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Designand Testing of Pipeline Inspection Robot

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***Abstract* – Robotics is one of the faster growing engineering fields of today. The first industrial robot FAMULUS in the world was created in1973 by Kukawhich is used in cars and plastics manufacturing. The use of robots is more common today than ever before. Robotics used in precision cutting, electrical, danger places, welding, medical failed and other uses. The pipeline inspection robot which is usedfor maintenance, cleaning and inspection work is presented in this paper. This robotic system is remotely working. It will inspect the pipeline in right, left, reverse and forward direction. Although it has wireless camera, it capturesphotos and videos directly and communicate to computer. The direction of robot is controlled by microcontroller program. This robot consist of three items such as transmitter which sends the signals, receiver which receives the signal and keypad is such as remote to control and chose the robot directions.**

***Keywords* – Microcontroller, Pipeline, and Robotics Wireless Camera.**

I. INTRODUCTION

Robotics is one of the fastest growing engineering fields of today. It designed to reduce the human factor labor intensive or potential risks and to work in inaccessible environment. Robots are more common now than ever before and it is not necessarily only using in the heavy production industries. Pipeline transports the oil, gases, and other for far distances. The routine maintenance is necessary for these pipes which avoid any abnormality things such as, crack, leakage or deposit. That's why it was important to use safely and economically thing, therefore the robot becoming most attractive product available.

The major companies supplying and maintaining the oil pipelines faces many problems and difficulties when people want to inspect or check the oil pipeline and spent huge money on this process. During the maintenance of these pipelines, the employee's exposure to the risk of choking. Moreover the companies also incurred more maintenance cost also staff and labor costs. And more often they did not able to find any faults in pipeline so they lose money, time and human effort. Hence, it is proposed to design a simple pipeline inspection robot to inspect pipeline for any malfunctions and to perform maintenance work. This robot may solve the problems of companies facing for inspection and we can implement it.

These days, the robot attracts in many way. It has appeared to serve the community in many different forms. There are many benefits of these robots. Some of these robots have a remote control to adjust the direction of robot and wireless camera photo, video and voice to identify if there are any faults in the pipeline.

An in-pipe robot with active pipe-diameter adaptability and automatic tractive force adjusting is developed [1] for long-distance inspection of mains gas pipelines with different diameter series. To verify the pipe-diameter adaptability and tractive force adjusting of the robot, related filed experiments are implemented in actual underground gas pipeline. This robot which employs active mode for its adaptability to pipe diametercan be adaptable to the wide range of gas pipeline diameter from 400mm to 650mm and automatically provide a stable and reliable attractive force with strong capacity of tractive force adjusting. A reconfigurable robot which was [2] developed can be used for 80-100mm pipeline.They derived the kinematics of this mechanism and determined the actuator size by static analysis. The mechanism consists of three pairs of caterpillar, each of which is operated by a micro DC motor. The robot is designed foldable when each chain contacts the wall of pipelines. Thus, the robot can be operated in various sizes of pipeline. Controlling the speed of caterpillar independently provides a steering capability. So it can go through elbow and T-branch.A micro inspection robot [3] developed for 1-in pipes. The robot is 23 mm in diameter and 110 mm in length and is equipped with a high-quality micro charge-coupled device (CCD) camera and a dual hand for manipulating small objects in pipes. It can travel through both vertical pipes and curved sections, making possible inspections that would be difficult with conventional endoscopes. the authors have specially designed and developed several micro devices and micro mechanisms: a novel micro mechanism called a planetary wheel mechanism for robot drive; a micro electromagnetic motor with a micro planetary reduction gear to drive the planetary wheel mechanism; a micro pneumatic rubber actuator that acts as a hand; a micro CCD camera with high resolution; and a pneumatic wobble motor for rotating the camera and hands.

