

Development of a multi-channel wireless data acquisition system for swarm robots

A Mechatronic Approach using Arduino UNO and Matlab

¹Priyam A. Parikh, ²Hitesh B. Shah, ³Saurin Sheth

¹P.G. Student, ²Professor, ³Accosiate Professor

^{1,3}Mechatronics Department, G.H. Patel College of engineering and Technology, Anand, India

²Electronics and communication, G.H. Patel College of engineering and Technology, Anand, India

¹myrobo56@gmail.com, ²saurinsheth@gcet.ac.in, ³hiteshshah@gcet.ac.in

Abstract—nowadays use of swarm robotic system is increasing. They are being used in defense applications, material handling, agriculture and many more. Swarm robots comprise of many analog and digital sensors. They can be humidity, temperature, ultrasonic, IR sensors, light dependant resistors (LDR) and many more. Each swarm robot transmits information to its neighbor swarm robot as well as to the control room. It is necessary to acquire real time data (in graphical format) from swarm robots to know the condition of the environment in which swarm robots work. However the actual concept of swarm robotics is not described here. This work deals with only real time wireless multichannel data acquisition. Here just a reference of swarm robots has been taken. Each swarm robot has Arduino UNO microcontroller and WIRDIN 1186 wireless module for transmitting the information to the control room. Control room has another WIRDIN 1186 wireless module to receive the information from the sensors mounted on swarm robots. Control room receives the information in Matlab graphical user interface. The technique of finding root locus of the acquired signal is also described. In a nut shell the intention is to show the multichannel wireless real time data acquisition technique.

Index Terms—Swarm robots, Arduino UNO, WIRDIN 1186 wireless module, Multi channel data acquisition, Analog sensors, Root locus.

I. INTRODUCTION TO THIS WORK

Data acquisition (DAQ) involves the collection and processing of data for use in automated control, and programming is an integral part of Mechatronics when designing data acquisition (DAQ) systems. It is impossible to use Mechatronics without using data acquisition. Even the most basic system requires some feedback. For example, a simple IR distance sensor must use a DAQ system to first get raw data (in voltage from the IR sensor), process this data, and calculate a real-world distance from the voltage, and send the data back out in the form of a display for the user. Most of this is accomplished through programming. As the requirements of the system become more complex, more sensors will be added and the DAQ system will become more complex.[1-4]

Most DAQ systems involve both a microprocessor and a personal computer (PC). A key premise of the work of this paper is that the core needs of a fully equipped DAQ system can be split between the microcontroller requirements, and the PC requirements. For microcontrollers, all have the ability to read digital and analog inputs and change digital outputs (digital I/O). Swarm robot transmits sensor information serially via Arduino and WIRDIN wireless module. Control room receives the signal serial via another WIRDIN module and plotting it on Matlab (Real time). [11] [12][24][25]

Here each swarm robot has got five sensors. The sensors are Light dependent resistor (LDR), DHT11 for Humidity, Ultrasonic distance measurement, IR (Infrared) sensor and LM35 as temperature sensor. There could be N number of swarm robots. User can acquire data from any swarm robot using Matlab Graphical User Interface (GUI). Each swarm robot has Arduino UNO microcontroller and WIRDIN wireless module. Arduino and its interfacing have been described in next chapter. Here data acquisition is not achieved using simulink but the new serial communication technique is shown. The work block diagram can be observed in fig. 1 [7-9][27]

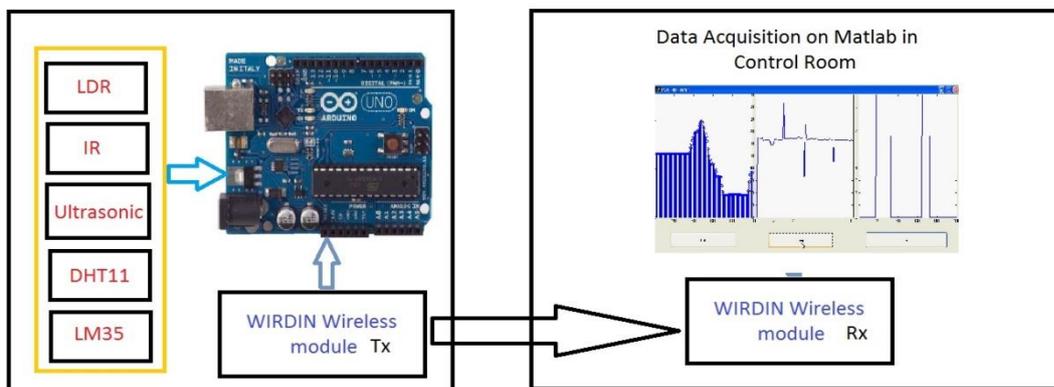


Figure 1 Block diagram of the system (Left side Transmission side and right side control room for data acquisition)

II. ARDUINO UNO CONTROLLER AND SENSOR INTERFACING

TABLE 1 ARDUINO SPECIFICATIONS [21]

Arduino	Specifications
No. of digital I/O	14
No. of analog Inputs	06
PWM pins	03, 05, 06, 09, 10,
Clock Frequency	16 MHz
Power Supply	5 to 12 volts
Flash Memory	32 K
Microcontroller	Atmega 328
Board	Arduino UNO

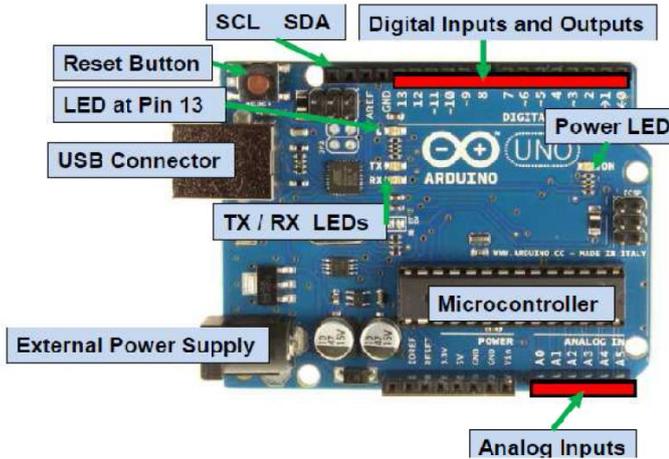


Figure 2 Arduino UNO with description [21]

