Proceedings of the Pakistan Academy of Sciences:
A. Physical and Computational Sciences 53 (1): 37–48 (2016)

ISSN: 0377 - 2969 (print), 2306 - 1448 (online)

Pakistan Academy of Sciences

Research Article

Design and Development of a Data Logger Based on IEEE 802.15.4/ZigBee and GSM

Muhammad Asif[1], Muhammad Ali[2], Naveed Ahmad[3], Sana Ul Haq[1], Tariqullah Jan[4*], and Muhammad Arshad[1]

[1]Department of Electronics, University of Peshawar, Peshawar, Pakistan
[2]Department of Physics, University of Peshawar, Peshawar, Pakistan
[3]Department of Computer Science, University of Peshawar, Peshawar, Pakistan
[4]Department of Electrical Engineering, University of Engineering and Technology, Peshawar, Pakistan

Abstract: The Data Logger (DL) is a special device which is designed to accomplish a common task that is to collect data in a targeted area. Some of the DLs have onboard integrated sensors while some collect data using the wireless sensor nodes WSNs. According to the literature some of the proposed DLs are expensive and slow in operation while some do not fulfill all the application requirements i.e. long and short range data logging. Thus a cost efficient, fast and a wireless DLs are the need of a day. In this paper a customized wireless DL is designed, which is cost efficient, fast and can perform in a wide and short range. The designed data logger is based on IEEE 802.15.4 and GSM Technology and use a 32bit microcontroller as a central processing unit. The designed DL is beneficial for the researchers and application developers in data logging and monitoring of environment, weather and road traffic etc.

Keywords: GSM, data logger, TCP/IP, PIC microcontroller, Zigbee

1. INTRODUCTION

Data recording and data analysis play a vital role in the development of new innovations and the prediction of high probable future events. An application such as recording road traffic data, climate change, pollution monitoring, environmental data collection, energy monitoring are now gaining a worldwide attention. A data logger is a device which is used to record and monitor data of a certain process in a specific location.

Using DLs it is now become possible to record and monitor data such as the movements of individual sharks, whales, sea turtles and jellyfish in the bottom of a sea [1]. The data monitoring and recoding period can be as short as several milliseconds such as monitoring a signal propagation time from source to destination or measurement of the I-V characterization of an electronic device, hence the DL must be very fast that it can monitor and record the transient dynamics of a process [2]. The data logging periods of some processes are very long like monitoring and recoding the environmental parameters, collecting road traffic data, the availability of wind and solar energy, hence the DL must be energy and data efficient such that it can perform for a long time with a battery backup and can store a large amount of data [3]. It is justified that in designing of an embedded systems minimum cost, high speed and maximum power efficiency in a design are primary concern. The

Received, May 2015; Accepted, February 2016
*Corresponding author: Tariqullah Jan; Email: tariqullahjan@uetpeshawar.edu.pk

main contribution of this paper is to showcase a DL which is cost and energy efficient and can also perform as a wide and short range wireless data logger.

The development of the proposed data logger is being done in the following sections: Section I gives an introduction, In section 2 some related literature to the proposed work proposed is presented along with prior work. In section 3, The operation of the DL and wireless sensor network and TCP/IP communication of the DL is explored. In section 4, Circuit implementation of the designed DL is presented. Section 5 includes experimentation and testing of the designed DL. Finally, the conclusions and further work are given in section 6.

2. PRIOR WORK

A low cost tele-health monitoring system which is based on a microcontroller and computer based software for an on line data monitoring and recoding is presented in [4]. While a field programmable gate array based super conductor characteristics monitoring system is designed in [2]. A general purpose low- cost, low power consumption, flexible sensor attachment with an optional WI-FI facility and XML-based spatial-temporal DL is presented in [5] and a microcontroller based low cost DLs integrated with humidity or temperature sensors having extended flash memory or SD card was designed in [6-11].

The DLs presented in [2-5] are few expensive and are application specific, while the DL proposed in [5-10] are based on low speed 8-bit microcontrollers and lakes the IEEE802.15.4/Zigbee interfacing facility, which is very essential for wireless data logging in modern systems [12] [13] while in the proposed DL it is included.

Minimum cost, less energy consumption and high speed have great importance in the embedded market, hence design- in an embedded system like a DL minimum cost, minimum energy consumption and high processing speed are kept in the first priorities, In the proposed DL maximum speed and minimum cost are achieved by using low cost 32 bit microcontrollers i.e. PIC32MX250F128B and jennic JN5148. The use of portable DLs and remote data logging is gaining importance in many applications as in [14-17], hence the designed DL is enhanced by adding Internet access through TCP/IP using Global System for Mobile (GSM).

3. THE PROPOSED DATA LOGGER

The PIC32, JN5148 and GSM module are the main components in the designed DL, PIC32 microcontroller acting as a control unit of the DL. Data from wireless sensor nodes is received by JN5148, PIC32 takes data from the JN5148 through UART2, after the data is successfully received, if GSM services are not available data is than saved on EEPROM and if GSM services are available the data is transmitted on a TCP/IP.

In order to explore the working of the designed DL its data flow and interfacing with a data base and some wireless sensor nodes is presented in Fig. 1.

The designing of the DL is divided in three sections: in the first section the integration of the main control unit i.e. PIC32MX250F128B within the system and its advantages are described, in the second section interfacing of GSM-TCP/IP and JN5148-IEEE 802.15.4/Zigbee is discussed. In III section the block diagram and schematic of the designed DL are presented.

