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EQUIJOST

Equity Journal of Science and Technology, 2020 7(2): 9 - 15

ISSN 2354-1814; E-ISSN 2683-5961

An Official Publication of Kebbi State University of Science and Technology, Aliero, Nigeria

Design Analysis of a Microcontroller Based Wireless Wattmeter

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Received: May 16, 2020: Accepted: June 26, 2020; Published Online: June 29, 2020

Abstract

This paper considered the design of a microcontroller based wireless wattmeter which can be used to measure power in both domestics, hazardous and industrial locations where restrictions to movement is critical. The wireless wattmeter is made up of the transmitter and receiver parts kept at a distance not more than 300 m apart. PIC16F877A is programmed using *C* language to measure current, voltage, frequency and power which is shown on the liquid crystal display screen. The results obtained showed that the wireless wattmeter constructed from a microcontroller has a steady reading compared to fluctuating readings obtained from contemporary meters. The readings are also comparably accurate and can be accessed wirelessly within a distance of approximately 300 m making it usable in hazardous areas where human movement is strictly prohibited.

Keywords: Wireless wattmeter, Transmitter, Receiver, Microcontroller

1. Introduction

In the existing Nigerian power utility set up, consumers are presented with power usage information only once a month via their bill. The length of time between updates of power usage is far too long for a consumer to observe changes on power usage from the last bill. An opportunity to educate customers on power usage is lost because of these realities [1]. Nonetheless, if a customer can instantaneously observe the rate of energy consumed by an electronic device as well as the bill incurred, such customer would be more careful with power usage. Accordingly, an instrument that can be used to measure power is known as the wattmeter. Recently, clamp probes are used with some meters to measure electrical power and energy. The clamp measures the current, and in other circuitry, the voltage. As a result, the true power is the product of the instantaneous voltage and current integrated over a cycle. Comprehensive meters which are designed to measure several parameters of electrical energy (power factor, distortion, instantaneous power as a function of time, phase relationships, etc.), energy analyzers, use this principle. A single clamp is used for single- phase measurements; with an appropriate instrument with three clamps, measurements may be made on three-phase power systems [2].

Eduardo *et al*. [3] presented a novel prototype of wattmeter for energy consumption monitoring that measures voltage and current using Hall Effect. The drawback of this design is its complexity and its inability to incorporate frequency measurement. On the other hand Makanjuola *et al.* [4] employed the use of PIC16F876A controller for the design of a digital wattmeter using a robust design technique. Unfortunately, their work could not simultaneously measure and send data wirelessly. Alternatively, Sadhakar *et al.* [5] designed a three-phase wattmeter that trips off if overloaded. The design technique is however complex and provides no wireless access to the load consumption.

In contrast to the existing results, in this paper, Microcontroller PIC16F877A is programmed to measure and calculate parameters such as current, voltage, frequency and power using *C* language, and the result is shown on the liquid crystal display (LCD) screen. Specifically, this study presents a novel design that allows the wireless wattmeter to measure power within a distance of approximately 300 m making the device usable in hazardous areas where human movement is strictly prohibited.

2. Materials and Methods

The proposed design measures voltage, current, frequency and power which in turn is displayed on a 20 x 4 LCD screen, and the measured values are transmitted wirelessly through a radio frequency (RF) module for convenient use. This feature distinguishes the proposed design from other contemporary designs. Figure 2.1 shows the block diagram of the wireless wattmeter.