Arduino is a tool that makes the computers to sense and control the physical world. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board. Arduino can be used to develop interactive objects. Taking inputs from a variety of switches or sensors, controlling of variety of lights, motors, and other physical outputs can be achieved. Projects of Arduino can be stand-alone, or they can be communicating with software running on the computer (e.g. Flash, Processing, MaxMSP) The boards can be assembled by hand or purchased preassembled; the open-source IDE can be downloaded for free. In this research work Arduino UNO has been utilized. It has 14 digital I/O and 6 Analog I/O. It works on +5volts DC, 10 bit analog to digital converter and 14kb ROM. (www. ATMEL.com). Fig.2 shows the image of an Arduino UNO controller. Table 1 shows the specifications of the microcontroller. [11][16] [21]

ARDUINO INTERFACING WITH SENSORS

Fig. 3 shows five sensors utilized in this work with Arduino UNO. Hardware connections are shown in fig 5. The fritzing software is used to simulate the circuit. The simulated circuit is shown in fig 4. The first one is ultrasonic distance measurement sensor. The second one is humidity sensor (DHT11). Third sensor is LDR. Fourth one is IR digital sensor and the last one is LM35 (temperature sensor). It should be notified that Vcc (input power supply) and GND (ground) are taken common from each sensor, so five sensors could have one common Vcc and a common GND. This Vcc can be taken from Arduino UNO. [12]

Analog sensors, such as a Temperature Sensors (LM35) often work like a variable resistor the resistance of which is directly influenced by the condition it measures (in the case of the photocell it is the amount of light). Its sensitivity is 10mv/°C. Its range is -55 to 100 °C. Its middle pin is connected with Arduino's analog pin 0. [12][13]

Ultrasonic Distance Sensor provides range from very short (2 cm) to long-range (5 m) for applications in detection and ranging. The sensor provides precise and stable noncontact distance measurements from about 2 cm to 5 m with very high accuracy. The ultrasonic sensor can easily be interfaced to microcontrollers where the triggering and measurement can be done using two I/O pin. The sensor transmits an ultrasonic wave and produces an output pulse that corresponds to the time required for the burst echo to return to the sensor. By measuring the echo pulse width, the distance to target can easily be calculated. Here the ECHO pin is connected with digital pin No. 2 and TRIG pin is connected with digital pin No. 3 of Arduino. [14][17]

This work covers the low cost DHT temperature & humidity sensors. These sensors are very basic and slow, but are great for hobbyists who want to do some basic data logging. The DHT sensors are made of two parts, a capacitive humidity sensor and a thermistor. There is also a very basic chip inside that does some analog to digital conversion and spits out a digital signal with the temperature and humidity. The digital signal is fairly easy to read using any microcontroller. Here pin No. 3 is not be connected and pin No. 2 is connected with Arduino digital pin No. 4. [14][15]

LDR and IR sensors are connected with analog pin No. 1 and digital pin No. 5 respectively.