3.1 The Central Processing Unit PIC32

The PIC32MX250f128b is chosen as a centralized control unit for the DL due to the following reasons:

- To achieve the maximum processing speed the microchip PIC32 is selected which is a 32 bit microcontroller with MIPS4000 core and maximum clock speed of 80Mhz, 512 KB programming memory and 32KB RAM [18]

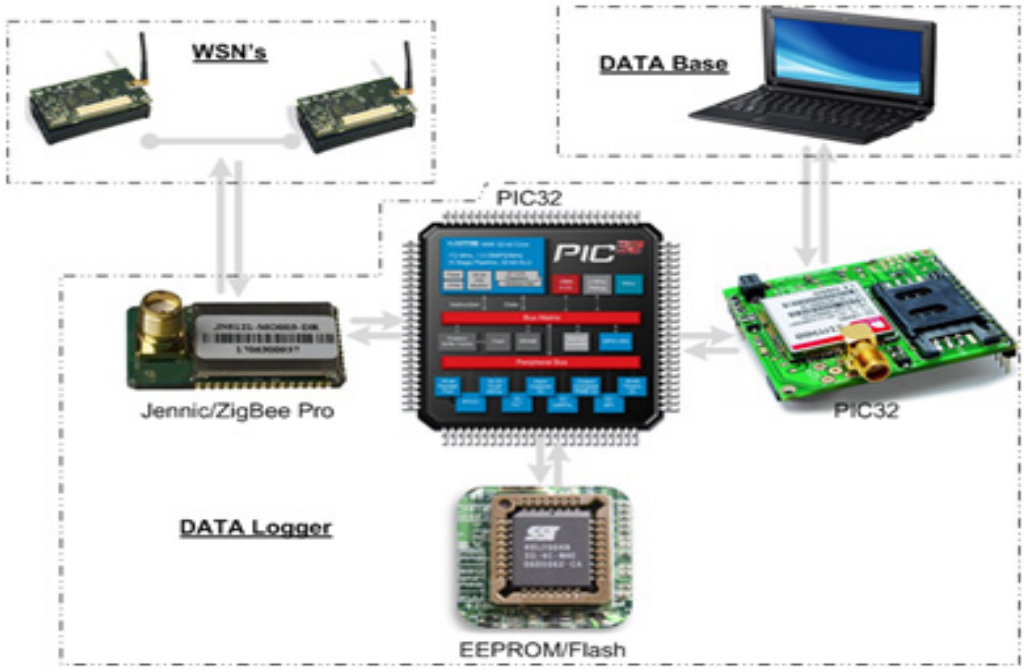

Fig. 1. Data flow diagram of the designed DL and interfacing with database and wireless sensor nodes.

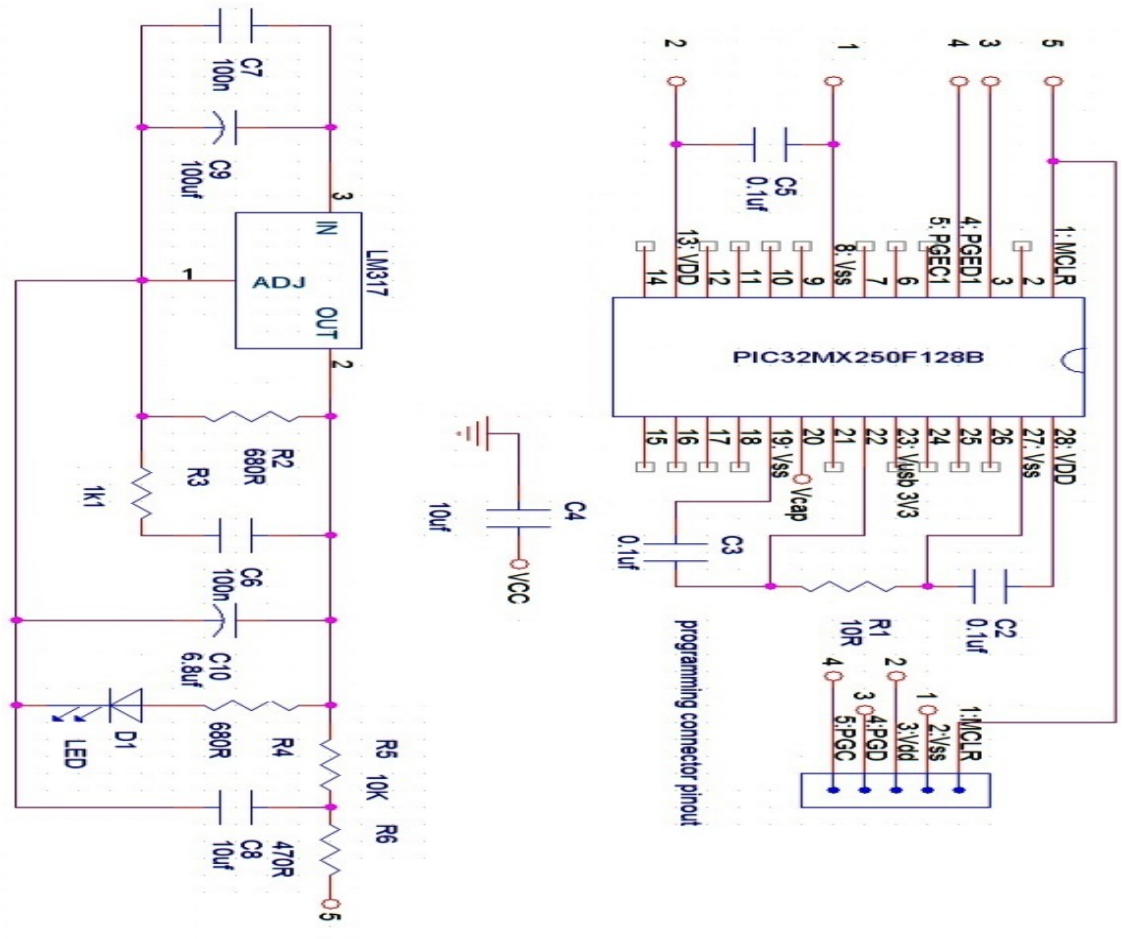

Fig. 2. The Basic PIC32MX2xxFxxxB circuitry with a programming header interface.

and is relatively four times faster than the8bit microcontrollers which are used in [5-10].

- As the minimum cost of the designed DL is required, PIC32MX250f128b is used in the system which is a cost effective solution and all mostly it costs less than 3$ per chip.
- PIC32MX250f128B is an energy efficient solution, normally it operates at 2.3 V to 3.6 V DC and consumes less than 0.5 mA/Mhz.
- PIC32MX250F128B is DIP-SOC and can easily be integrated on any circuit board.
- To make the designedDL user friendly PIC32 is selected because it supports on board and Graphical User Interface (GUI) based programming, hence one who has limited knowledge about C language can easily implement the complicated algorithms over PIC32 using MATLAB Simulink blockset GUI [19].