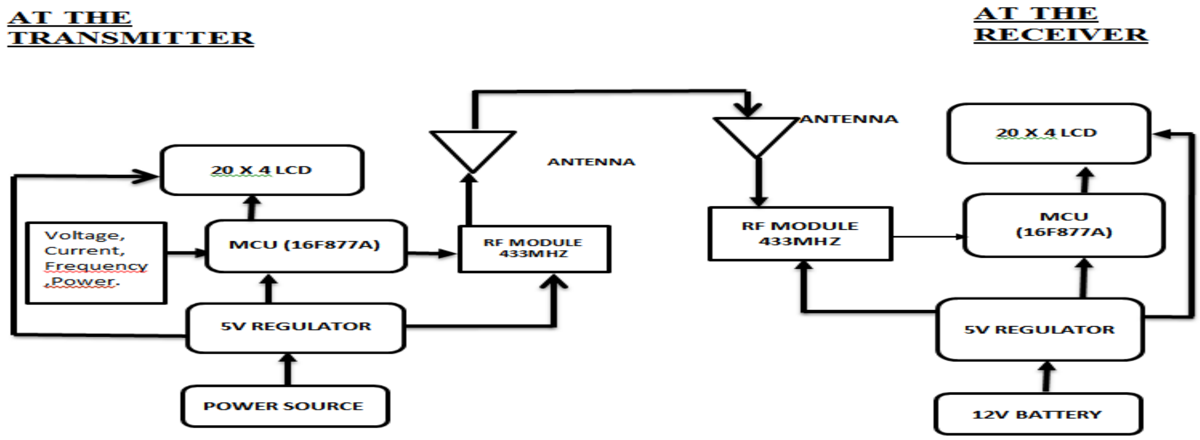

Figure 2.1: Block Diagram of the Wireless Wattmeter

As shown in Figure 2.1, the wireless wattmeter is made of two distinctive modules namely: the transmitter and the receiver modules which consist of two circuits namely the transmitter and the receiver circuit. At the transmitter circuit, the microcontroller performs the function of encoding the programmable measured parameters (voltage, current, frequency, temperature and power) and transmit or send the measured values wirelessly to the receiver through a 433 MHz RF module. At the receiver, the information received from the transmitter through a 433 MHz RF module is decoded by the microcontroller at the receiver and displayed on the LCD screen. The transmitter and receiver are kept apart at a distance not greater than 300 m.

2.1 Wattmeter Section

The wireless wattmeter is divided into three sections which are discussed below:

2.1.1 Power Section

A power supply is an electrical device that supplies electric power to an electrical load [6]. The power circuit for this design is shown in Figure 2.2. The power section consists of series of calculations which are presented below.

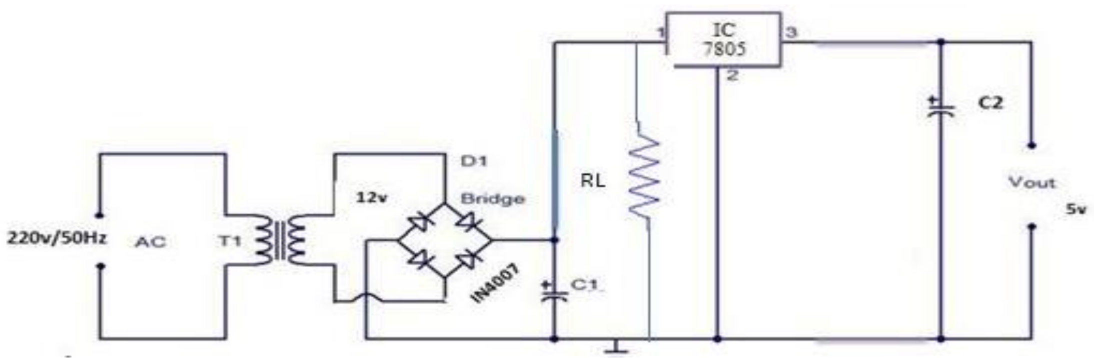

Figure 2.2: Power Circuit

Output direct current (dc) voltage is given by:

$$Vdc = Vp(in)[1 - \frac{1}{2FRLC}] \qquad (1)$$

where

Vp (in) = Peak full rectified voltage at the filter input.

Vp (in) = Peak rectified full - wave voltage applied to the filter.

F = Output frequency.