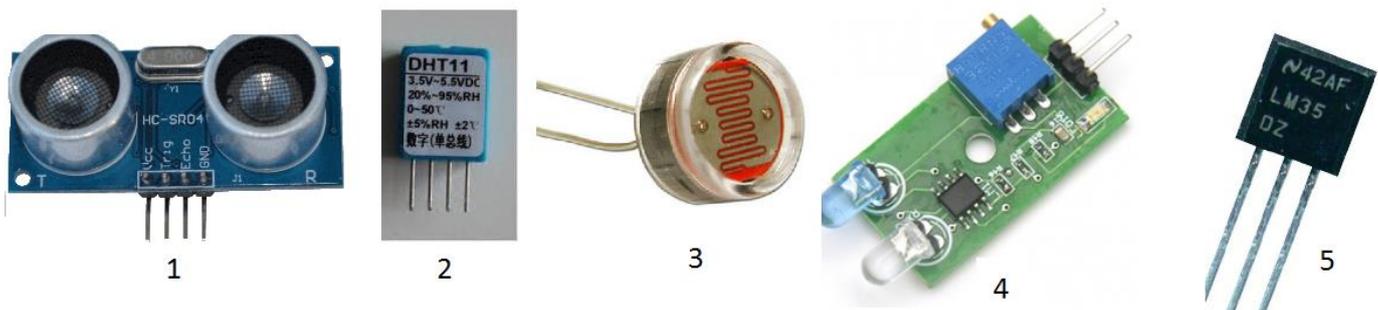


Figure 3 Five Sensor interfaced with Arduino on Robot

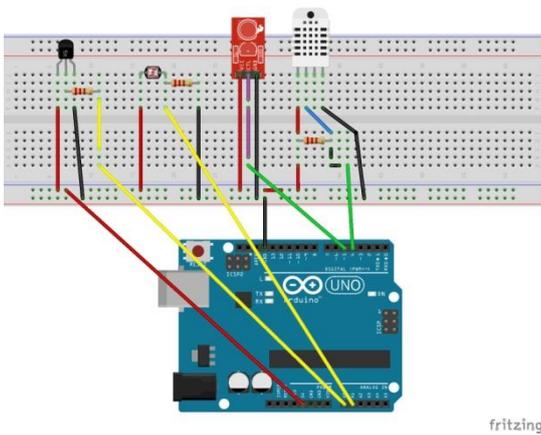


Figure 4 Sensor simulated circuit on fritzing software

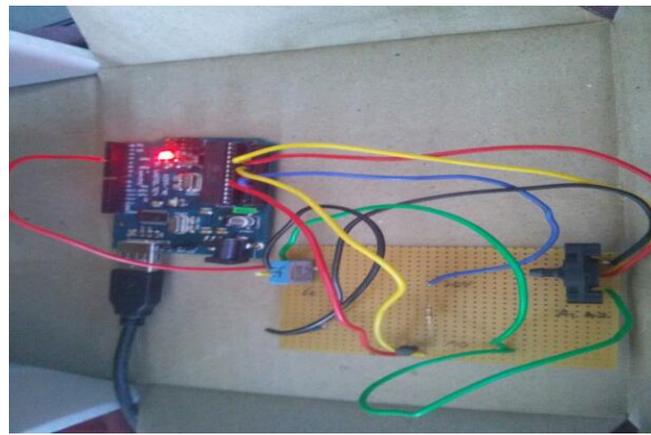


Figure 5 Actual Sensor circuit on swarm robot

In fig.4 considering sensors from left hand side, the first one is LM35, second is LDR, third is IR sensor and the last one is DHT11 humidity sensor. However the Ultrasonic sensor is not shown in fig. 4, because it is not available in the software library.

III. WIRDIN 1186 WIRELESS MODULE AND ATCOMMAND

The WIR-1186 module is a low-power wireless communication solution that is ideal for Smart Grid, home automation, smart lighting, industrial sensor data acquisition and remote control applications [21][26]. This module integrates SPIRIT1, an extremely low-power sub-GHz transceiver, an MCU for wireless network control, data handling and hardware interface, a PCB antenna and matching circuitry. WIRDIN 1: Setting S=0021 (Source ID of WIRDIN 1), D=0051 (Destination ID of WIRDIN 1). WIRDIN 2: Setting S=0051 (Source ID of WIRDIN 2), D=0021 (Destination ID of WIRDIN 2). It means to get connected; Source ID of WIRDIN 1 should be equal to the destination ID of WIRDIN 2 and vice versa. H=5 is called hopping limit, which should be small for limited network. M=1 will enable the hopping limit. [11][20] Fig. 6 shows ATCOMMANDS entered in hyper terminal. X-CTU hyper terminal used as hyper terminal.

Technique of interfacing Arduino UNO with WIRDIN module is shown in fig. 7. As described earlier, Arduino UNO's Tx pin is connected with WIRDIN's Rx pin and vice versa. Fig.7 shows the connection of WIRDIN with Arduino UNO.

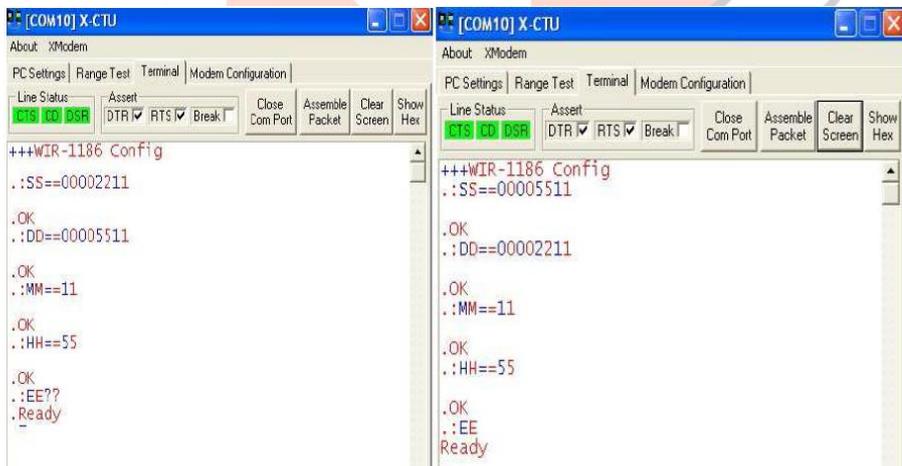


Figure 6 X-CTU Hyper terminal Screen shot for WIRDIN 1 and WIRDIN 2

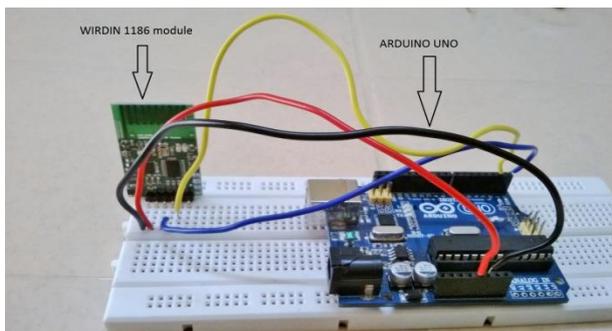


Figure 7 Arduino Uno with WIRDIN module

TABLE 2 WIRDIN CONNECTIONS WITH ARDUINO

NO.	WIRDIN PIN	ARDUINO
1	1. GND	GND
2	2. Vcc	Vcc
3	3. PROG	NC
4	4. TX	RX
5	5. RX	TX
6	6. CTS	NC

IV. MATLAB SERIAL COMMUNICATION AND GRAPHICAL USER INTERFACE

As discussed earlier all Swarm robots send information (from sensors) serially to the control room via WIRDIN 1186 module. For data acquisition purpose graphical user interface is made in Matlab (Fig. 8). Communication mode is serial, so a serial object is created in matlab. A particular Swarm robot can be selected from the Popup Menu. Two push buttons are there to connect and disconnect the system with control room. A sensor panel can be observed in the GUI. User can select any sensor for data acquisition. The graph shows the data acquisition in time domain. [11]