The schematic and basic circuit of PIC32MX250F128B is given in Fig.2, while the technical data about PIC32 microcontroller family, which is more important for designing a data logger which is given below:

- MIPS 4000 core, maximum clock speed 80 MHz
- Maximum of 512 KB program memory, 32 KB RAM
- Up to 85 I/O pins and two I2C buses.

3.2 IEEE 802.15.4/ZigBee Implementations

To communicate with wireless sensor nodes in the designed DL the IEEE802.15.4 based Zigbee JN5148 M003 wireless microcontroller is used. The ZigBee is a wireless data communication and networking protocol which is based on IEEE 802.15.4 standard and is primarily designed because of the following reasons as given in [20-21].

- Zigbee is a Low power wireless short range data communication and networking solution.
- Zigbee is a self-organizing wireless data communication and networking option.
- Zigbee based devices are cost effective, highly reliable, short latency, has low rate and has high capacity as compared with Bluetooth, IrDA, Wi-Fi and GPRS

ZigBee networks can be divided into four layers, in bottom of ZigBee protocol stack we have physical layer (PHL), after PHL media access control layer (MAC) and then network layer (NWK) and application layer (APL), each layer provides data to its upper and management services. More over ZigBee application layer consists of sub-layer (APS), ZigBee device object (ZDO) and manufacturer-defined application objects.

The network based on ZigBee protocol is composed of three kinds of i.e. sensors nodes (End-Device), routing node (Router) and a pool node (Coordinator). The coordinators act as a parent while router and end devices act as a childes. To organize ZigBee network there must be at least one coordinate is it is the responsible of a coordinator in a network to initialization and maintain a network. End devices acts as a sensor nodes usually they collects data from sensors. The function of Router is to rout information in between coordinator and end devices. ZigBee supports Star network (star), tree network (tree) and the mesh network (mesh) topology, the topology is implemented on the bases of application [21].

In the designed DL the IEEE802.15.4 based Zigbee JN5148M003 wireless microcontroller is used, which only support all network topologies. In the proposed DL before doing any wireless sensors data acquisition operation the JN5148 M003 must be programmed as a coordinator.

4. TCP/IP IMPLEMENTATION

The SIM900 GSM module is used to connect the data logger with remote data base through TCP/IP. There are two modes of connection for SIM900 TCP/IP application i.e. single connection and Multi connection. In single connection mode, SIM900 can work at both transparent mode and non-transparent mode and under these two

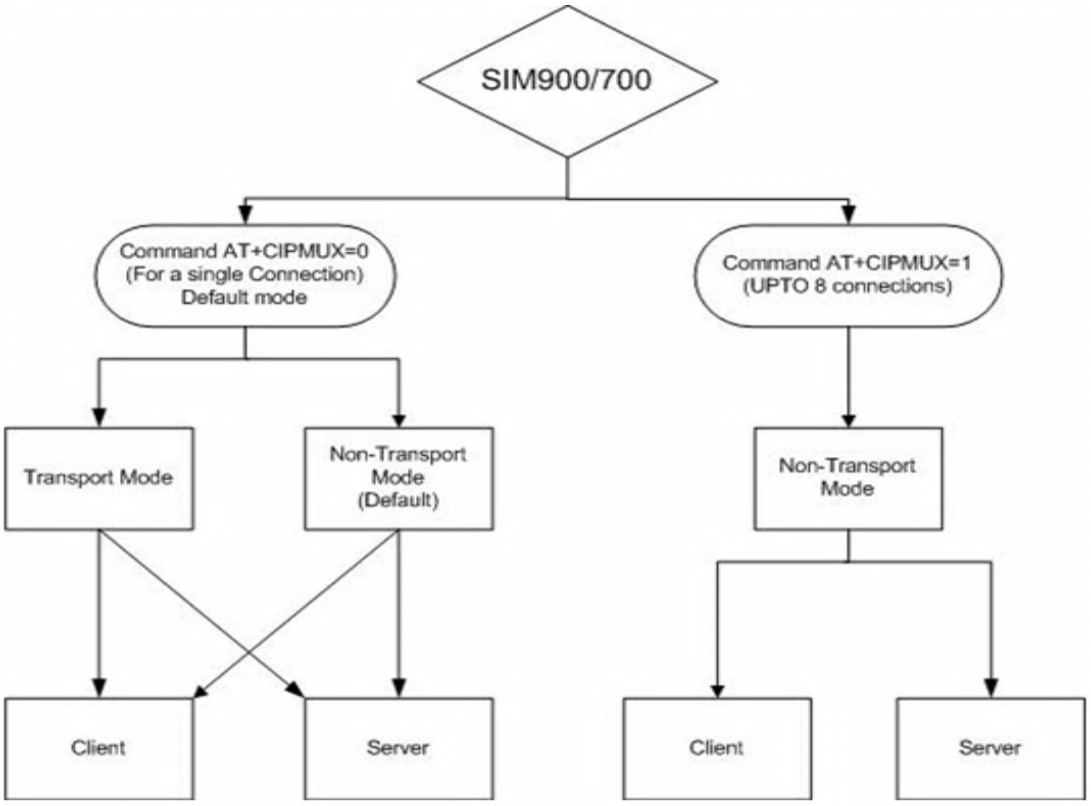

Fig. 3. GSM Modem-SIM900-TCP/IP configuration.