Peak primary voltage $= \sqrt{2} \text{ x } 220 = 311$ V

Peak secondary voltage $= \sqrt{2} \text{ x Vs} = \sqrt{2} * 12 = 16.97$ V

Peak full rectified voltage at the filter input is

$$\text{Vp(in)} = \text{Vp (sec)} - 2 \text{ x } 0.7 = 16.97 - 1.4 = 15.57 \text{ V} \qquad (2)$$

Full wave rectification,

$$F = 2Fin = 2 \text{ x } 50 \text{ Hz} = 100 \text{ Hz}$$

Therefore,

$$\frac{1}{2*F*R*L*c} = \frac{1}{2*100*2.2*10^3*50*10^{-6}} = 0.045 \quad (3)$$

The part of DC component which could not be bypassed by C1

$$\text{Vdc} = Vp(in)\left[1 - \frac{1}{2FRLC}\right] \quad (4)$$

$$\text{Vdc} = 15.57\ (1 - 0.045) = 14.86 \text{ V}$$

V_{dc} = 14.86 (voltage at the output of the transformer)

2.1.2 Voltage Regulator Section

Fixed voltage regulator 7805 is used to produce 5v from the power supply. The 5 V is used to power the microcontroller and the RF-transmitter module.

2.2 Micro Controller AC Voltage Measurement Calculation

2.2.1 AC Voltage Measurement using PIC Microcontroller and Potential Transformer

AC voltage can be measured easily using PIC Microcontroller [7]. In this paper, a PIC Microcontroller and a potential transformer is employed to measure AC voltage. The potential transformer is used to step down AC voltage from 220 Vac to 12 Vac. After rectification, the pulsating 5Vdc voltage obtained is measured with the help of microcontroller and displays it on an LCD screen. Figure 2.3 shows an analogue to digital converter (ADC) input pin 1 of the microcontroller used for voltage calculation.

Resistors R1 and R2 are used as voltage divider to the ADC input of the microcontroller which is pin 1. Recall that

$$\text{Vdc} = 14.86 \text{ V}$$

$V_{R2} = [\frac{1}{101} * 1v]$ = 0.0099 V (at 1 V input)

5 V is the maximum value the microcontroller can attain which is equivalent to 1023 in decimal which is 10 bits.

1023 in binary = 1111111111

Data used = 0b01111111,

The ADC resolution taken is 10 bits = 1023 in decimal

Therefore, 1 bit of ADC =

$$\frac{5}{1023} = 0.00488 \text{ V}$$

adc_volt = (adc_result x 0.00488)/0.0099 V (5)

Equation (5) measures the dc voltage at the output of the power transformer, this can be used to calculate the AC input voltage.

If 220 Vac input = 14.86 V_{dc} output

$$X = \frac{220*(x*0.00488)}{0.0099V*14.86} \quad (6)$$

X = AC input voltage the microcontroller prints out to the LCD screen and also sends wirelessly to the receiver.

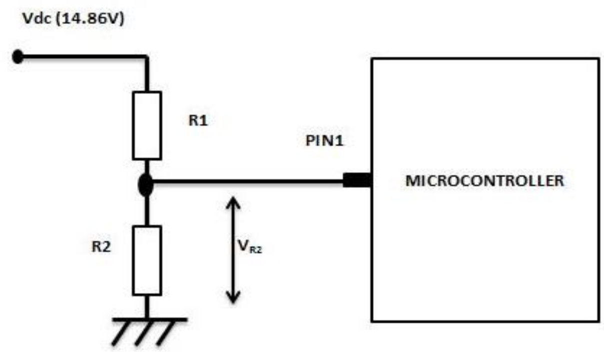

Figure 2.3: The ADC Input Pin 1 of the Microcontroller Used for Voltage Calculation.

2.3 Current Measurement Calculation

2.3.1 AC current is measured with the use of PIC Microcontroller using a Current Transformer

This research work employed the use of a shunt resistor to measure AC current. PIC16F877A microcontroller is used to measure AC current with the help of analog to digital converter. LCD screen is used to display the value of the current. Shunt resistor is used as a transducer which converts current into voltage. (Note that the microcontroller cannot read current directly). Voltage across the shunt resistor is measured with the use of PIC Microcontroller. The measured voltage is again converted back into current using ohm's law formula. Because the value of shunt resistor is known and voltage across shunt resistor is measured with the use of microcontroller, the current can be determined. By using V=IR, the value of the current can be easily calculated via some programming instructions. Figure 2.4 below shows a microcontroller circuit used for current calculation.

