensing circuitry

This is the unit that senses the current to be measured with ZMCT103 sensor. Micro-controllers or any microcomputer system cannot read current directly. Micro-controllers only sense voltage. Micro-controller's logic high and low is also based on voltage level. Therefore, micro-controllers do not sense current directly. When current passes through shunt resistor, voltage appears across shunt resistor. This voltage can be easily measured with the help of analog to digital converter channel of PIC16F876A micro-controller. This measured voltage value can be converted back into current in programming using ohm's law formula:

V = IR;

I: Input current

R: Sampling resistor

V: Sampling Voltage

V: Sampling Volta

The current being sensed by the current sensor is giving by

$$V = \frac{I}{1000} \times R \qquad (3.2)$$

To determine the value of sampling resistor

Maximum sensor output = 5V

Maximum current to be measured =10A

Therefore from equation 3.2,

$$I = \frac{1000V}{R} = \frac{1000 \times 5}{10} = 500\ \Omega$$

Design of liquid crystal display unit

The digital input lines (DB4-DB7) are interfaced with the pins from 5-2. To adjust the contrast of the display here we are using a 10K potentiometer. The current through the back LED light is from the 560-ohm resistor require the +5V power supply it is taken from the 5V source on Pic board.

LCD Current = 100mA

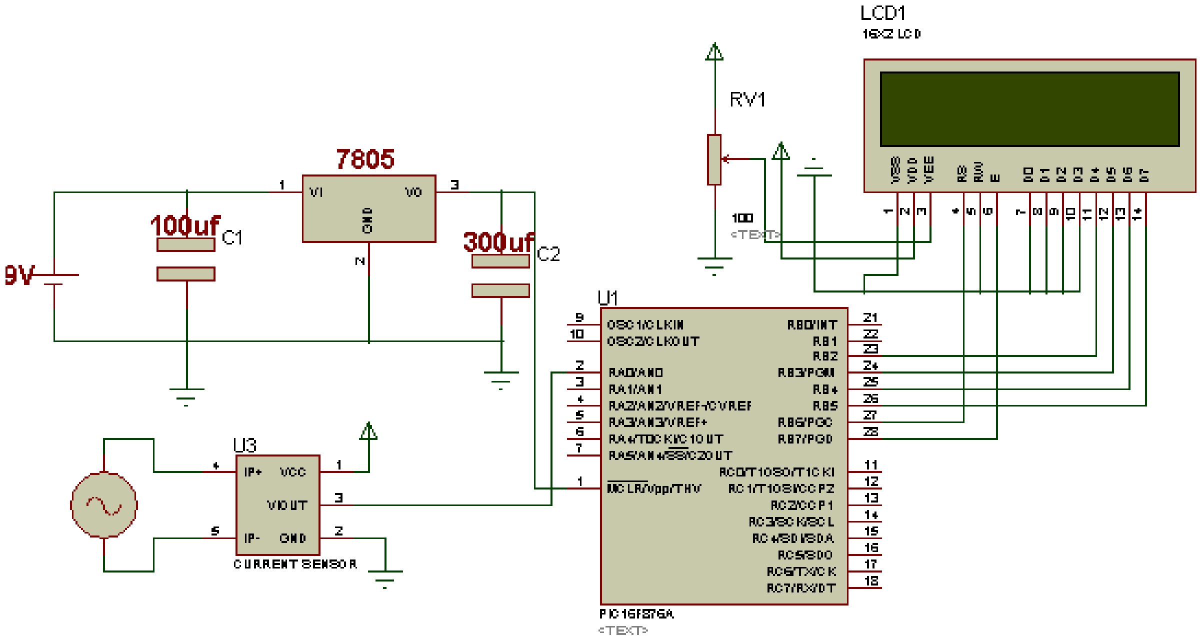
Voltage = 5V

Power = IV

Therefore, P $= 100mA \times 5V = 100 \times 10^{-3} \times 5 = 0.5W$

Power consumed by the LCD = 0.5W

Digital Ammeter using pic micro-controller



Complete circuit diagram of digital ammeter Figure 3.4

RESULTS AND ANALYSIS