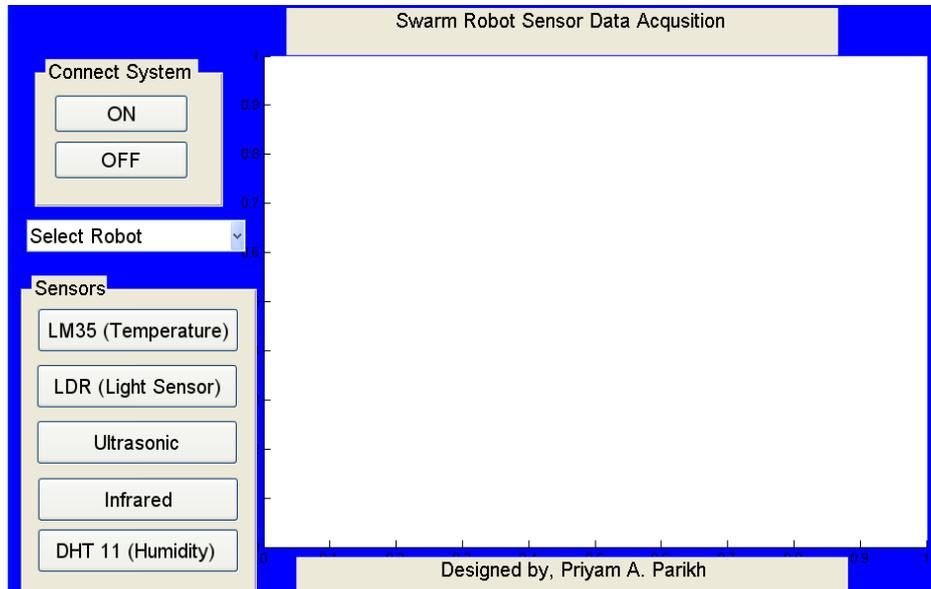


Figure 8 Matlab GUI for data acquisition

V. RESPONSE RECEIVED FROM LDR IN TIME DOMAIN

For data acquisition samples have been taken at every 1 sec or 1 Hz. After completion of data acquisition, the time domain equation can be found from the graph. This time domain equation can be converted into frequency domain using Laplace transform. At the end root locus of the system for step response can be found [25][26]. This procedure has been followed for all five sensors.

The resistance of the Light Dependent Resistor (LDR) varies according to the amount of light that falls on it. As discussed earlier Arduino has 10 bit Analog to digital converter (ADC). 2^{10} is equal to 1024. This value can provide us the output voltage V_o . Equation 1 shows the output voltage. Equation 2 shows the light intensity. Fig.9 shows the real time data acquisition of LDR and fig 10.shows the Root locus of the system. Equation 3 shows time domain equation of the system (based on spline interpolation) and equation 4 shows the transfer function (T.F) of the system. [15][18]

$$(5.0 * \text{ADC value}) / 1024 = V_o \tag{1} \qquad \text{LUX} = ((2500 / V_o) - (500)) / 3.3 \tag{2}$$

$$Y = (X - 10.5) / 5.91; \tag{3} \qquad \text{T.F} = (-1050 * s + 100) / 591 * s^2 \tag{4}$$

