DESIGN AND CONSTRUCTION OF A COMPUTER BASED SOLID-STATE POWER METERING DEVICE

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DEDICATION

This write-up is dedicated to the Almighty Allah, who made it possible for my five year program in the award of the degree of B.ENG. to be a success. I would not forget the help of my beloved parents, whose guidance and advice lead me to a very great height of achievement, especially my departed farther ('he was a good man'), may his soul rest in perfect harmony. And also to the entire Adano family, where ever they are.

ATTESTATION

I, Adano U. Ja'afar, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna.

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ACKNOWLEDGEMENT

I want to express my heart-felt gratitude to my entire family, the Adano family, a great family that will assail in all there endeavors in life insha Allah. I also want to express my sincere gratitude to my sister, Hajiya Fatima and her beloved husband Alhaji Hussaini Halilu Pai, for their assistance, both financially and otherwise. To all of my friends, especially Mr. Christopher aka "SEAWOLF" who have contributed to my life in one way or the other. Yoshi! You are not forgotten.

My sincere appreciation to my humble project supervisor, Mr. S. N Rumala, for giving me the necessary guidelines to achieving a presentable thesis, and the advices he gave me on achieving greater successes in life, sir, i thank you once again, God bless.

ABSTRACT

Although not exhaustive, this thesis highlights the basic requirements that should be adhered if one was to embark on a computer based solid-state power metering project. Chapter one, this thesis gives the general overview of most if not all power metering technology. In chapter two, we get an introduction as well as the basic requirements in the commencement of a power metering device. Chapter two also gives the theoretical background of the principles behind building electronic (solid-state) meters. In chapter three we get to see the actual implementation i.e. the design and construction of the metering device itself. Chapter four gives the general test and results obtained after the completion of the project. In chapter five, the conclusion as well as the recommendations are sighted.

TABLE OF CONTENT

LIST OF FIGURES/TABLES

CHAPTER ONE
Introduction

1.1 BACKGROUND

A power metering utility apparatus is used to measure the amount of power consumed by a monitored system (home, facility or industry), this measurement is then transmitted to the monitoring base either wirelessly (RF, Satellite, etc), or by cable (LAN, Telephone, Fax, etc) [1].

Electrical utilities and principal power consuming industries have employed a variety of metering approaches to provide quantitative and qualitative evaluation of electrical power [5]. The output provided by such metering system vary to suit the particular needs of the user selection of read-outs generally being made from the parameters including: watt-hours, Q-hours and var-hours[5]. These quantities are designated as in or out depending on the direction of current flow, the term "out" representing delivery to the user and the term "in" representing return of power to generating entity.

Typically, a metering system monitors power supplied through isolation and scaling components to derive poly-phase input representations of voltage and current. These basic inputs are selectively treated to derive the units of power like watt-hour, var-hour just as mentioned as above. The most extensively used technique has been the measurement of watt-hour through the use of an electromechanical induction meter [5]. However such devices are limited. Other early analogue approaches use thermally responsive coil element and also the use of hall-effect devices [5].

Analogue approaches to electrical parameter monitoring and multiplication technique physically are beset with problems in achieving desired output accuracy. Pure digital approach to measuring electrical power has been contemplated as ideal [5]. With such arrangements, for example, high rates of sampling may be employed and instantaneous sampled values may be converted or digitized as binary values. These digital values can then be manipulated using techniques that allow for computer based power monitoring, LAN based monitoring or even wireless transmission of data [5].

1.2 PROJECT OBJECTIVES

The objective of this project is to develop a functioning computer based solid-state power monitoring device, which is able to monitor the amount of power consumed by a system(home, industry, or apparatus), by simply manipulating the parameters of power such as current and voltage. The power computed is conveyed via cable to the computer system hosted monitoring station.

1.3 METHODOLOGY

The method of implementing this uses basic digital techniques to solve the problem. Since power is the product of voltage and current i.e.considering only purely resistive loads, where the phase angle is zero i.e. power factor is unity. Current and voltage consumed by a facility is scaled appropriately and then time multiplexed, the values read is then digitizes as appropriate, the digital values are then manipulated by a host processor or controller as the case may be, for reasons such as, data address allocation and data encryption. These values are then encoded and then transmitted through cable to a hosting PC (personal computer), where the final value of the computed power is displayed and used for the purpose for which it is intended. The scheme is as shown in fig. 1.1

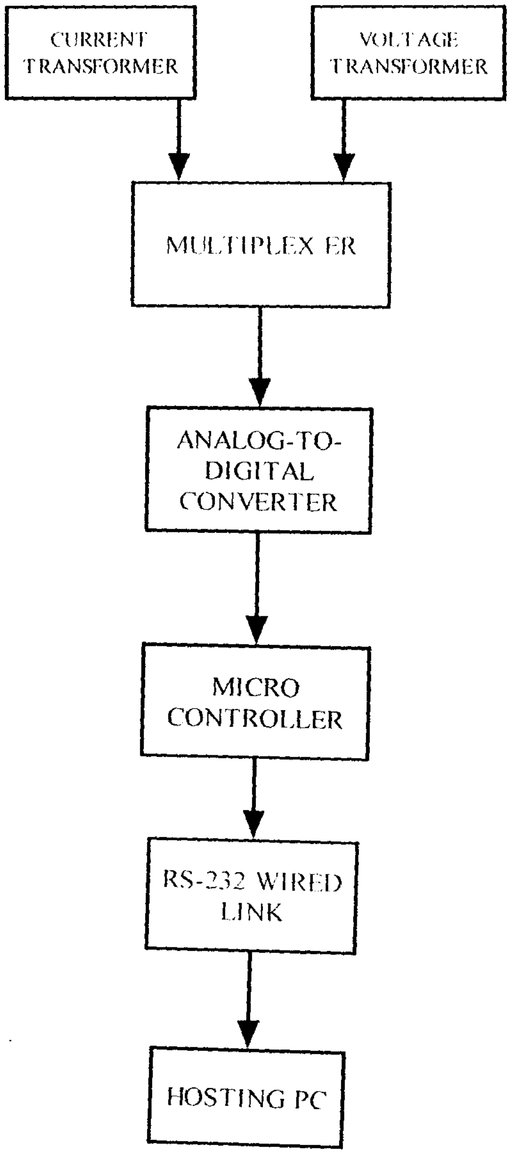

Fig 1.1: Block schematic of computer based solid-state power metering device.