In other hand,[4]presented a comprehensive work for moving inside underground urban gas pipelines with a miniature differential-drive in-pipe robot, called the multifunctional robot for in-pipe inspection (MRINSECT) IV. MRINSPECT IV has been developed for the inspection of urban gas pipelines with a nominal 4-in inside diameter.The mechanism for steering with differential-drive wheels, arranged three-dimensionally, allows it to easily adapt to most of the existing configurations of pipelines, as well as providing excellent mobility during navigation. After carrying out analysis for fittings in pipelines, mathematical descriptions of their geometries are presented, which make it possible to estimate the movement patterns of the robot while passing through the fittings. Also, they propose a method of controlling the robot by modulating speeds of driving wheels that is applicable without sophisticated sensory information. To confirm the effectiveness of the proposed method, experiments are performed, and supplementary

considerations on the design of the in-pipe robot are discussed. Further a prototype micro mobile robot [5] is developed in which possesses a pair of fins and moves them symmetrically. The size of the robot is 50 mm in length and 6 mm in width. This robot has many possible applications, such as small pipeline inspections and use in bio medical fields. They utilizing a PZT(Pb(Zr,Ti)O3) as an actuator. A robot driven by a PZT requires a magnification mechanism and the effects of the resonance to enlarge the displacement of the PZT. They proved the effectiveness of the mechanism and the propulsion principle by using a pair of fins both theoretically and experimentally through computer simulations and swimming experiments in fluid. The original robot architecture [6] for in-pipe inspection is presented. Therobot consists of two parts articulated with a universal joint. One part is guided along thepipe by a set of wheels moving parallel to the axis of the pipe, while the other part isforced to follow a helical motion thanks to tilted wheels rotating about the axis of thepipe.Pipe inspection robots have been studied for a long time, and many original locomotion concepts have been proposed to solve thenumerous technical difficulties associated with the change in pipe diameter, curves and energy supply. Researchers [7], [8] showed for small size, many projects follow the earthworm principle consisting of a central partmoving axially while the two end parts are provided with blocking devices connectedtemporarily to the pipe. Pneumatic versions of this concept have been proposed, but they require an umbilical for power. For smaller diameter (10 mm or less), apiezoelectric actuation has been considered, according to the inchworm principle, oraccording to an inertial locomotion driven by a saw-tooth wave voltage, or usingvibrating fins with differential friction coefficients.Some researchers [9], [10] proposed electromechanical systems for medium size piping, withvarious architectures involving wheels and tracks, with more or less complicate kinematical structures, depending on the diameter adaptability and turning capability.The design results from an attempt to reduce the electromechanicalcomplexity [11] through the use of a single actuator to achieve mobility along the tube. Although our studycan be regarded as an independent effort, it appears that the “spiral wheel” strategy was exploredbefore.

The aim of this work is to design and fabricate Pipeline Robot for investigation and monitoring of any crack, leakage, deposition or any malfunction in the oil pipeline. To reduce the inspection time, cost of man power and minimize the potential risk.There are many robots with different features. In this project design of robot is undertaken with an extra features work the remote control of the robot from very far distance and fitted with video camera to take photographs inside the pipeline to identify the faults.

II. Design of Pipeline Robot

The main purpose of this paper is to design a pipeline inspection robot to carryout inspection in the pipelines carrying gas laid over ground and underground.It consists of three main components, firstly the transmitter, secondly the receiver and thirdly the controller board. Transmitter (keypad) work is to transfer the signals; the responsibility of receiver is to receive the signals and the purpose of controller board is to follow the information and according that move the motors. Relay used in the controller board is very important to move the motors, but relay without transistor will not work. So the relay and transistor work together.Building the circuits of transmitter, receiver and controller board are considered first.Firstly the movement of robot, this is achieved by arranging four wheel driven by four motors. To control right movement, the two right side motors of robot connect together and to control left movement, the two left side motors of robot connect together and this is represented in Fig 1.

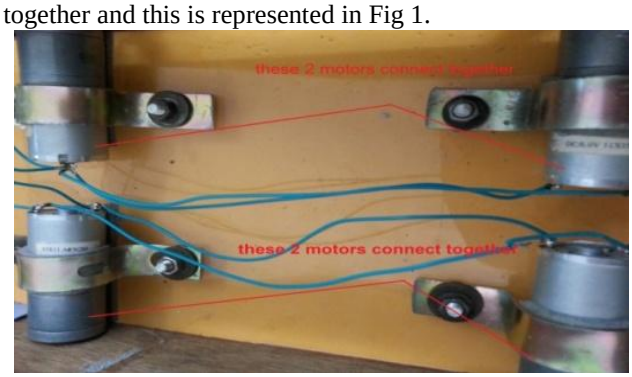

Fig.1. Wire connections for motors for wheel rotation

The front right side of the motor has four wires, two wires connect to the back motor, one connects to the ground, and it is shown in by black wire fitted in the controller board. And last wire to the right side of the board connection is also shown in the same by black wires.