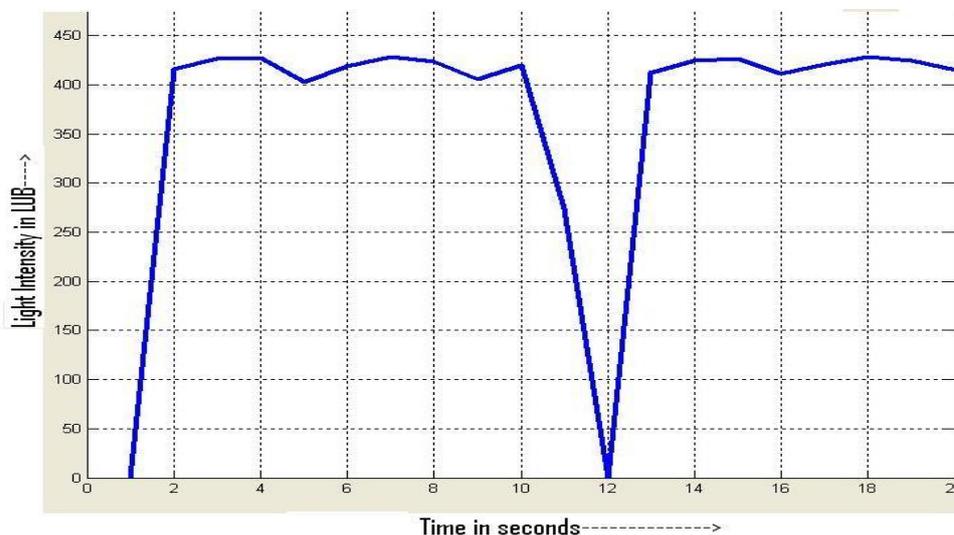


Figure 9 Response of LDR in time domain

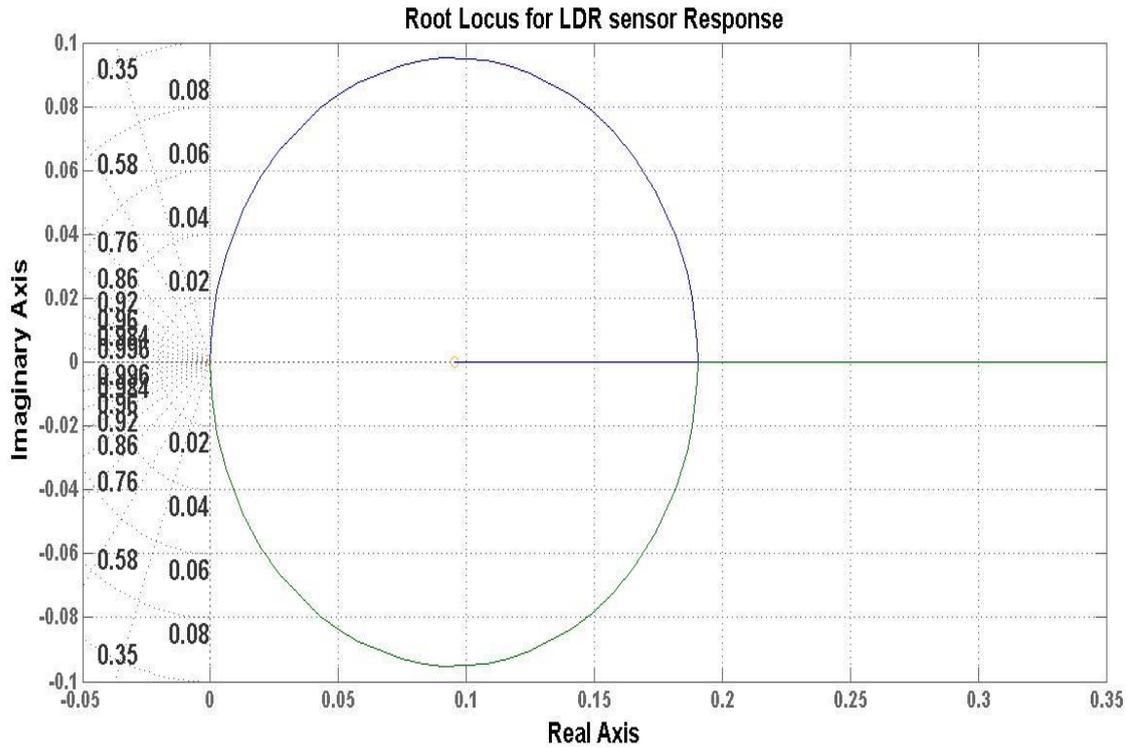


Figure 10 Root locus of LDR's response

VI. RESPONSE RECEIVED FROM IR IN TIME DOMAIN

When robot comes near the object, IR sensor senses the object and sends the impulse to the control room. Equation 5 and 6 shows the time domain equation and the transfer function of the given response. Fig.11 shows the real time data acquisition of IR sensor and fig 12.shows the Root locus of the system. The trapezoidal part in the Fig. 11 shows the detection of object when it comes near any hurdle or object. The time domain equation is made on the basis of 4th order polynomial equation. [11][18]