1.4 SOURCE OF MATERIALS

When building electronic projects, the hardest thing can sometimes be finding the parts. This is especially true if one lives in a relatively small town with little or no specialty electronic stores. Sometimes, there is a local surplus shop, but they might not have what on needs. The use of data book comes into play, when sourcing for the materials to use. Data book provides alternative component to adequately substitute a particular component of a circuit, which is not readily available at a point in time, to facilitate interchangeability of components. It was partly of this basis that the materials for this project were sourced. The materials were then purchased locally at electronic stores.

CHAPTER TWO

LITERATURE REVIEW/THEORETICAL BACKGROUND

2.1 INTRODUCTION

As the energy metering industry convert from electromechanical meters to more accurate solid-state meters, power system designers have a chance to incorporate new features that measure energy more accurately than electromechanical meters, incorporate multiple-billing, and are capable of being read remotely by the utility company.

Solid state meters bring flexibility and added value, attractive features to utility companies seeking to changing consumer demands. Such meters must meet industry accuracy standards, have low power consumption and unit cost, particularly avoiding the additional cost and component cost of external device such as precision analogue-to-digital converters.

The consumer electricity meter basic function is to calculate the total energy consumed during any given billing period. It does this digitally by sampling voltage and current periodically, then multiplying these values to give instantaneous power consumption. These results are summed over time to calculate the number of units consumed.

Clearly, there are tough constraints of sampling accuracy, including resolution and frequency. The chosen analogue-to-digital converter must therefore deliver sufficient resolution and the chosen processor must be capable of performing the necessary calculations within the target cycle time.

The standard governing electricity meter accuracy – IEC61036 for class 1 devices- is used by regulations and watchdogs throughout the world [5]. Its stipulates a basic accuracy of ±1% when current amplitude is between its maximum value and 0.0125 of the maximum and an accuracy of ±1.5 % when current amplitude is between 0.0125 and 0.0050 of the maximum. Absolute conversion accuracy therefore increases as current amplitude falls.

An error of 1.5% in 0.0050 is 1 in 13,333 and this implies that current measurement inaccuracy must be less than 1/13,333 of the maximum. Since 13,333 is approximately 2^13.7, an effective a/d converter resolution of at least 14bits is required to read currents at the low end of their range with sufficient accuracy to support the Class 1 requirement[5].

2.2 PREREQUISITES TO SOLID STATE METERING

To ensure metering accuracies and to meet-up with customer needs, all standard solid state metering apparatus should employ or incorporate the following conceptual ideas[5];

2.2.1 Current waveform scaling

When current amplitude is low, scaling the signal by a known multiple allows conversion accuracy to be improved to meet Class 1 requirements. In practice, a different scale can be achieved by, for example, introducing an op amp gain stage or by altering the effective shunt in a current transformer. Altering the scale by a number corresponding to a simple shift in binary terms – such as 2, 4 or 8 – keeps the arithmetic simple. For example, scaling low current values by four effectively increases a/d converter resolution by 2bit.

By feeding raw and multiplied versions of the current signal into different a/d converter input channels simultaneously, the a/d converter's read routine can test whether the multiplied signal is near or above the a/d converter limit. If so, the raw signal can be used because extra resolution is not required on larger signals.

2.2.2 Oversampling and averaging

An important consideration is to maintain accuracy over time, as well as instantaneous accuracy. The effects of accumulated quantization errors can be alleviated by increasing the effective resolution of the a/d converter using oversampling and averaging. This relies on adding noise to the signal to be measured, creating a new signal that spreads over a number of a/d converter steps. The noise can either be naturally present in the measurement electronics or added deliberately. The resulting signal is said to be "dithered" as shown in fig 2.1. The added signal may be true random noise or a triangular waveform. The results will depend on both the characteristic and the amplitude of the added signal [5].