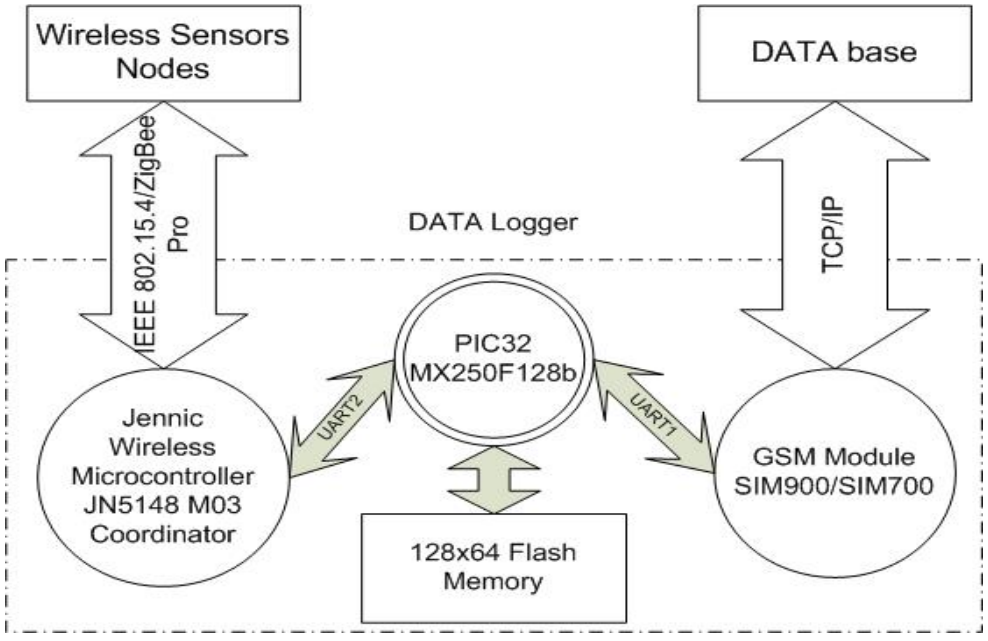

Fig. 4. Working flow diagram of the proposed data logger.

transmission modes, SIM900 can be configured as either TCP/UDP client or TCP server. When in multi connection mode, SIM900 only can work at non-transparent mode. In this mode, SIM900 can work as an absolute TCP/UDP client, which can establish 8 connections in total. In this mode, it also can be configured as one TCP server, which allows 7 TCP/UDP clients to connect in and the TCP server also can act as a client, establishing seven connections to one remote server. The structure of the TCP/IP application is given in Fig. 3.

5. THE SYSTEM DESCRIPTION AND WORKING

The overall working of the data logger is presented in a form of a block diagram in Fig. 4. A wireless sensor network is composed of a coordinator, end device and router. Coordinators act like parents and end node and routing devices acts like childes during a network formation. In any wireless sensor network at least one coordinator is required, in the designed data logger the (Jennic wireless microcontroller JN5148 M003) which is acting as a coordinator and is responsible to collect data from the deployed wireless sensor nodes. The main control unit that is PIC32 has two UARTs one is used to communicate with Jennic microcontroller while other is used to communicate with the GSM module. The coordinator transfer received data serially to the main control unit that is PIC32. As the data is received on PIC32, the control unit checks the availability of GSM services and if GSM services are available the data is transmitted to the data base and online monitoring software, if GSM services are not available the collected sensor data is than stored on the flash and at the same time at regular intervals the control is also checking the GSM services, as soon the GSM services appeared the data stored on the flash is transferred to the data base via TCP/IP. This whole operation of data exchange and storage is commanded by the control unit, the explanation of the operations performed by the control unit is given Fig. 5 in form of a flow chart.

6. HARDWARE FABRICATION

A prototype of the proposed DL is fabricated initially to test the device. A PCB of the proposed DL is designed is a ALTIUM designer software, however no any electronic simulator is available in the market which can simulate the PIC32, Jennic MCU and GSM-SIM900 device there for each and every device is tested and evaluated in real time. To test the data logger each device is programed and tested separately on a computer UART and finally the end product is developed. A photograph of the prototype of the designed data logger is given in Fig. 6. The DL can communicate with a remote data base through a TCP/IP in a case when the hardware is configured as an ”A” of Fig. 6, while using the DL as in ”B” of Fig. 6 the device only stores data on the flash.

7. SOFTWARE DESIGNING

Monitoring and recoding of meteorological, geographical and transportation information etc. have a great importance in research and development, usually monitoring and recoding of meteorological, geographical and transportation information is accomplished through the data loggers. In literature review it is analyzed that minimum cost, minimum energy consumption, wireless facility, portability and maximum processing speed of a data loggers is the need of a day. The work in this paper was carried out to design a data logger which is a cost efficient, energy efficient, wireless, portable and high processing speed than the data loggers designed in the literatures. Achieving minimum cost, maximum speed and low energy consumption of the proposed design was become possible by introducing the PIC32 and Jennic JN5148 microcontrollers.

The designed DL is wireless and is compatible with IEEE 802.15.4, GSM and TCP/IP and it is also able to perform in both off line and on line modes in off line mode the designed data logger stores data on its flash while in on line mode the data logger send data to the data base.

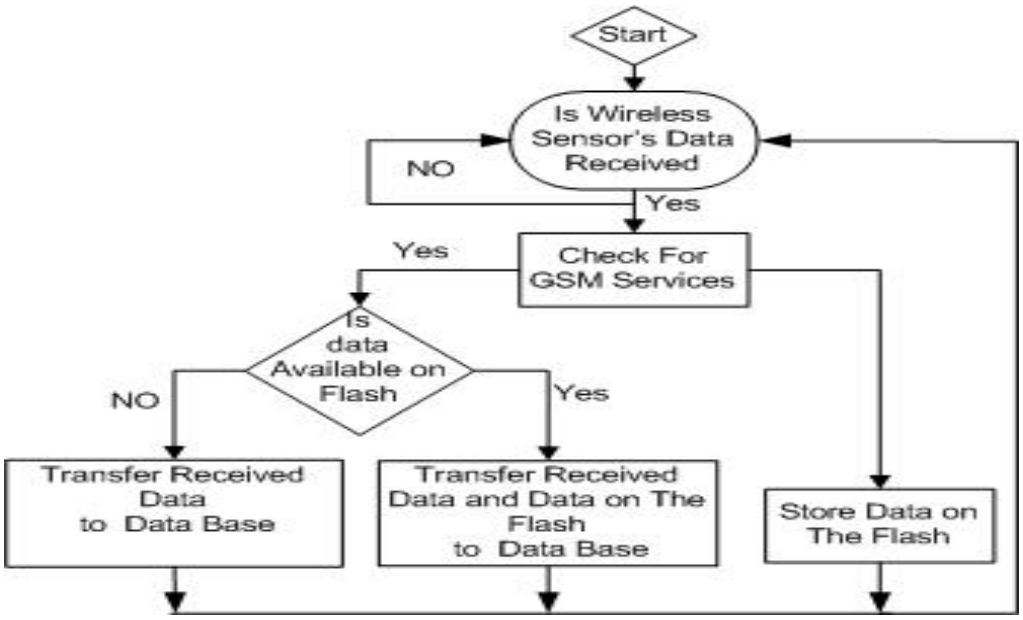

Fig. 5. Operations and functions performed by the control unit.