$$f=a*t^4+ b*t^3+ c*t^2+ d*t+ e \tag{5}$$

$$T.F= (10 s^4 + 40 s^3 + 43 s^2 - 108 s - 264)/ (50 s^5) \tag{6}$$

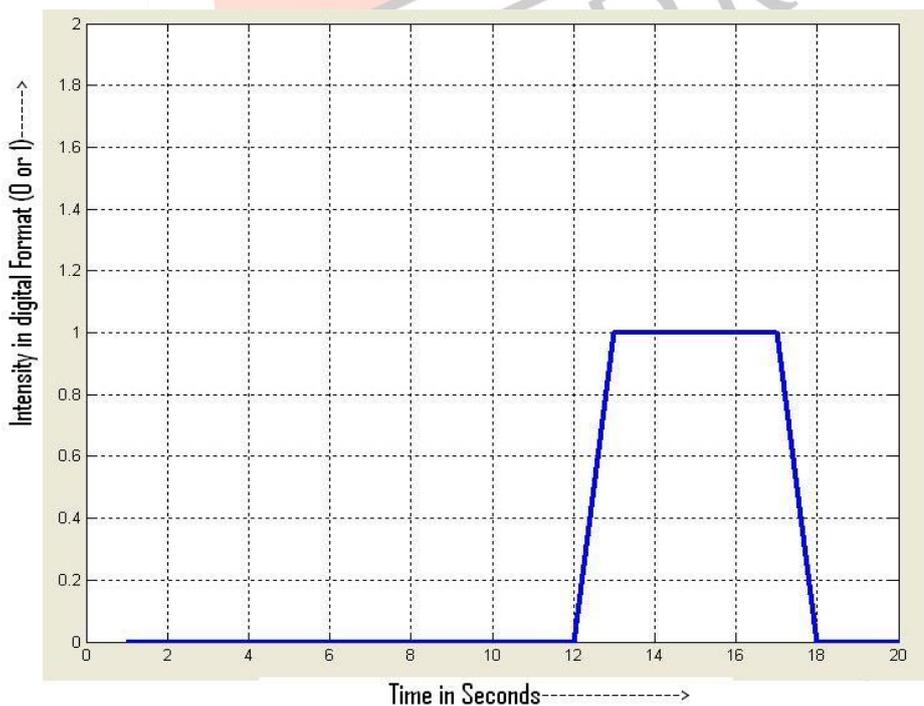


Figure 10 Response of IR sensor in time domain

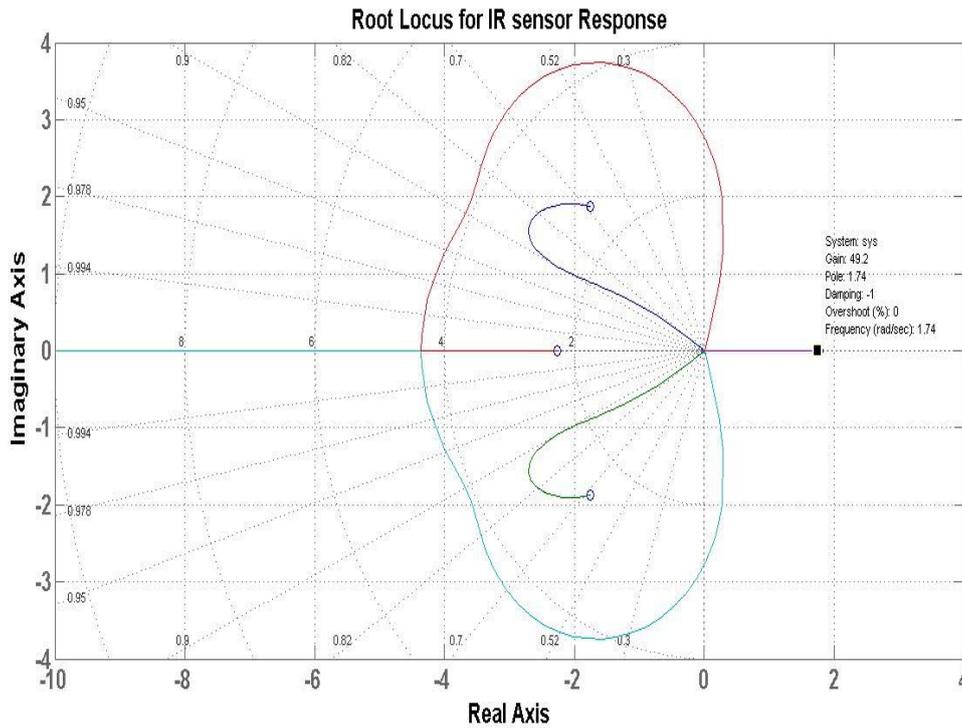


Figure 11 Root locus of IR sensor's response

VII. RESPONSE RECEIVED FROM HUMIDITY SENSOR IN TIME DOMAIN

DHT 11 is nothing but a hygrometer. It measures not only temperature but also relative humidity. It gives output in the form of relative humidity. Maximum value could be 100% and minimum is 0%. Here robots work in constant humidity environment, so very few changes in the graph are observed. Equation 7 and 8 shows the time domain equation (based on 6th degree polynomial) and the transfer function of the given response. Fig.12 shows the real time data acquisition of DHT11 sensor and fig 13.shows the Root locus of the system. [14][19]

$$f = p1*z^6 + p2*z^5 + p3*z^4 + p4*z^3 + p5*z^2 + p6*z + p7; \quad (7)$$

$$TF = (1057 s^6 + 118 s^5 - 904 s^4 - 1728 s^3 + 14832 s^2 + 16440 s - 144000) / (100 s^7) \quad (8)$$