In this work, four experiments carried were out. The first experiment was on current sensor vs. sensing voltage and values were obtained and graphs were plotted which gives us a straight line graph. This can be seen in experiment setup. The experiment results obtained from the other three experiment by testing the JP Ammeter under different load and this was compared with other two Ammeters in order to confirm that the results obtained from the other two control Ammeters are the same or very close to differentiate one from the other. This goes to further elucidate the fact that the JP ammeter has a high accuracy and that the error margin is infinitesimal. It has also proved that the designed Ammeter (JP AMMETER) and other theories, principles and concepts were considered on this design.

Results of the current sensor characterization experiment

Calibration was done to apply corrections to the nominal ratio, or to verify that the true value of the current sensor is sufficiently close to the nominal value that no corrections are required. It is impossible to manufacture anything with absolute precision. In general terms, the more precisely something is manufactured, the more expensive it is. There are two physical factors that each contributed to the uncertainty in the value that we read for the current. These are:

a) The value of the sampling resistor. (50 ohms) can be seen in the datasheet. Appendix A

b) The accuracy with which the sampling voltage is measured.

Item three has two components – ADC non-linearity and reference uncertainty.

Normally, both of these have three components that contribute to the possible error to a greater or lesser extent:

a) An initial uncertainty in the value at the time of manufacture.

b) Drift due to physical changes over time.

c) External influences.

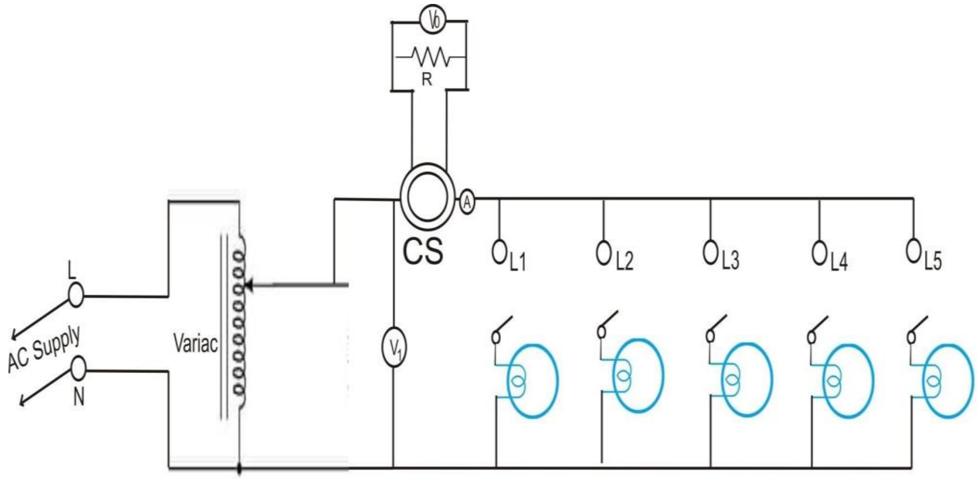
The experimental setup for the calibration of ZMC103 current sensor is as shown in Experiment 1

Figure 4.1. This current voltage equation is also shown on the experimental setup Figure 4.2.