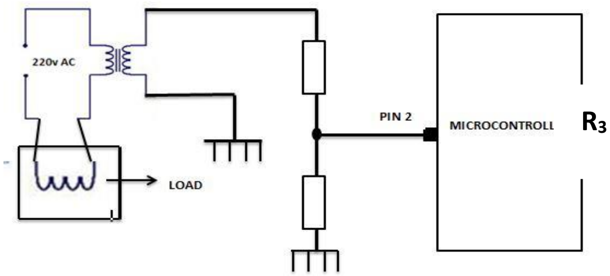

Figure 2.4: The ADC input pin 2 of the microcontroller used for current calculation

At 1A current input, the current sensor gives 1v. The output from divider R_3 and R_4 are connected to ADC pin 2 of the Microcontroller.

$$\mathrm{VR4} = \left[\frac{\mathrm{R4}}{R3 + R4}\right] \mathrm{Vc_{out}} \quad (7)$$

$$\mathrm{Current} = \left[X * \frac{5}{1023 * 0.0099}\right]$$

The LCD prints the value contained in current to the LCD screen and also sends it wirelessly to the receiver circuit.

2.4 Power Calculation

$$P = \mathrm{IV} \quad (8)$$

$$P = \mathrm{Current} = \mathrm{x} \times \mathrm{adc} - \mathrm{volt}$$

2.5 Frequency Measurement

The timer in the microcontroller is used to measure the frequency. Figure 2.5 shows a simple circuit designed for frequency measurement.

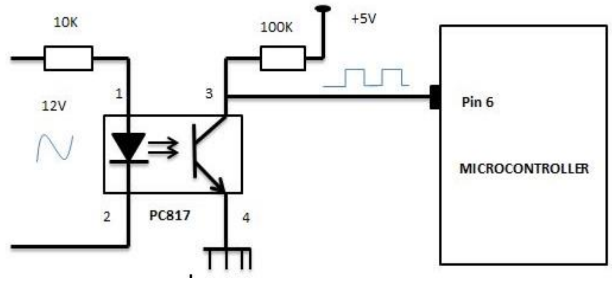

Figure 2.5: Frequency Measurement

The ADC input pin 6 of the microcontroller is used for frequency measurement. The circuit diagram of the proposed design is shown in Figure 2.6.

2.6 The Programming Section

For the programming section, ***C*** programming language is used which is object oriented for the microcontroller [7]. The code used at the transmitter is given in Appendix A.

3. Results and Discussion

To carefully assess the operational efficiency of the wireless wattmeter, a second meter was used as a reference meter to measure the power ratings of the appliances used in the measurement shown in Table 3.1. It was discovered that there were variations in the readings due to the sinusoidal input voltage. In particular, it was observed that the reading of the reference wattmeter used for the comparison is close to the reading of the wireless wattmeter and also slightly varies with constantly fluctuating values as shown in Table 3.1.

Table 3.1: Reading of Wireless Wattmeter and Other Wattmeter Used.

Appliances	**Wireless Wattmeter (Watt)**	**Other Wattmeter (Digital Wattmeter)**	**Error difference (Watt)**
Television	355.120	374.454	19.334
Heater	1282.571	1140.808	141.763
Microwave oven	1091.812	1130.247	38.435
Electric iron	540.888	565.042	24.154
Laser printer	1232.481	1208.681	23.80