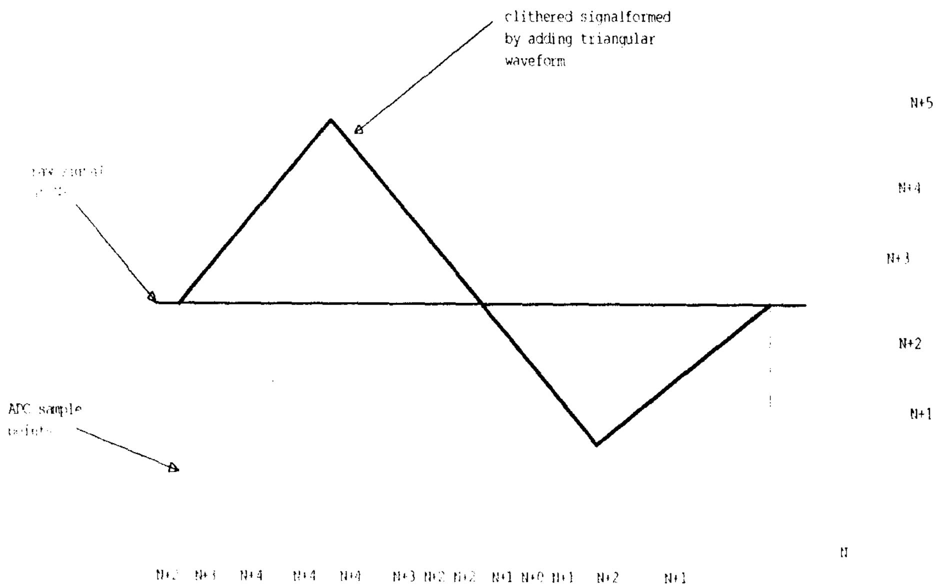

Fig 2.1: Adding a clithered waveform, oversampling and averaging

2.2.3 Cycle time considerations

Whilst current scaling and cithering the input signal can increase the effective a/d converter resolution, the processor must be capable of carrying out the necessary multiply and add arithmetic at sufficient speed. There are also limits on how much power the meter can take from the supply, so processor power consumption should be low. The power calculation consists of multiplying the voltage by the current – both 16bit integers – to give a 32bit result. This calculation in C would require both operands of type INT and return a result of type LONG.

However, prior to multiplication, both operands are promoted to LONG and then multiplied to give a LONG result – a significant overhead in the power calculation. Recoding the multiplication in assembler avoids this.

Coding assembler routines also provides efficient means of adding values into a 64bit total. For specific high performance calculations, the TMP86FS23 may be considered [5]. This incorporates a MAC unit that can multiply two 16bit values and add a 32bit value in 750ns, helping to boost performance. Mask and OTP versions are in mass production.

2.2.4 Timing basics

To ensure accurate timing, sampling and calculation code is driven by a timer interrupt and MCU timer/counters 3 and 4 are configured as a 16bit timer for this purpose. Using an fc/8 clock as input allows a resolution of 0.5μs. With a 16bit modulo register, the timer can then generate a period between 0.5μs and 32.7675ms. With 50Hz UK mains, an initial goal would be to take 10 samples per half cycle. This would require a sample period of 1ms. Obviously, more samples per cycle would generate more accurate results [5].

2.2.5 A/D converter sampling

The interrupt must first sample the voltage and current drawn using an on or off chip a/d converter. The a/d converter must take, at most, four samples if accurate measurements at low current are required [5]. The a/d converter requires 312/fc seconds minimum to take a measurement. With an fc of 16MHz, this gives a measurement time of 19.5μs. Consecutive readings will take slightly longer than this, since it is first necessary to remove the previous result from the a/d converter register, setup the next channel ready for sampling and then start sampling. Testing for when a sample is ready will also consume a few additional cycles.

Taking a conservative approach and adding an extra 50% overhead to the sample time, this gives, for example, for a four channel a/d, 4 x 19.5 x 1.5 = 117μs; well within the 1ms starting requirement.

2.2.6 Calculation

The interrupt then needs to perform the power calculation. Power calculation firmware calculates power from both the instantaneous current and voltage (V*I) summed separately and from the rms (average) current and voltage across all points. This allows processor accuracy to be evaluated by calculating the power factor and comparing the figures obtained by each method.

The most suitable current channel is selected by checking the a/d converter result for the direct and multiplied channels. Where the input voltage is too low (less than or equal to Ground), the result will be zero. Conversely, where the voltage is too high (greater than or equal to VAREF), the result will be the maximum possible value (0x03FF (1023) for the 10bit a/d converter). The currents also need to be adjusted to make them relative to one another. This can be done with a few shifts and additions to account for scale and zero line adjustment. The result is that current can vary from zero to 0x0FFC (4092) and calculation time can vary similarly.

2.2.7 Power requirements

In simulations, running the metering application and driving the LCD resulted in the microcontroller consuming around 12mW at a nominal 3.3V supply. This should be sufficient to support practical metering without presenting undue challenges in the power supply design. Furthermore, with nine power saving modes switching the microcontroller from 32 kHz operation (12μA/3.3V) to high speed 16MHz (6mA) operation, integral power consumption over time can be tailored to a minimum whilst providing full flexibility.

2.3 THE CONCEPT OF A.C POWER

2.3.1 POWER IN RESISTIVE AND REACTIVE A.C CIRCUITS

Consider a circuit for single phase a.c power system shown in fig 2.2, where a 120 volts, 60Hz a.c voltage source is delivering power to a resistive load;

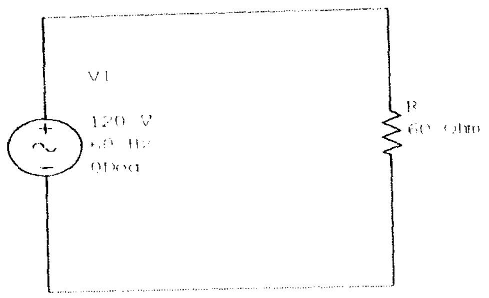

Fig 2.2: Single phase A.C power circuit

Z (circuit impedance) = (60+J0) ohm or 60∟0deg.

I (circuit current) = E (source voltage)/Z

I = 120 V/60 ohm = 2 amp.

In this example, the current to the load would be 2 amps, RMS. The power dissipated at the load would be 240 watts. Because this is purely resistive (no reactance), the current is in phase with the voltage, and calculation look similar to that in an equivalent DC circuit. If we were to plot the voltage, current and power waveform for this circuit, it would look like that shown in fig 2.3.