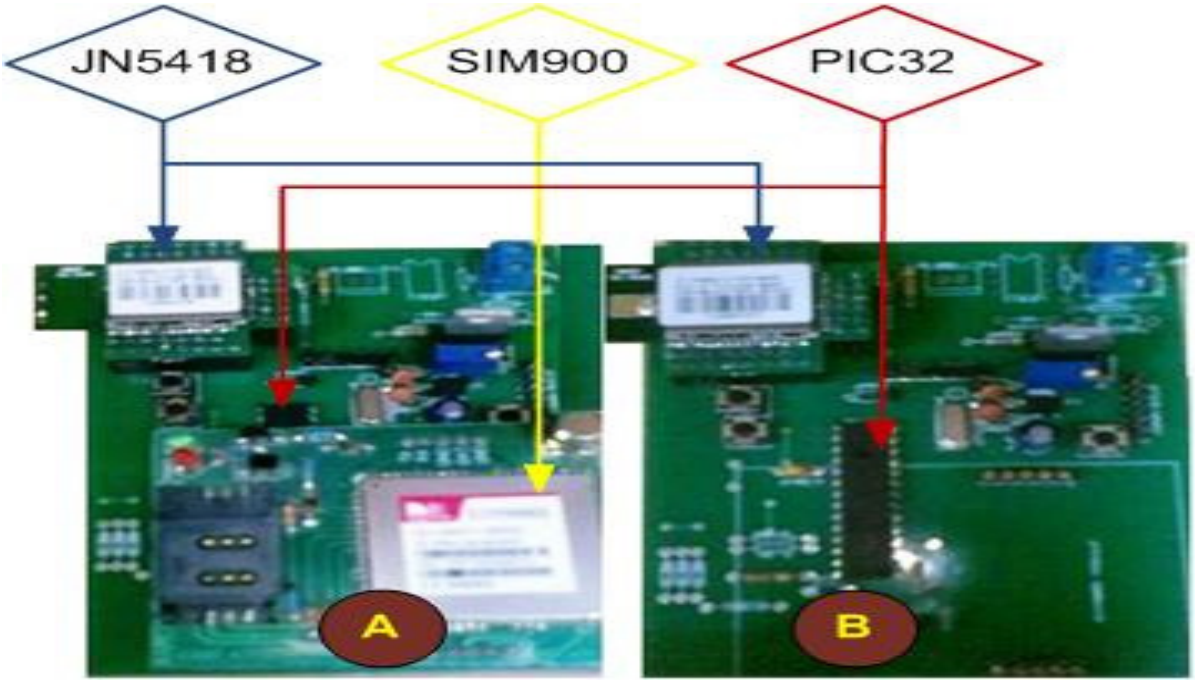

Fig. 6. In Figure "B" the designed DL board is shown without a GSM module while in Figure "A" the GSM module is mounted over the DL board.

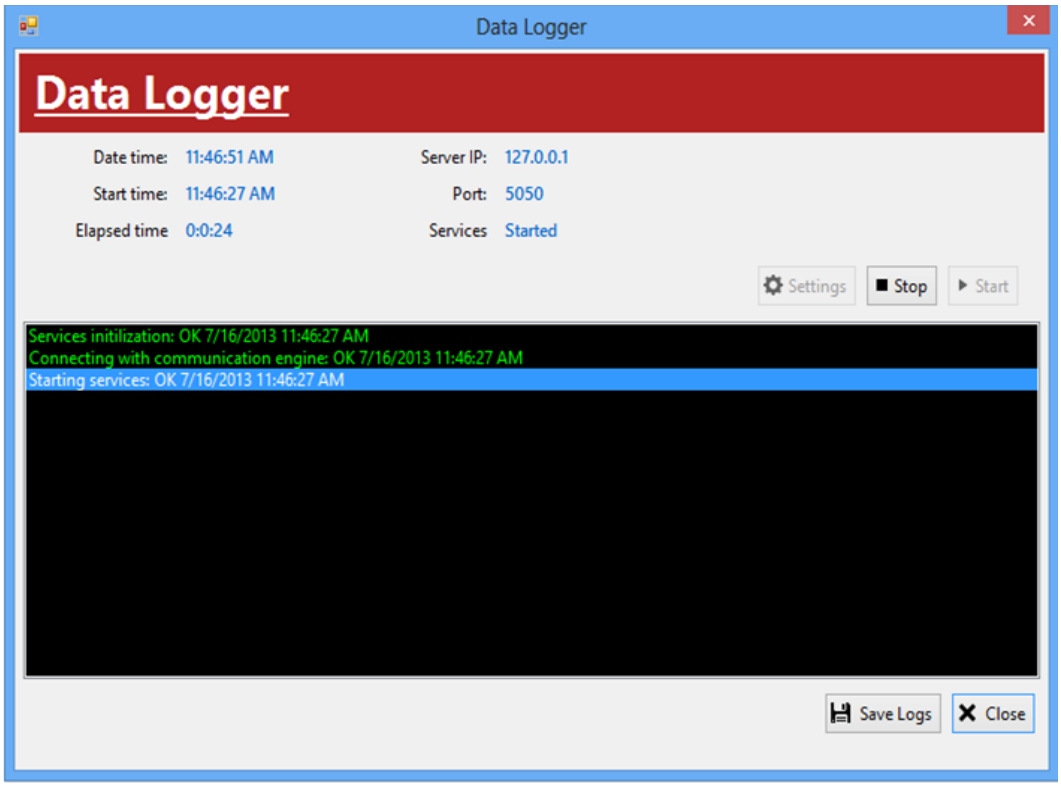

Fig. 7. A screenshot of the data logger software for TCP/IPC on figuration and communication.