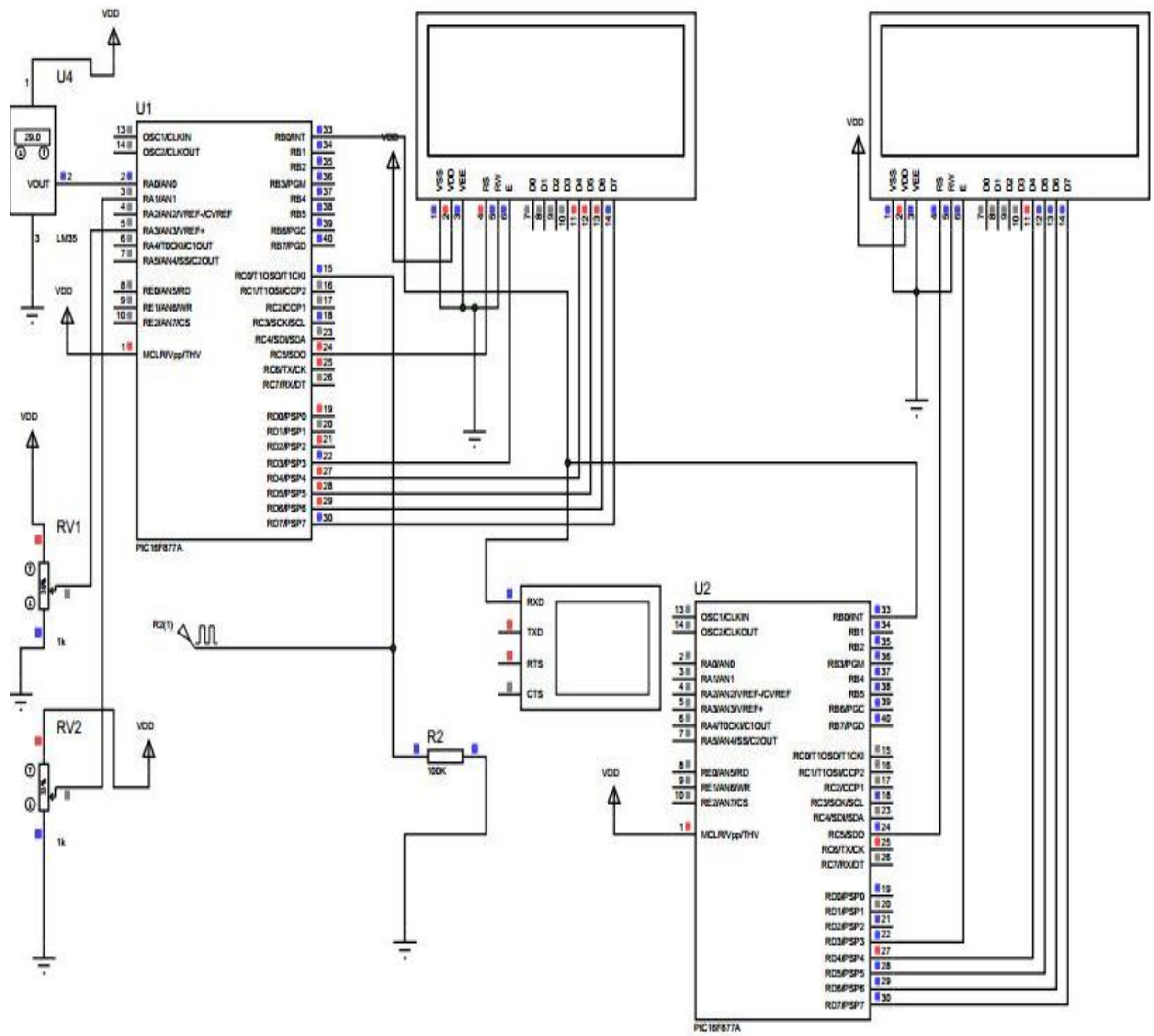

Figure 2.6: Circuit Diagram of a Wireless Wattmeter

4. Conclusion

This paper presented a wireless wattmeter device that allows power usage measurements at a convenient distance to a user. The energy used was obtained real-time and transmitted wirelessly through the RF link to a wireless terminal unit. Various parameters such as current, voltage, temperature, frequency was measured by the device and displayed on a digital LCD screen. The wireless wattmeter constructed from a microcontroller has a steady reading compared to fluctuating readings obtained from contemporary meters. The readings were also comparably accurate and can be accessed wirelessly within a distance of approximately 300 m making it usable in hazardous areas where human movement is strictly prohibited.