Experiment 1

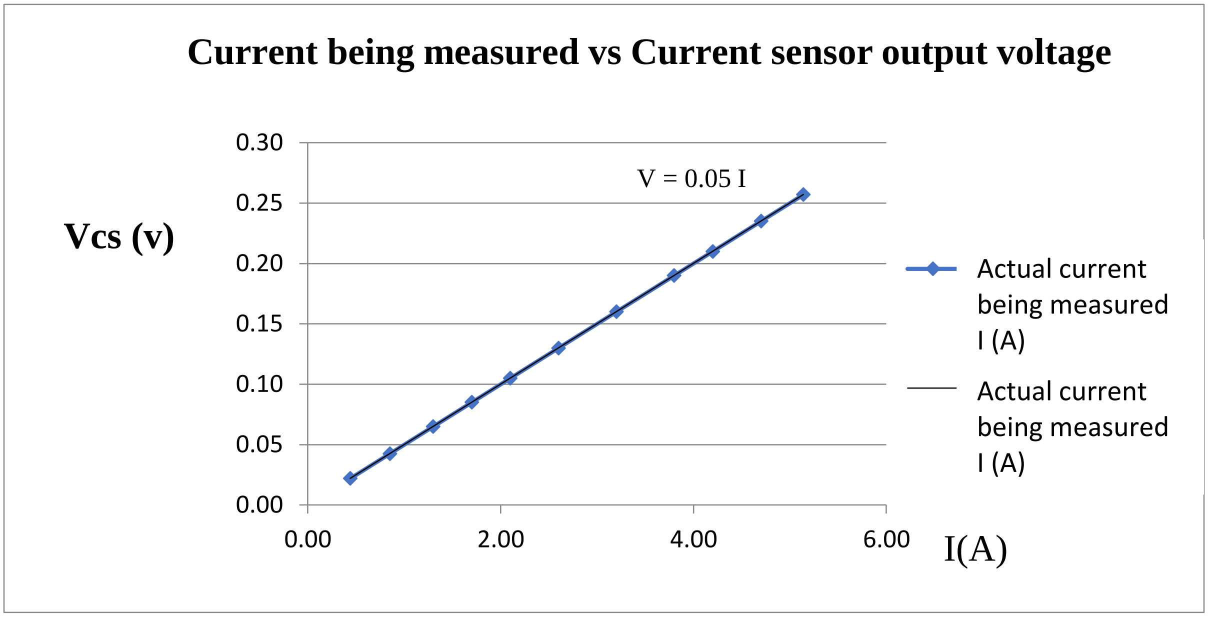
Figure 4.1

Experimental setup



Actual current being measure	Current sensor output voltage
I (A)	**Vcs (V)**
0.44	0.02
0.85	0.04
1.30	0.07
1.70	0.09
2.10	0.11
2.60	0.13
3.20	0.16
3.80	0.19
4.20	0.21
4.70	0.24
5.14	0.26

Figure 4.2



$$Vcs = 0.05I$$

Where VCS is the output voltage of the current sensor,
I = Current being measured

Therefore $I = \frac{Vcs}{0.05} = 20Vcs$ 4.1

This is equation was used to program the microcontroller

CONCLUSION AND RECOMMENDATION

Conclusion

The result of this design of JP Ammeter has shown that the current values can be successfully measured and displayed using the Light Emitting Diode (LED) because its energy consumption is very low, has environmental advantage.

The result of this experiment has also shown that ZMCT103C current sensing technique has offered an improved and cheaper way of measuring current which can be used as an alternative current sensor in digital panel meters.

And the wide range of current that can be sensed by the ZMCT103C current sensor makes it more reliable for sensing high current systems.

The result of this work also validates the known theory of rogowski coil in terms of it linear characteristics. The knowledge developed in this work can be used as stimulation for further research on ZMCT 103C technology with the view of developing a local patent that motivates local industry in mass production of ZMCT 103C current sensor for various current measurement applications.

Summary of Results

From the results of the experiments, the R^2 regression value of the digital panel meter was determined by carrying out four different experiments in the departmental laboratory to verify the reliability and viability of the measuring instrument using ZMCT 103C current sensing technology and the R^2 value obtained was equal to 1 ($R^2 = 1$) for all the experiments. The essence of determining the regression value is that if there exist any relationship or correlation which may be linear or non-linear between those two variables, then it shall indicate if there is a change in the independent variable in value, then the other dependent variable will likely change in value say linearly or non-linearly.

The economic and technical benefit of implementation of digital Ammeter meter with LCD display to industries includes but not limited to

a. Very cheap and easy way of upgrading obsolete analog metering systems.
b. Modular architecture that allows for easy configuration
c. Improved accuracy and better precision in controlling and monitoring.
d. Enhanced possibility of developing an entirely home grown patent that can open new job opportunities through mass of ZMCT 103C current sensor.