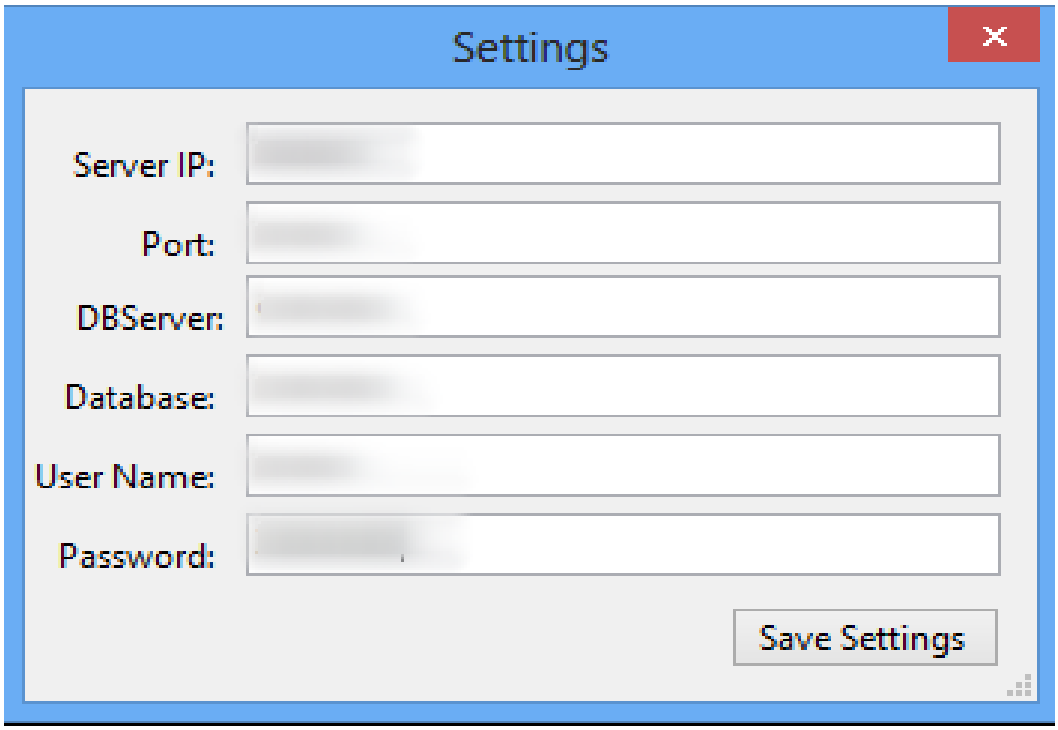

Fig. 8. A screenshot of setting window of the designed software.

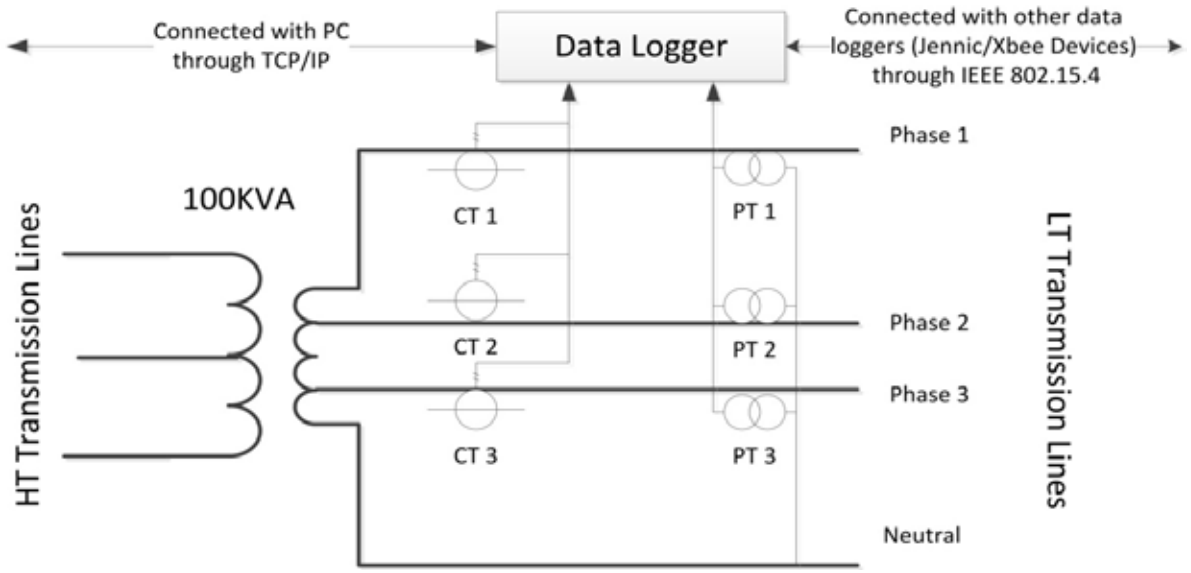

Fig. 9. Schematic diagram of DL operation.

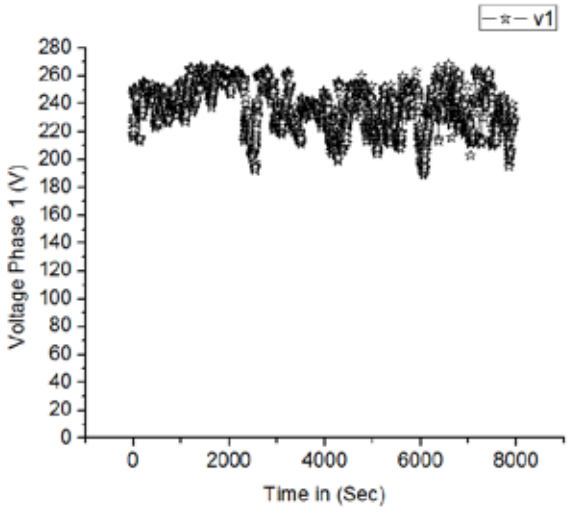

Fig. 10. Voltage of Phase 1 of the transformer.