The left front side of the motor has four wires, two wires connect to the back motor, one connects to the ground and it is shown in by red wire fitted in the controller board. And last wire to the left of board connection is also shown in the same figure by red wires. The final connected circuits are shown in Fig 2.

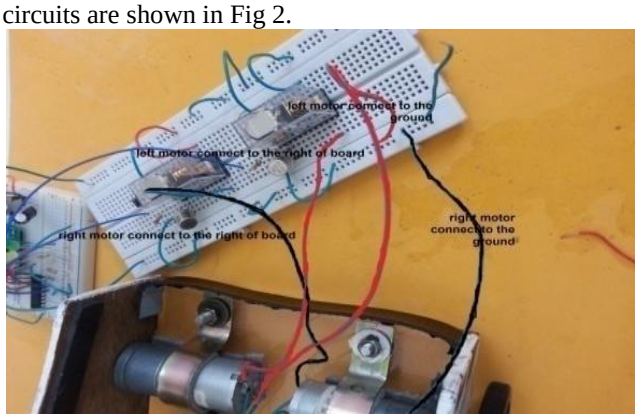

Fig.2. Wire connections of motor to control board

In the controller board it is used the relay to move the motors. The relay work by transistors principles, the KTS418 transmitter [12] which is show in Fig 3 operates at 418MHZ using CW modulation. It has a KES encoder with a programmable access code to control which receiver is activated by its transmission. The encoder is supplied with a default code of 1. A new random access code can be generated by grounding the A terminal for one second. The random access code will be a number from 1 to 1000. The access code will be stored in non-volatile memory and will not be lost when the KTS418 is powered down. The transmitter has four data inputs and can send up to four control data bits individually or in any combination including all four bits simultaneously. In the circuit are made as the left switch by 1, forward switch connected by 2 and right switch to the 3. The battery which is used for operation has 9V input.

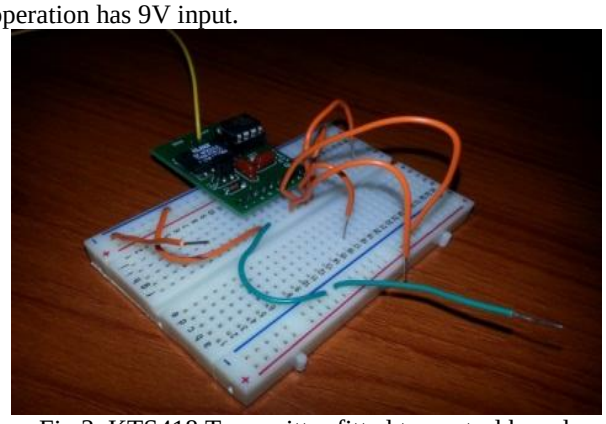

Fig.3. KTS418 Transmitter fitted to control board

All data inputs are internally pulled up to 5 volts through 200 microampere current source. Transmission is starts when one or more transmitter data inputs are grounded to circuit board ground. When not grounded, the data inputs should be allowed to float; they should not be directly driven to a high level. A transmission will continue for as long as a data input is grounded. When no inputs are grounded the KES encoder automatically goes into a low power standby mode where it draws only one microampere. The RF transmitter circuit draws no current when it is not sending data.

The receiver depends on microcontroller device and it is used to receive the signal from keypad and send to controller board. The Receiver circuit show in Fig 4. The resistors connected to RB7, RB6 and RB5 of microcontroller (PIC1 6f628A). Resistors have 1.5k. resistor1 (RB7) connected to the number1 in the chip, RB6 to 2 and RB5 to 3. RB0 choose as right so it is connected by the left side of motors. RB1 choose as left so it is connected by the right side of motors. When moving the left motors and right motors stop, then the robot will move to the right direction.

Serial data received by the receiver circuit IC1 feeds into serial data input pin 4 of the IC2 decoder. The address stored in the decoder memory is compared with the address contained in the received data and if they match, the received data is considered valid and is sent to the decoder output pins.