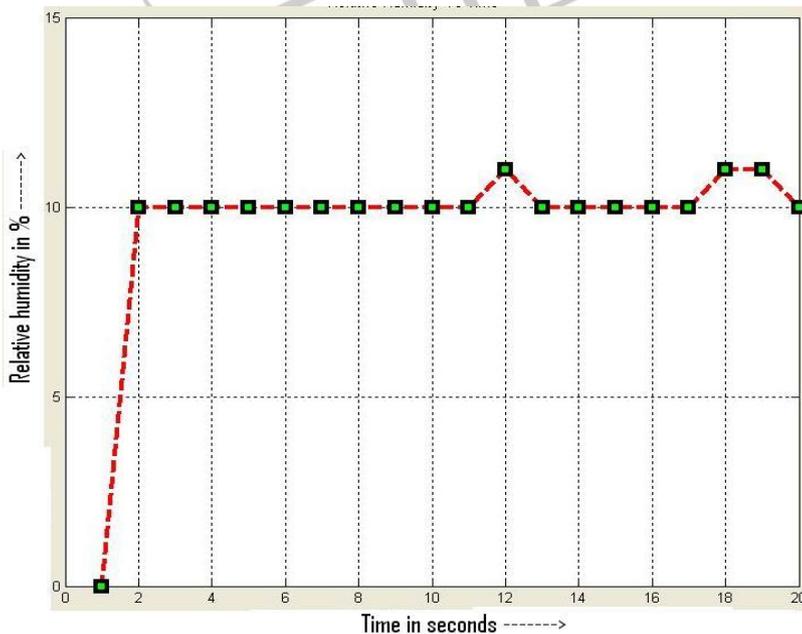


Figure 12 Response of DHT11 in time domain

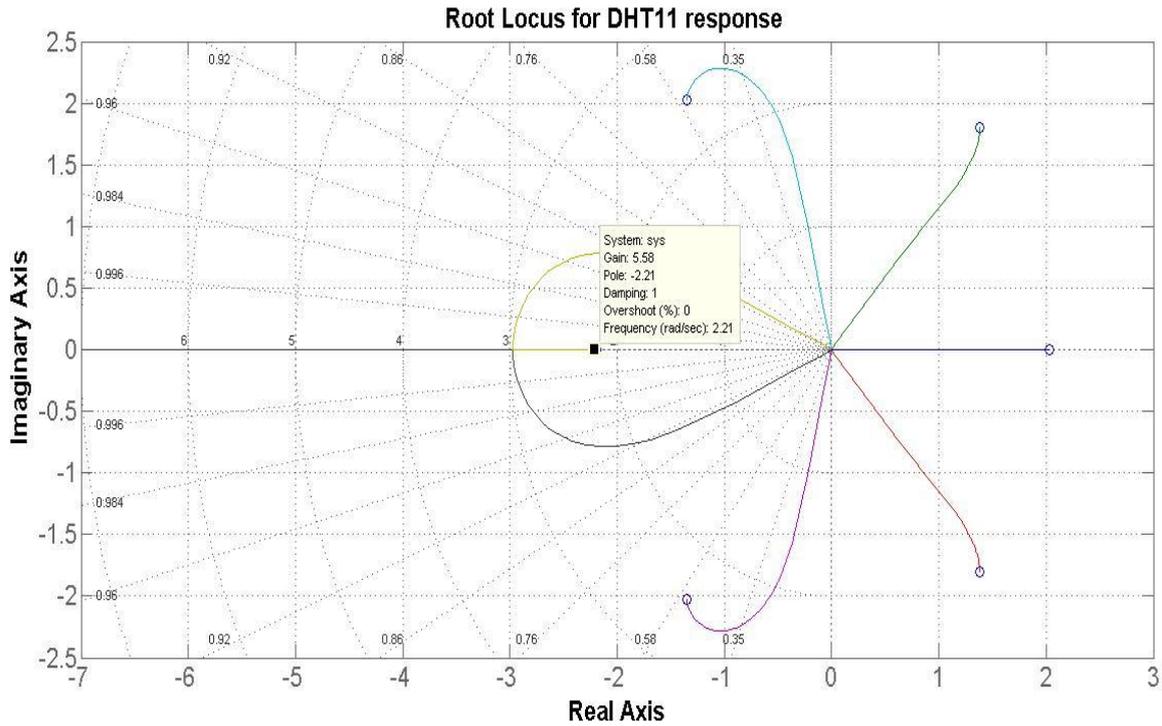


Figure 13 Root locus of DHT11 Response

VIII. RESPONSE RECEIVED FROM TEMPERATURE SENSOR LM35 IN TIME DOMAIN

. Equation 10 and 11 shows the time domain equation and the transfer function of the given response respectively. Fig.14 shows the real time data acquisition of ultrasonic sensor and fig 15.shows the Root locus of the system.

$$(5.0 * \text{ADC value} * 100.0) / 1024 = \text{Temperature (in } ^\circ\text{C)} \quad (9)$$

$$f = p1 * z^4 + p2 * z^3 + p3 * z^2 + p4 * z + p5 \quad (10)$$

$$\text{TF} = (-2925 s^4 + 5850 s^3 - 1750 s^2 + 300 s + 24) / (250 s^5) \quad (11)$$