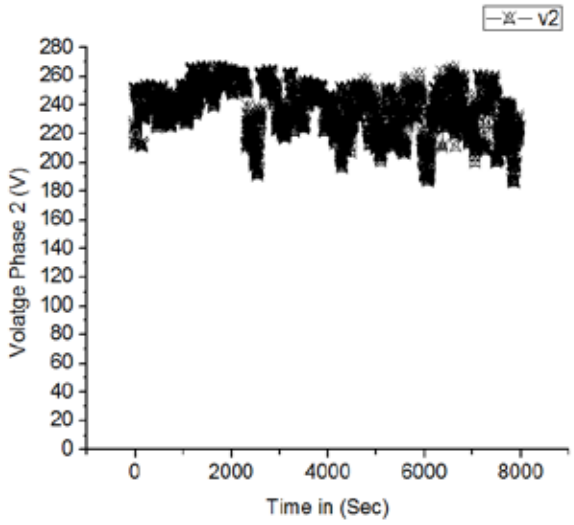

Fig. 11. Voltage of Phase 1 of the transformer.

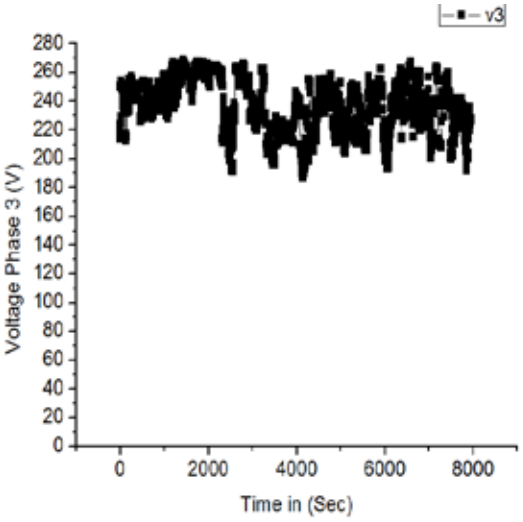

Fig. 12. Voltage of Phase 1 of the transformer.

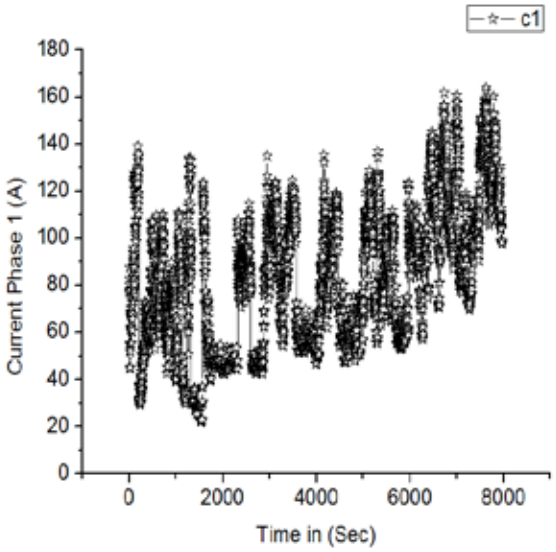

Fig. 13. Voltage of Phase 1 of the transformer.

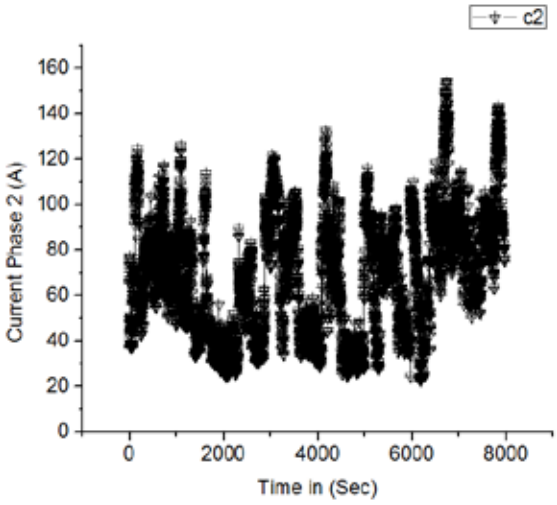

Fig. 14. Current of Phase 1 of the transformer.

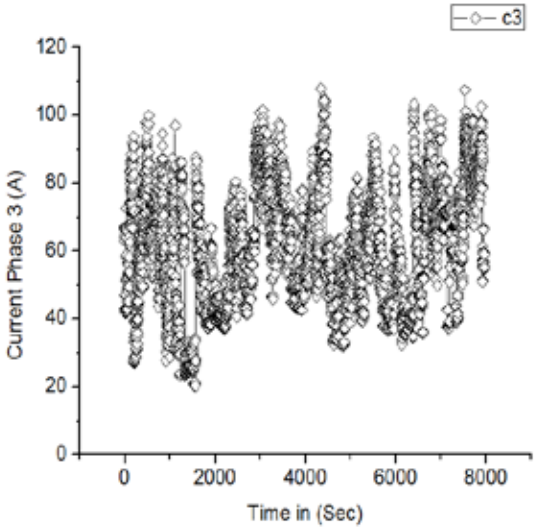

Fig. 15. Current of Phase 1 of the transformer.

Some of the screen shorts of the designed data logger are given in Fig.7&8, whichproves its validity. The current printed circuit board PCB of the designed data logger is a single layer in future one can more miniaturizes the size of the designed data logger by implementing it on a two or more layer PCB. The power supply of the designed data logger is not rechargeable hence in future it is needed to design a power supply for the designed data logger which is rechargeable from some renewable resource such that one can easily use it in remote applications.