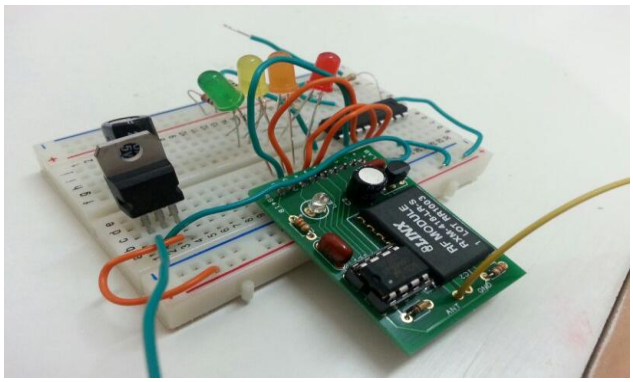

Fig.4. KRS418 Receiver fitted to control board

The KRS418 receiver outputs are low when no signal is being received and each output will go high to +5 volts when a signal is received by grounding a corresponding transmitter input. The decoder outputs are connected to PC board output pad positions 1, 2, 3 and 4. Outputs can both source and sink 25 milliamperes each. An output can directly power a load that draws up to 25 milliamperes at 5 volts when it is high and can sink up to 25 milliamperes from an external 5 volt source when it is low. The KRS418 draws about 6 milliamperes all of the time while waiting for a signal to be received. Current will increase to about 15 milliamperes when a signal is received and the LED lights and might increase more if a load is driven.

The receiver consists of LED to show that the signal is received. Also it has resistor to reduce the current value and protect LED from damage, and the very important piece is microcontroller.The LED on the receiver module will light whenever any valid data is being received and it also indicates the following conditions.

Double blinks fast four times to indicate learn mode has been entered.

Blinks slow three times to indicate that a new address has been learned.

Blinks eight times to indicate that a signal was received but an address match could not be found in memory.

III. MICROCONTROLLER PIC16F628A

The Microcontroller PIC16f628A is small computer containing a process core, memory and programmable. It is very important part which is used to adjust the command and direction by using microcontroller program. It has 16bit each bit has certain number. Firstly it must specify the output and input, then write the code according the bit number. Fig 5 represents the microcontroller pic and the LR series receiver pin out.

PIC16F628A has 5 ports A and 8 ports B determined the input and output ports and chooses the work for each port. In Robot project we choose VCC connect to the ground, RB7 connected to resistor1 (1.5k), RB6 connected to resistor2(1.5k) and RB5 connected to resistor2(1.5k).On other side of microcontroller MCLR connected to the resistor 10k, GND connect to the ground, RB0 connected to the right of controller board and RB1 to the left of the controller board.

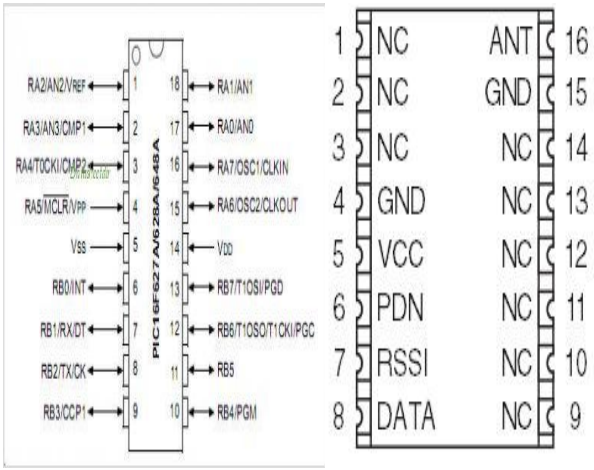

Fig.5. Microcontroller pic and LR series receiver pin out

The port RB0 controlling the robot and it move to the right and port RB1 to the left.Fig 6 shows the microcontroller ports connection and flow chart.

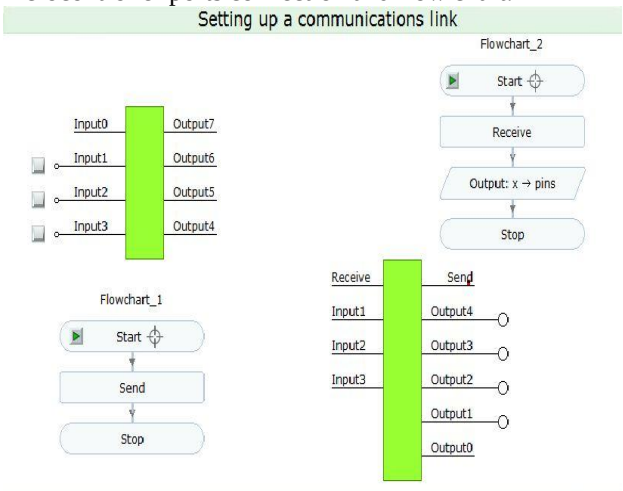

Fig.6. Microcontroller ports connection and Flow chart of PIC

Microcontroller PIC16f628A consists memory unit which is the part from microcontroller to save and storage the data. The memory organizes the information in certain places and each place has specific name. The benefit from put names to be easily recovery the data