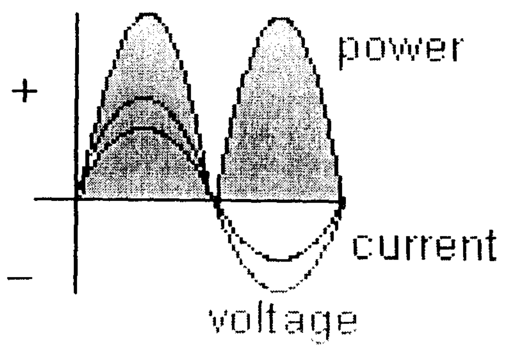

Fig 2.3: Waveform of current, voltage and power in pure resistive A.C circuit

Note that the waveform of power is always positive, never negative for this resistive circuit. This means that power is always being dissipated by the resistive load, and never returned to source as it is with reactive loads. If the source were a mechanical generator, it would take practically 240 watt of mechanical energy to turn the shaft [6].

Also note that the waveform for power is not at the same frequency as the voltage or current; Rather, its frequency is double that of either current or voltage.

For comparison, consider a simple AC circuit with purely reactive load as shown in fig 2.4

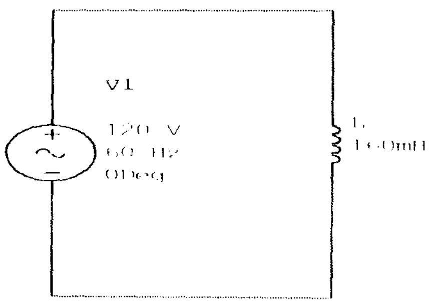

Fig 2.4: Purely reactive AC circuit

X (inductive reactance) = 60.319Ω

Z (j60.319Ω or 60.319 ∠ 90 deg)

I = E/Z

I = 120V/60.319Ω

The waveform for current, voltage and power is shown in fig 2.5

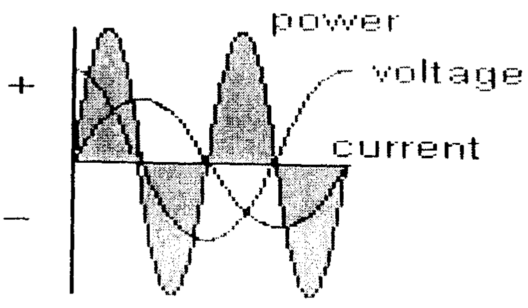

Fig 2.5: Waveform for voltage, current and power in purely reactive AC circuit

Note that the power always alternates between cycles of positive and negative. This means that power is being alternately absorbed from and returned to the source. If the source were a mechanical generator, it would take (practically) no net mechanical energy to turn the shaft.

Now consider an AC circuit with a load consisting of both inductance and resistance, as shown in fig 2.6.

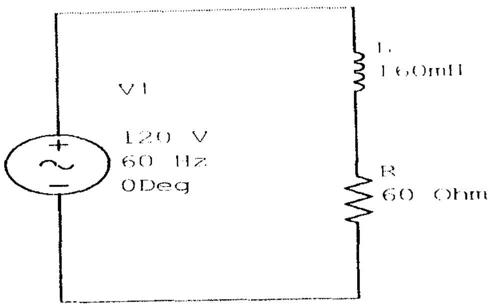

Fig 2.6: Resistive-inductive AC circuit

X= 60.319Ω

ZL= j60.319Ω or 60∟0 deg.

Ztotal = (60 + j60.319) Ω or 85.078∟45.152 deg.

I = E/Ztotal = 120V/85.078Ω

I = 1.410 Amps

At a frequency of 60 HZ, the 160mh of inductance gives us 60.319Ω of inductive reactance. This reactance combines with the 60Ω of resistance to form a total load impedance of 60+j60.319Ω, of 85.078∟45.152 deg. If we are concerned with phase angle(which we are not at this point), we may calculate current by taking the polar magnitude of the voltage source(120 volts) and dividing it by the polar magnitude of the impedance(85.078Ω). With a power supply voltage of 120 volts RMS, our load current is

1.410 amps. This is the figure an RMS meter would indicate if connected series with the resistor and inductor [6] is.

We already know that reactive components dissipate zero power, as they equally absorb power from, and return power to the rest of the circuit. Therefore, any inductive reactance in this load will likewise dissipate zero power [6]. The only thing left to dissipate power her is the resistive portion of the load impedance.

As with any reactive circuit, the power alternates between positive and negative instantaneous values over time. In purely reactive circuit that alternation between positive and negative is equally divided, resulting if net power dissipation of zero. However, in circuits with mixed resistance and reactance like this one, the power waveform will still alternate between positive and negative, but the amount of positive power will exceed the amount of negative power. In other words, the combined inductive/resistive load will consume power than it returns back to the source.

Mathematically representing power in an AC circuit is a challenge, because the power wave is not at the same frequency as voltage or current. Furthermore, the phase angle for power means something quite different from the phase angle for either voltage or current. Whereas the angle for voltage or current represents a relative shift in timing between two waves, the phase angle for power represents a ratio between power dissipated and power returned.

2.3.2 TRUE, REACTIVE AND APPARENT POWER

We know that reactive loads such as inductors and capacitors dissipate zero power, yet the fact that they drop voltage and draw current gives the deceptive impression that they do actually dissipate power. This "phantom power" is called the reactive power, and it is measured in a unit called VOLTS-AMPS REACTIVE (VAR), rather than watts. The symbol for reactive power is the letter Q. The actual power being used, or dissipated in a circuit is called the true power, and it is measured is watts, symbolize by the letter P. The combination of reactive power and true power is called the apparent power [6], and it is the product of circuit's current and voltage, without reference to phase angle. The unit of apparent power is the volts-amps (VA) and is symbolized with the letter S.

2.4 TYPES OF METER

Modern electricity meters operate by continuously measuring the instantaneous voltage (volts) and current (amperes) and finding the product of these to give instantaneous electrical power (watts) which is then integrated against time to give energy used (joules, kilowatt-hours etc). The meters fall into two basic categories, electromechanical and electronic [7].