8. DATA LOGGER IMPLEMENATIOAN AND RESULTS

The designed data logger is connected with a 100KVA transformer in the way as shown in the Fig. 9. The current and voltage of each phase of the transformer was monitored for 8000 Sec (Iteration time 1 Sec). The collected data of the voltage and current is transferred to Computer using TCP/IP module from DL. The voltage data of each phase of transformer, i.e., V1, V2 and V3 are shown in Fig. 10, Fig. 11 and Fig. 12, respectively. Also the current data of each phase of transformer, i.e., I1, I2 and I3 are presented in Fig. 13, Fig.14 and Fig. 15, respectively.

9. REFERENCES

1. Cyr, A. & S. Nebel. Satellite and data logger telemetry of marine vertebrates. *Nature Education Knowledge* 4(2): 4 (2013).
2. Pilipenko, R., R.H. Carcagno, A. Makulski, R. Nehring, & D.F. Orris. An FPGA-based quench detection and continuous logging system for testing superconducting magnets. *IEEE Transactions on Applied Superconductivity* 23(4): 9500503–9500503 (2013).
3. Suzdalenko, A. Guidelines for autonomous DL design. In: *Proceeding of IEEE International Symposium on Industrial Electronics,* Gdansk, Poland, 27 -30 June, p. 1426–1429 (2011).
4. Ken, K., & L. David. Innovative low-cost telemonitoring: A versatile system using generic hardware-open source software and free data brokeringservices. *Health Care and Informatics Review Online* 17 (1): 2-10 (2013).
5. Coopmans, C., & Y.Q. Chen. A general purpose low-cost compact spatial temporal DL and its applications. In: *Proceedings of IEEE Conference AUTOTESTCON,* Salt Lake City, Utah, USA, 8-11 Sept, 2008, p. 64-68 (2008).
6. Purwadi, A., Y. Haroen, F.Y. Ali, N. Heryana, D. Nurafiat, & A. Assegaf. Prototype development of a low cost DL for PV based LED street lighting system. In: *Proceeding of International Conference on Electrical Engineering and Informatics,* Bandung, Indonesia, 17-19 July 2011, p. 1-5 (2011).
7. Liu, N., & Z. Su. Research and implementation of newt ype multichannel DL. In: *Proceeding of IEEE International Conference on Computer Application and System Modeling,* Taiyuan, China, 22-24 Oct. 2010, p. 102-105 (2010).
8. Nkom, B., & H. Musa. Development of a novel microcontroller-based DL. In: *Proceeding of 2nd IEEE International Conference on Adaptive Science & Technology*, Ghana, Africa, 14-16 Jan 2009, p. 314-324 (2009).
9. Costa, G.N. & A. Arnaud. A low frequency RFID temperature DL. In: *Proceedings of Argentine School of Micro-Nanoelectronics Technology and Applications,* Argentina, 11-12 Aug 2011, p.1-4 (2011).
10. Moghavvemi, M., M.O. Faruque, N.K. Eng, & S.C. Yip. Asimple low cost data acquisition system for remote sensing of relative humidity and temperature. In*: Proceedings of the 44th IEEE Midwest Symposiumon Circuits and Systems*, Dayton, Ohio, 14-17 Aug 2001, p. 202-206 (2001).
11. Karakehayov, Z. Zero-powerdesign for Smart dust networks. In: *Proceedings of first International IEEE Symposium on Intelligent Systems,* Verna, Bulgaria,10-12 Sept 2002, p. 302-305 (2002).
12. Sehgal, V.K, D.S. Chauhan, & R. Sharma. Smart wireless temperature DL using IEEE 802.15.4/ZigBee protocol. In: *Proceedings of IEEE Region 10 Conference,* Hyderabad, India, 19-21 Nov 2008, p. 1-6 (2008).
13. Toscano, E., & L.L. Bello. Comparative assessments of IEEE 802.15.4/ZigBee and 6LoWPAN for low-power industrial WSNs in realistic scenarios. In: *Proceedings of 9th IEEE*

International Workshop on Factory Communication Systems, Lemgo, Germany, 21-24 May 2012, p.115-124 (2012).

14. Jun, C., & L. Jing-li. A wireless data acquisition and transmission system design. In*: Proceedings of First International Workshop on Education Technology and Computer Science,* Wuhan, TBD, 7-8 March 2009, China, p. 768-772 (2009).
15. Sathik, M.J., A. Abdullah, & K. Yogeshraj. Modified GSM based DL system with two way communication. In*: Proceedings of International Conference on Emerging Trends in Science, Engineering and Technology,* Tiruchirappalli, Tamilnadu, India, 13-14 Dec 2012, p.74-77 (2012).
16. Naja, R. A survey of communications for intelligent transportation systems. *Wireless Vehicular Networks for Car Collision Avoidance,* R. Naja (Ed.). Springer, New York, p.3-35 (2013).
17. Siew, Z.W., C.H. Wong, S.E. Tan, H.P. Yoong, & K.T.K. Teo. Designand development of a tablet based real time wireless DL. In: *Proceeding of IEEE Global High Tech Congress on Electronics* ,Shenzhen, China, 18-20 Nov 2012, p. 111-116 (2012).
18. Drochner, M.,P. Kammerling, H. Kleines, & P. Wustner. Micro TCA developments for PANDA data acquisition. In: *Proceedings of 17th IEEE Real Time Conference (RT),* Lisbon, Portugal, 24-28 May, p. 12 (2010).
19. Rogers, J.R., & R.C. McVay. Graphical micro controller programming. In: *Proceedings of 2012IEEE International Conference on Technologies for Practical Robot Applications,* Woburn, Massachusetts, USA, 23-24 April 2012, p. 48-52 (2012).
20. Sultan, S., U. Rana, I. Ahmed, & S. Rabbani. A new technology of online-condition monitoring of energy conservation generation and loads. *Sensors* 4(1):18-22 (2013).
21. Xiaoqin, L., H. Jianbin, Z. Xiaoli, & W. Hairan. Design and implementation of indoor environmental monitoring wireless sensor networks based on JN5139. In: *Proceedings of 3rd International Conference on Advanced Computer Theory and Engineering, Chengdu,* China, 20-22 May 2010, p. 615-618 (2010).