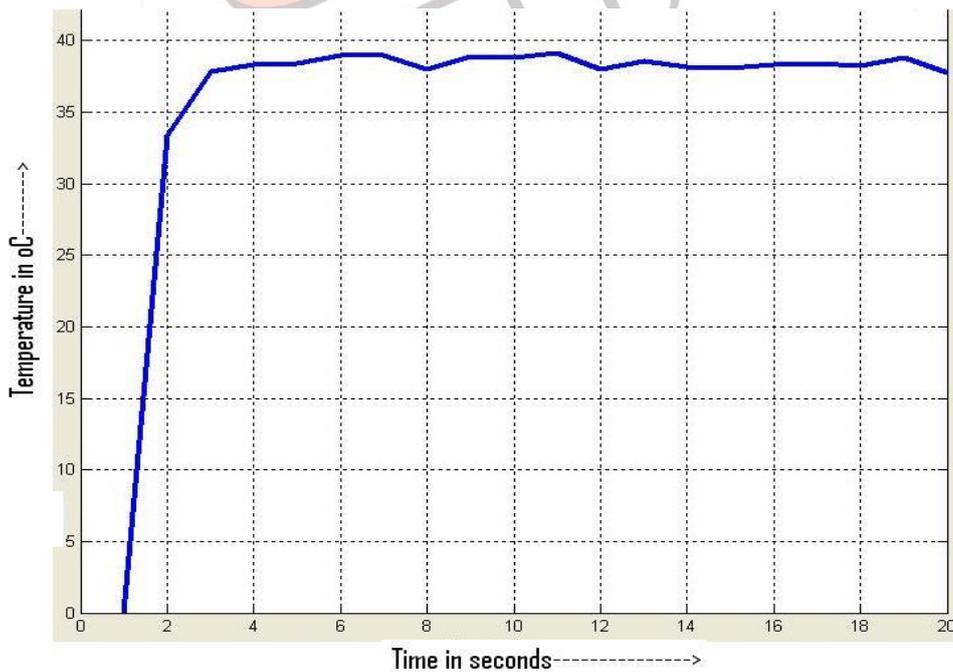


Figure 14 Response of LM35 in time domain

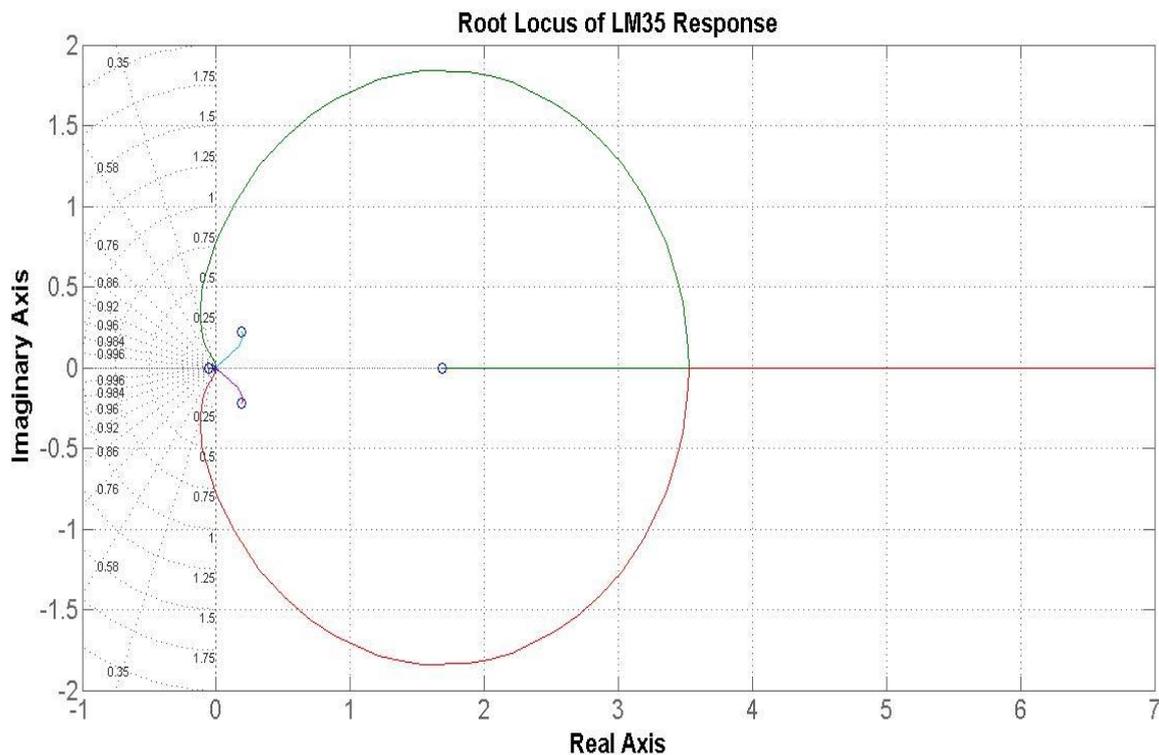


Figure 15 Root locus of LM35's response

IX. CONCLUSION

At the end it can be concluded that, a low cost multichannel wireless data acquisition system can be designed and developed for number of swarm robots for gathering the information from environment. This system could be useful in agriculture, defense, manufacturing industries, rescue operations and many more. Control room is not only plotting the real time data but also gives us root locus of the particular sensor's response. In a nut shell this system works as a vital unit as far as swarm robotics is concerned. In future wireless dynamic response also can be found using for each and every system using this approach.

REFERENCES

- [1] Ampatzis, C., Tuci, E., Trianni, V., Christensen, A. L., & Dorigo, M. (2009). Evolving self-assembly in autonomous homogeneous robots: experiments with two physical robots. *Artificial Life*, 15, 465–484.
- [2] Manuele Brahmilla, Marco Dorigo, Swarm robotics review from swarm engineering perspective, Springer NEW YORK, 17th JAN, 2013
- [3] Anderson, C., Theraulaz, G., & Deneubourg, J.-L. (2002). Self-assemblages in insect societies. *Insectes Sociaux*, 49(2), 99–110.
- [4] Bachrach, J., Beal, J., & McLurkin, J. (2010). Composable continuous-space programs for robotic swarms. *Neural Computing & Applications*, 19(6), 825–847.
- [5] Bahçeci, E., & Sahin, E. (2005). Evolving aggregation behaviors for swarm robotic systems: a systematic case study. In *Proceedings of the 2005 swarm intelligence symposium, SIS 2005* (pp. 333–340). Piscataway: IEEE Press.
- [6] Mataric, M. J. Robotics education for all ages. *Proceedings of AAAI Spring Symposium on Accessible, Hands-on AI and Robotics Education*, Palo Alto, CA, Mar 22-24, 2004
- [7] Korpela, C. M. and Adams, W. J. Robotics in multidiscipline multicultural projects. *Proceedings of the 2007 Middle Atlantic Section Fall Conference of the American Society for Engineering Education*.
- [8] You, Y. A project-oriented approach in teaching robotics application engineering. *Proceedings of the 2009 American Society for Engineering Education Conference*.
- [9] Yogeswaran M. and Ponnambalam S. G., 'Swarm robotics an extensive research review, School of engineering, Monash University, Malaysia.
- [10] Soren Gohel and Vikas Kumar Singh, 'Line Follower using PID controller', ROBOCON2012, IIT Kanpur.
- [11] Priyam Parikh, Keyur Joshi and Saurin Sheth, 'Color Guided Vehicle- An intelligent material handling Mechatronic system, '1st International conference INACOM13 at IIT roorkee on Machines and mechanism,' Dec2013

- [12] Zin Chen, A review of Humidity sensors, Department of Electrical and Computer Engineering and Center for Nanoscale Science and Engineering, University of Kentucky, Lexington, Kentucky 40506, USA (July 2005)
- [13] Frank Dabek, Jinyang Li, Emil Sit, James Robertson, M. Frans Kaashoek, Robert Morris, Designing a DHT for low latency and high throughput, MIT Computer Science and Artificial Intelligence Laboratory.
- [14] Design of Electromechanical Robotic Systems, Sensors and signal lab, MIT USA, Fall 2009
- [15] A Low-Cost Dynamic Plant and Data Acquisition System for Laboratory Courses on Control Systems and Mechatronics School of Engineering San Francisco State University, June 2009
- [16] A ppt by Dr. Kevin Craig, Rensselaer Polytechnic Institute, Root locus analysis and design.
- [17] Firdous Saleheen, Amrita Sahu and Tim Boger , Sensor Data Acquisition Robotic Arm to Demonstrate Implementation of Force, Temperature and Strain Sensors, A thesis submitted to Dr. Chang-Hee Won, Nov 2011
- [18] Derci Felix da Silva 1 and Daniel Acosta-Avalos, Light Dependent Resistance as a Sensor in Spectroscopy Setups
- [19] Using Pulsed Light and Compared with Electret Microphones, Sensors 2006.
- [20] ShiNung Ching, control methods for systems with nonlinear instrumentation: root locus, performance recovery, and instrumented LQG, A dissertation submitted in partial fulfillment of the degree of Doctor of Philosophy, The University of Michigan 2009
- [21] Viet Thang Pham, Qiang Qiu, Aung Aung Phyto Wai and Jit Biswas, Application Of Ultrasonic Sensors In A Smart Environment, Systems & Security Department, Institute for Infocomm Research (I2R) Heng Mui Keng Terrace, Singapore 119613
- [22] www.arduino.cc
- [23] www.mathworks.com
- [24] www.sunrom.com
- [25] www.robokits.co.in
- [26] www.infarmix.com
- [27] www.robotex.com
- [28] www.instructabel.com