2.4.1 Electromechanical meter

The electromechanical induction meter operates by counting the revolutions of an aluminum disc which is made to rotate at a speed proportional to the power. The number of revolutions is thus proportional to the energy usage. It consumes a small amount of power, typically around 2 watts [7].

The metallic disc is acted upon by two coils. One coil is connected in such a way that it produces a magnetic flux in proportion to the voltage and the other produces a magnetic flux in proportion to the current. This produces eddy currents in the disc and the effect is such that a force is exerted on the disc in proportion to the product of the instantaneous current and voltage. A permanent magnet exerts an opposing force proportional to the speed of rotation of the disc - this act as a brake which causes the disc to stop spinning when power stops is being drawn rather than allowing it to spin faster and faster. This causes the disc to rotate at a speed proportional to the power being used [7].

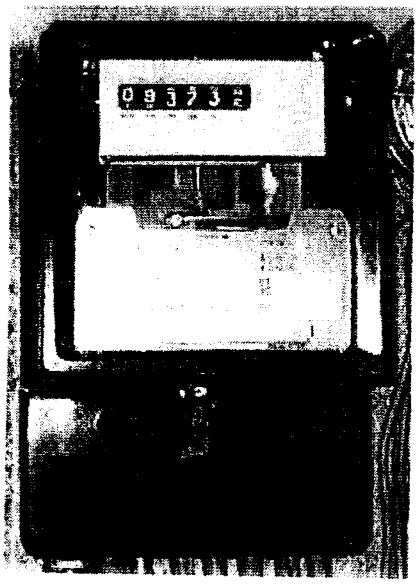

Fig 2.7: Three-phase electromechanical induction meter, metering 100 A 230/400 V supply. Horizontal aluminum rotor disc is visible in centre of meter.

The amount of energy represented by one revolution of the disc is denoted by the symbol *KWh* which is given in units of watt-hours per revolution. The value 7.2 is commonly seen. Using the value of *KWh*, one can determine their power consumption at any given time by timing the disc with a stopwatch. If the time in seconds taken by the disc to complete one revolution is t, then the power in watts is $P = 3600 \times KWh/t$ *[7]*. For example, if $KWh = 7.2$, as above, and one revolution took place in 14.4 seconds, the power is 1800 watts. This method can be used to determine the power consumption of household devices by switching them on one by one [7].

2.4.2 Electronic (solid state) meter

In fig 2.8 below, a solid state meter is shown as used in a home in Holland.

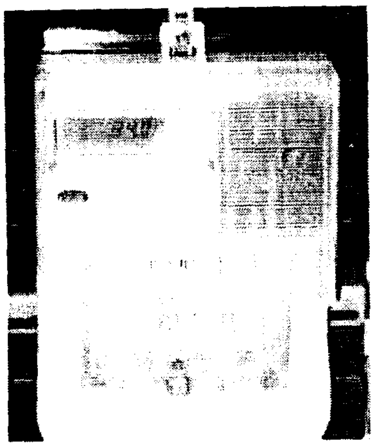

Fig 2.8: Solid state electricity meter used in a home in Holland

Some newer electricity meters are solid state and display the power used on an LCD, while newer electronic meters can be read automatically. In addition to measuring electricity used, solid state meters can also record other parameters of the load and supply such as maximum demand, power factor and reactive power used etc. They can also include electronic clock mechanisms to compute a value, rather than an amount, of electricity consumed, with the pricing varying of by the time of day, day of week, and seasonally.

2.5 SOLID STATE METERING TECHNOLOGY

Most solid-state meters use a current transformer to measure the current. This means that the main current-carrying conductors need not pass through the meter itself and so the meter can be located remotely from the main current-carrying conductors, which is a particular advantage in large-power installations. It is also possible to use remote current transformers with electromechanical meters though this is less common [7].

2.6 SOLID STATE METERING COMMUNICATIONS TECHNOLOGIES

High end electronic meters may now be equipped with a range of communication technologies including Low Power Radio, GSM, GPRS, Bluetooth, IrDA apart from the now conventional RS-232 and RS-485 wired link. They now store the entire usage profiles with time stamps and relay them at a click of a button. The demand readings stored with the profiles accurately indicate the load requirements of the customer. This load profile data is processed at the utilities and renders itself to a variety of representations, all sorts of graphs, reports etc. Remote meter reading is an application of telemetry. Often, meters designed for semi-automated reading have a serial port on that communicates by infrared LED through the faceplate of the meter. In some apartment buildings, a similar protocol is used, but in a wired bus using a serial current loop to connect all the meters to a single plug [7].

In the European Union, the most common infrared and protocol is "FLAG", a simplified subset of mode C of IEC 61107. In the U.S. and Canada, the favored infrared protocol is ANSI C12.18. Some industrial meters use a protocol for programmable logic controllers, Modbus. The most modern protocol proposed for this purpose is DLM/COSEM which can operate over any medium, including serial ports. The data can be transmitted by Zigbee, WiFi, telephone lines or over the power lines themselves. Some meters can be read over the internet [7].

2.7 SIMILAR WORKS ON SOLID STATE METERING

2.7.1 Three phase energy meter by John Markow:

This project was designed by john Markow. He used a single-phase energy metering IC i.e. the AD775. But he used the AD775 for metering three-phase, by simply connecting the three-phases individually to three separate AD775 IC and multiplexing them on to a single to an A/D converter on a microcontroller. Below in fig 2.9 gives the block schematics of his implementation.