Recommendation

Apart from reducing the cost in wiring, using ZMCT 103C as current sensor also reduces the complexity of the circuit and makes maintenance and troubleshooting much easier and flexible.

Additional energy savings was achieved by the use of energy saving techniques employed in our designs. More portable electronic products were integrated into our design eliminating the need for large components as much as possible. This in turn, made the products less expensive, and more energy efficient.

This work can be seen as an exposure for further research and will help lay a good foundation for the possibility of smart grid technology in Nigeria.

The result of this research clearly suggest that the implementation of digital Ammeter with LCD display model will dramatically improve process parameter integrity and functionality in industries, home, school and power system especially with respect to old substation in the country. We therefore recommend that the result of this research be circulated to the appropriate quarters namely; industries, national electricity regulation commission, ministry of power and the general public for the measurement of voltage and current so as to determine the voltage and current level at a point with necessary precaution applied. Secondly we wish to recommend that programming using various programming languages should be well taught and practicalized in schools so that student will be well grounded in programming.

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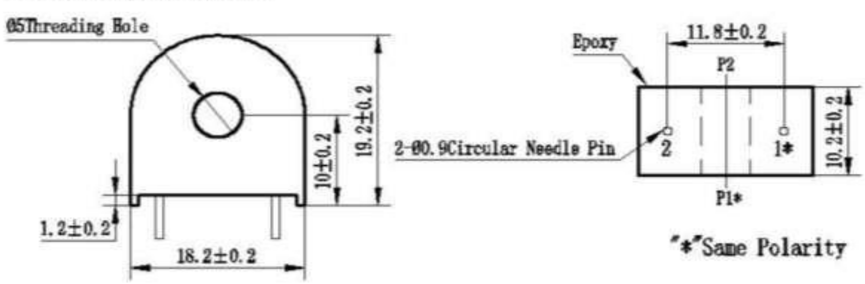
APPENDIX 1

Qingxian Zeming Langxi Electronic *www.micro-transformer.com*

ZMCT103C Current Transformer

Small size, high accuracy, good consistency, for current and power measurement

Structural parameters:



Remarks: primary input: straight- through type(make the measured circuit be through the hole)
1、2pin :secondary output

Front view **Bottom view**

The main technical parameters:

model	ZMCT103C
input current	0-10A（50Ω）
Rated output current	5mA at input 5A
turns ratio	1000:1
phase angle error	≤15' (input 5A，sampling resistor 50Ω）
Accuracy class	0.2
linearity	≤0.2%（5%dot~120%dot）
Permissible error	-0.2%≤f≤+0.2% (input 5A，sampling resistor50Ω）
isolation voltage	4500V
application	Precise measurement of current and power
Encapsulation	Epoxy
installation	PCB mounting（Pin Length>3mm）
operating temperature	-40℃~+85℃

Qingxian Zeming Langxi Electronic *www.micro-transformer.com*

Direction for use:

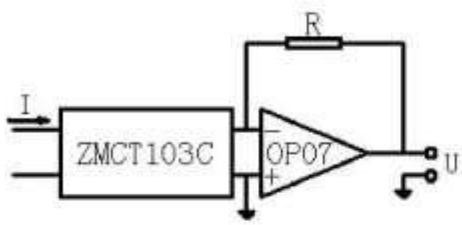


Figure Ⅰ

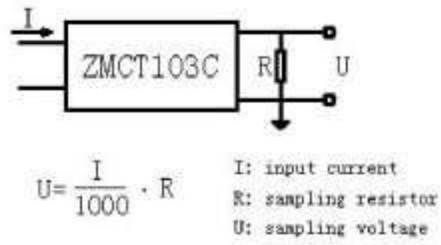


Figure Ⅱ

1. The typical usage of the product is for the active output (Figure Ⅰ). R is a sampling resistor
2. The product can be directly through the resistance sampling, easy to use (Figure Ⅱ).