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Appendix A
The C-Code Used.

```
unsigned char read_rf();
sbit Tx at RB0_bit; //RF MODULE INPUT
 //…..transmit code , initial configuration of the LCD display…………
sbit LCD_RS at RC5_bit;   sbit LCD_RS_Direction at TRISC5_bit;
sbit LCD_EN at RD3_bit;   sbit LCD_EN_Direction at TRISD3_bit;
sbit LCD_D4 at RD4_bit;   sbit LCD_D4_Direction at TRISD4_bit;
sbit LCD_D5 at RD5_bit;   sbit LCD_D5_Direction at TRISD5_bit;
sbit LCD_D6 at RD6_bit;   sbit LCD_D6_Direction at TRISD6_bit;
sbit LCD_D7 at RD7_bit;   sbit LCD_D7_Direction at TRISD7_bit;
 //………..initial configuration of the PIC 16F877A……….
 int i;
char k,datta,hold, buffer[40];
void main() {
delay_ms(2);
TRISA=0b11111111;
TRISB=0b00000001;
TRISC=0b10110111;
TRISD=0b11111010;
ADCON1=0b0000100;
OPTION_REG=0b00000111;
PORTB=0;PORTC=0;
delay_ms(2);
Lcd_Init();
Lcd_Cmd(_LCD_CURSOR_OFF);
Lcd_Cmd(_LCD_CLEAR);
delay_ms(1);
 while(1){
 i=0;
 do{
 hold=buffer[i]= read_rf();
 i++;
 }while( hold!=',');
 if(buffer[0]=='*'){
 }
 //Lcd_Cmd(_LCD_CLEAR);
 }  }
 unsigned char read_rf(){
………configuration of the Transmitter module……………..
TMR0=0;
  while (Tx==0) continue;
  TMR0=0;
  while (Tx==1) continue;
   if (TMR0>145) {  //146
    for (k=0; k<8; k++) {
  while(Tx==0);
    TMR0=0;
    while(Tx==1);
    datta=datta>>1;              w3e4
    if(TMR0>96){datta=datta|0b10000000; } //17 //96
    else{datta=datta&0b01111111;}
   } }
   return datta;  }
  unsigned char read_rf();
  sbit Rx at RB0_bit; //RF MODULE INPUT
 // LCD receiver code
  sbit LCD_RS at RC5_bit;   sbit LCD_RS_Direction at TRISC5_bit;
  sbit LCD_EN at RD3_bit;   sbit LCD_EN_Direction at TRISD3_bit;
  sbit LCD_D4 at RD4_bit;   sbit LCD_D4_Direction at TRISD4_bit;
  sbit LCD_D5 at RD5_bit;   sbit LCD_D5_Direction at TRISD5_bit;
sbit LCD_D6 at RD6_bit;   sbit LCD_D6_Direction at TRISD6_bit;
sbit LCD_D7 at RD7_bit;   sbit LCD_D7_Direction at TRISD7_bit;
```

```
//............................Receiver configuration
code…………….
 int i;
unsigned char k,datta,hold, bufx[35];
char Wireless_wattmeter[]="Wireless wattmeter";
char WAITING_FOR_RF_DATA[]="WAITING FOR
RF DATA ";
void main () {
TRISA=0b11111111;
TRISB=0b00000001;
TRISC=0b10110111;
TRISD=0b11111010;
ADCON1=0b0000100;
OPTION_REG=0b00000111;
UART1_INIT (9600);
PORTB=0; PORTC=0;
Lcd_Init();
Lcd_Cmd(_LCD_CURSOR_OFF);
Lcd_Cmd(_LCD_CLEAR);
delay_ms(1);
lcd_out(1,1,Wireless_wattmeter);
delay_ms(2000);
Lcd_Cmd(_LCD_CLEAR);
lcd_out(1,1,WAITING_FOR_RF_DATA );
delay_ms(2000);
Lcd_Cmd(_LCD_CLEAR);
 while(1){
i=0;
do {
 if (UART1_Data_Ready () == 1) {
 hold=bufx[i] = UART1_Read (); i++;
   }
 if((bufx[0] ='*')&&(hold=='+')){break;}
 if(i>34) {i=0;}
} while (1);
 Lcd_Cmd(_LCD_CLEAR);
 lcd_chr (1,2, bufx[1]);
 lcd_chr_cp(bufx[2]);
 lcd_chr_cp(bufx[3]);
 lcd_chr_cp(bufx[4]);
 //for(i=0;i<33;i++){
 //bufx[i]=0; }
 i=0;
 hold=0;
 bufx[0]=0;
  //while (1);
}
}
```