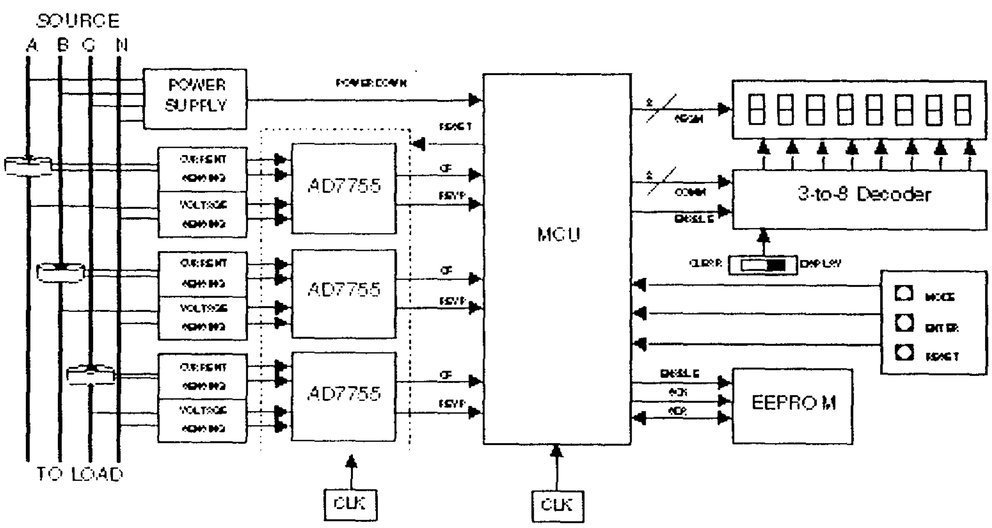

Fig 2.9: functional block diagram of a three-phase microcontroller based energy meter.

The microcontroller serves as the "brains" of the system, performing all the required housekeeping tasks and interacting with the other components—the energy meter ICs, the power supply, the EPROM, the display, and buttons to operate the meter—to view energy or power, calibrate the phases, or clear the reading. Besides low cost, the basic microcontroller requirements are [8]:

Sufficient I/O to drive the display.

If an LCD display is used a driver is required. If one is not incorporated into the MCU, an LED display can easily be controlled with a 3-to-8 decoder.

- Interrupts.

  To avoid missing any energy-indicating pulses, the system can be configured to trigger interrupts in the MCU. A power supply monitor can generate an MCU interrupt when it has detected a brownout condition and initiate an emergency energy measurement backup.

- EPROM Serial Interface.

  A simple serial interface can be created using only two or three I/O lines. An MCU with a built-in serial interface makes the design even easier.

- Timers.

  There are two main time intervals that need to be maintained. First, a display update rate must be set at about 2 seconds. Also, if an LED display is used, a timer must cycle through the digits at a sufficient rate to minimize on flicker. Additionally, the calibration routine must be carefully timed, but can be implemented with interrupt postscalers.

As an added feature, a second serial interface could be used to communicate with a host system for remote/automated metering. Also, either an external or internal clock could be used to implement multi-rate metering.

The advantage this design has is that, it can meter three-phase networks, it also uses a controller with built-in A/D converter which makes the work more compact.

The disadvantage it has is that, such implementations are quite expensive to envisage.

CHAPTER THREE

DESIGN AND CONSTRUCTION

3.1 DESIGN OVERVIEW

In circuit design, just as in many aspects of life, simplicity is often the order of day. Towards the end, the saying that the simplest option is usually the best is not new in circuit design.

This project is built on a minimal number of components, as depicted by the circuit diagram.of fig 3.1

3.2 CIRCUIT OPERATION

The operation of this circuit is pretty straight forward, as it employs digital concepts that are easily comprehensible. The basic concept behind the design is, digitization of the analogue quantities so that they can lend themselves to digital manipulations such as, serial communication.

3.3 FUNCTIONAL UNITS

3.3.1 Power supply unit

Knowing fully well the relevance of a power supply in virtually all circuits, it is with this notion that a well regulated power supply was built. The output voltage of the power supply is 5V d.c. This unit is made-up of a 220V/12V transformer, the bridge rectifier BR1, the capacitors c1, c2 and c3, with the 5V voltage regulator IC, 7805

3.3.2 Current transformation unit

This section of the circuit comprises of a current transformer, which was wound so as to achieve a transformation ratio of 100:1, this simply means that if a current of 100A was to be flowing in the primary, then at the secondary a current of 1A is obtained.

3.3.3 Current and voltage scaling unit

It is very essential that the values of the current and voltage are scaled down to an appropriate level, as they are the input to the analogue to digital converter. Resistor R1 and R2 are used to scale down the voltage. Resistors R12 and R13 are used to scale down the current.

3.3.4 Multiplexing unit

The CD4066 is a bidirectional analogue switch that can be used as a multiplexer.

3.3.5 A/D conversion unit

The A/D converter is used to convert our current and voltage from their analogue format to a digitized form.

3.3.6 TTL to RS-232 conversion unit

This section of the circuit is used to substitute for the MAX 232 IC which is used to make voltage compatibility between the TTL output and the serial port. This section comprises of transistor Q1, Q2, resistors R14, R15, R16, R17, R18, diode D1 and diode D2.

3.3.7 Processing unit

This section is where the necessary analysis is carried out.

The entire scheme is shown in fig 3.1

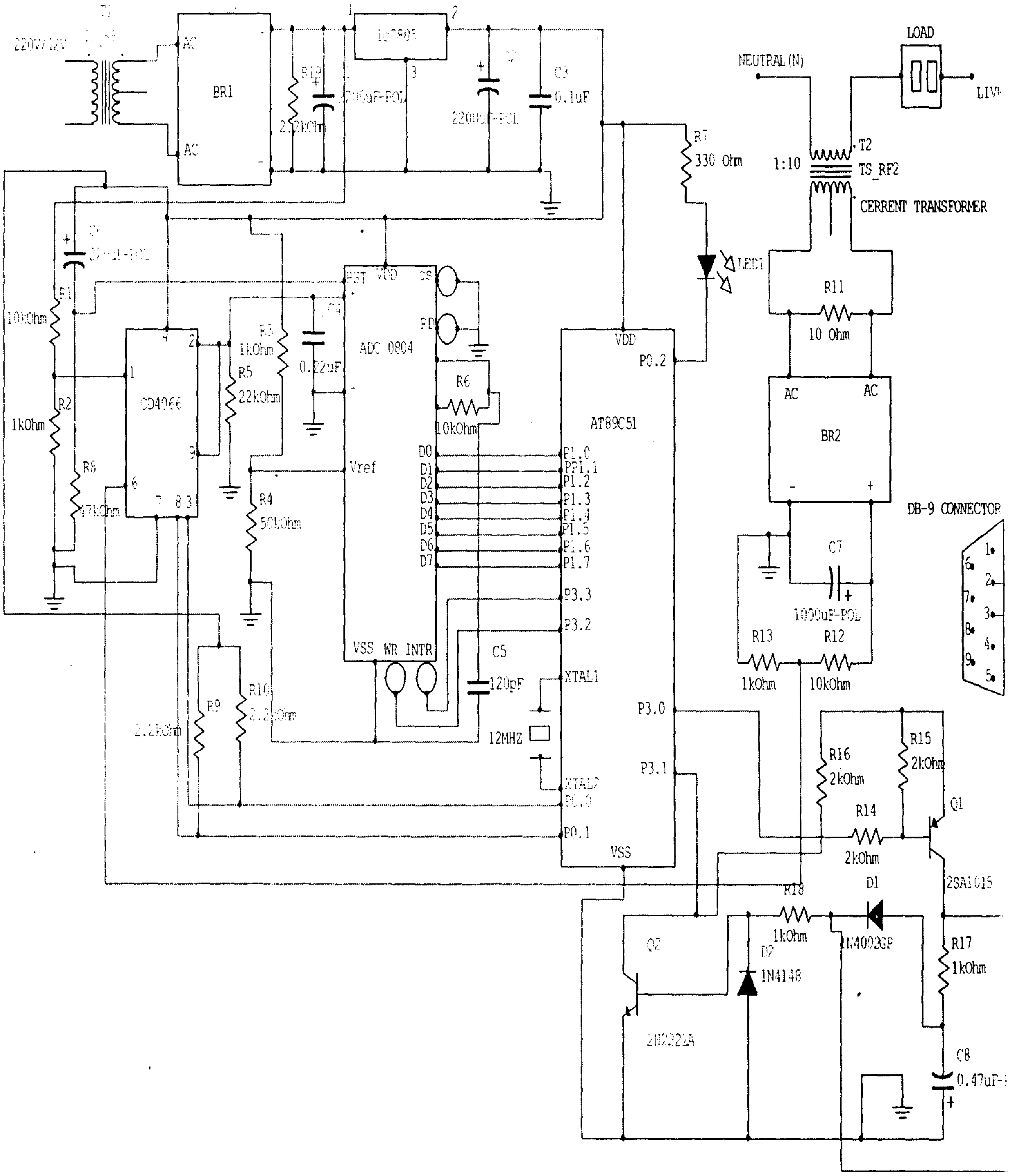

Fig 3.1: circuit diagram of Electronic power metering device.

CHAPTER FOUR

TESTS, RESULT AND DISCUSSION

4.1 TESTS

After construction, test was carried out at various points and joints of the circuit to ensure the gadget operates as designed. The main tests that were carried out are as follows:

- The power supply was properly tested to ensure that it produced the correct voltage output, as power supply is a crucial component for the proper operation and functionality of the system.
- The entire board was examined to ensure that was no short circuiting on any of the joints and tracks of the board.
- The A/D converter was examined to make sure the frequency of operation does not exceed the maximum sampling frequency of the microcontroller, so as to conform to Nyquist criterion of sampling.
- The communications between the controller and the hosting personal computer was tested to ensure there is proper data communication, as it is very critical to such implementations.
- A 60 watt bulb was connected in series with the current transformer so as to try and compute the power consumed, which will ultimately help in computing the energy consumed.

4.2 RESULTS /DISCUSSION

The results obtained during prototyping and testing were satisfactory. In the final testing of the power metering device, some test loads were used such as a 60 watt bulb, a 1200 watt heater, so as to ascertain there power consumption over a period of at least an hour. However due to little inaccuracy in the calculations in software so as to make-up for lost power due to meter power consumption considerations and voltage drop at various parts of the circuit, the result was fairly accurate, without much deviations from the normally expected results, it was a success.

4.3 CONSTRAINTS

There was little or no problem encountered by me, as regards the soldering of the work that was no problem, since its something i have been doing for a long while prior to embarking on this project. The only problem I encountered per say, would have to be in the coding of the microcontroller.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Design and construction of computer based power metering device was the aim of the project.

The principle of the project earlier stated has been actualized. The device computes satisfactorily the amount of electrical power consumed by a monitored facility (home, industry or appliances).

The project has brought to fore simple technique of building a cheap, reliable and flexible means of metering or monitoring electrical power, thus a considerable success.

5.2 RECOMMENDATION

As discussed earlier, the working principle of the device "power metering device" is based on transmitting the digitized values of current and voltage through to a hosting personal computer via the RS-232 cable where the necessary power manipulations and computations are carried out. Usually the distance of the RS-232 is limited to 45 feet and a speed of 10mbps-100mbps. But however, since the essence of this thesis is to demonstrate the working principle of such devices, such limitations as mentioned can be tolerated.

To alleviate such shortcomings such as distance and speed, future works on this should consider the possibility of developing a wireless means of implementing the same concept or even the use of wired link such as the RS-485. Also, considering that the emphasis of this project is on the metering of purely resistive loads, one can develop a full fledged power metering device that takes into consideration the reactive loads as well, consider the single chip power monitoring IC (integrate circuit), MCP 3905.

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APPENDIX

Bill of Engineering measurement and Evaluation

(BEME)

Materials	Units	Unit cost (naira)	Total cost (naira)
RECTIFIERS	2	50	100
CAPACITORS	8	20	160
RESISTORS	19	10	190
CD 4066	1	100	100
ADC 0804	1	450	450
CRYSTAL	1	300	300
AT 89C51	1	1500	1500

```
LUDE 89c51.mc

_port EQU p1
_wr BIT p3.2
_intr BIT p3.3
rent_in BIT p0.1
tage_in BIT p0.0
er_led BIT p0.2
ck EQU 40h
tage DATA 08h
rent DATA 09h
d DATA 0ah
nversion_cnt DATA 0bh
d_set BIT 00h


g 0000h
art_up:        CLR ea                    ; disable interrut
               MOV sp,#stack             ; init stack
               ACALL DELAY
               ACALL DELAY

               ACALL sys_init            ; init system
inloop:        ACALL get_power           ; read V*I
               ;ACALL scan_port                  ; check port
               ;JNB cmd_set, mainloop    ; loop if no remote command
               ACALL send_data           ; else send conversion data
               SJMP mainloop             ; loop for life


s_init:        CLR power_led             ; turn on power indicator
               MOV adc_port,#0ffh        ; configure port for input
               CLR current_in            ; disable CD4066 voltage control pin
               CLR voltage_in            ; disable CD4066 current control pi
               SETB adc_wr                       ; set adc write bit input on p3
               SETB adc_intr             ; set adc intr bit input on p3
               MOV tcon,#0                       ; init tcon
               MOV tmod,#20h             ; configure serial port
               MOV scon,#50h             ;
               MOV th1,#0f3h             ; 2400 baud rate
               MOV tl1,#0f3h
               SETB ti
               SETB ren
               SETB tr1
               MOV conversion_cnt,#10
               RET


      scan_port:               JBC ri,get_cmd
                               RET

      get_cmd:                 MOV A, sbuf
                               XRL A,#0aah
                               JNZ exit
                               JNB ti,$
                               CLR ti
                               MOV sbuf,#55h
                               ;CLR p2.0
```

```
                        usama
                  ACALL send_data
exit:             RET



t_power:    SETB voltage_in
            NOP
            NOP
            NOP
            CLR adc_Wr
            NOP
            NOP
            SETB adc_Wr
            JB adc_intr,$
            NOP
            NOP
            NOP
            MOV voltage,Adc_port
            CLR voltage_in
            NOP
            NOP
            NOP
            SETB current_in
            NOP
            NOP
            NOP
            CLR adc_wr
            NOP
            NOP
            NOP
            SETB adc_Wr
            JB adc_intr,$
            NOP
            NOP
            NOP
            MOV current, adc_port
            CLR current_in
            RET

nd_data:    CLR ren
            JNB ti,$
            CLR ti
            MOV sbuf, voltage
            JNB ti,$
            CLR ti
            MOV sbuf, current
            SETB ren
            RET


            DELAY:  MOV R7,#0
            RELOAD:       MOV R6,#0
                          DJNZ R6,$
                          DJNZ R7, RELOAD
                          RET
```

```
#include <dos.h>
#include <ctype.h>
#include <stdio.h>
#include <conio.h>
#define PORT1 0x3F8


void get_data();
void init_serial();
void compute_power();
unsigned char ready, remote_ack,data_ready;
unsigned char data[2];
            int x;
            unsigned char voltage,current;
            float ac_voltage,ac_current,power;




void init_serial()
{
        outp(PORT1 + 1 , 0);
        outp(PORT1 + 3 , 0x80);  /* SET DLAB ON */
        outp(PORT1 + 0 , 0x30);  /* Set Baud rate - Divisor Latch
Low Byte */
        outp(PORT1 + 1 , 0x00);  /* Set Baud rate - Divisor Latch
High Byte */
        outp(PORT1 + 3 , 0x03);  /* 8 Bits, No Parity, 1 Stop Bit */
        outp(PORT1 + 2 , 0xC7);  /* FIFO Control Register */
        outp(PORT1 + 4 , 0x0B);  /* Turn on DTR, RTS, and
OUT2 */
}

void compute_power()
{
voltage=data[0];
    current=data[1];
ac_voltage= ((2.2*voltage)+28)/1.41421357;
ac_current=((0.11*current)+1.4)/1.41421357;
power  = ac_voltage*ac_current;
printf("\npower: %f",power);
}
```

```
void main()
{

init_serial();
while(!kbhit()){
get_data();
compute_power();
}
 }




/*use this blobk of code*/
void get_data()
{
outportb(PORT1,0xaa);
do{
data_ready =(inportb(PORT1+5)&0x01);
}while(data_ready!=0x01);
do{
remote_ack = inportb(PORT1);
}while(remote_ack!=0x55);
//  printf("remote ack: %x",remote_ack);
for(x=0; x<=1;x++){
do{
data_ready= (inportb(PORT1+5)&0x01);
}while(data_ready!=0x01);
//      printf("data ready: %x",data_ready);
data[x]=inportb(PORT1);
printf("\nData: %x", data[x]);
}
}
```

MANUAL OF OPERATION

This device is operated as specified below;

- Put the device on a flat surface before commencing on any connections.
- Now connect the male plug of the serial cable to the device and the female end to a system i.e. a PC.
- Now connect the power plug to the socket outlet of the mains supply.
- Now connect the device whose power is to be determined to the socket provided on the device.
- Run the software provided on the system.
- The values read are the values of current, voltage, and power itself.
- Make sure all necessary disconnections are made afterward.