Although memory use to write and read the data, so there are lines or bus to identify the type of process whether is read or write process. In addition, there are otherlines.The memory share the information with Central Processing Unit (CPU) according to the type of process, for example if the process is reading only then the data will send from memory to data line after that the CPU will reading it. But if the process writing only then the data will send from the data line and put in its place according to the bit which is identify by CPU. The address data is line has one direction from CPU to memory and not allows sending versa. Where the CPU is send the required data which want to save it. Fig 7 represents the flow charts for both bus and address data.

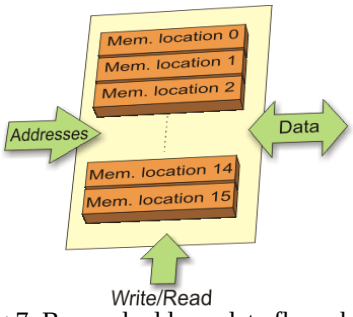

Fig.7. Bus and address data flow chart

Central processing unit is a part from computer that is interprets instructions and processing the data. CPU consider as important device of micro-computer. It is consist of memory, input and output. It is responsible for connecting all the components of the controller in addition to that responsibility for the implementation of logical operation. These CPU get the information from the microcontroller program. The CPU is shown in Fig 8.

Fig.8. Central Processing Unit

Address bus is contains a number of wires sufficient to express the size of memory. For example, if the memory size 64k, then the width of bus will conclude from this equation:

2^n=memory size

2^n=64

So the result will be 8. That is meaning the bus width or the number of wires is 8. Also it is called 8-bit.

The data bus is used to transfer the data from memory to CPU or from CPU to memory. And the control bus is used to send the control signals from CPU to different microcontroller pieces such as read or write command and not allow versa. The system bus flow chart is shown in Fig9.

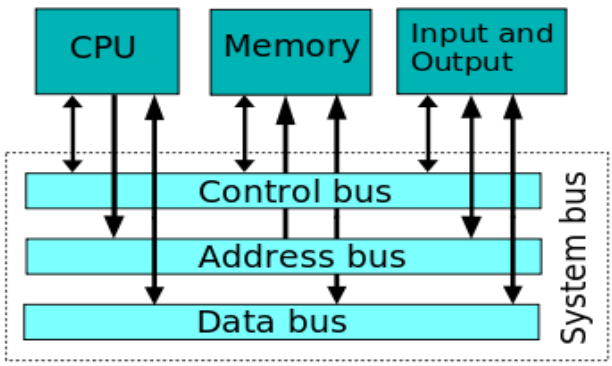

Fig.9. System bus flow chart

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The input-output units are connecting the microcontroller by the outside world which is called ports. The microcontroller program put the data in the ports to other device take it. These data which is other device take from ports is considered as commands. The input and output flow chart is given in Fig 10.

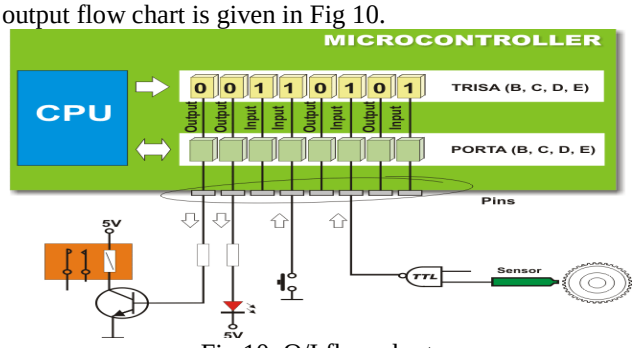

Fig.10. O/I flow chart

Timer unit is in the microcontroller clock to organizing the process which is done by CPU, this clock called in the microcontroller by oscillator. It is responsibility of generate pulses or vibration which is necessary to adjust the synchronization and discipline in the microcontroller through programming (through writing the code)in other meaning it is choose the synchronization which is required when the program doing whether to identify the start point to reach to the end of program. In addition to control the microcontroller speeds. Usually this oscillator give as 4 or 10 to 20MHZ.In Robot project we choose 4MHZ.

Serial communication is the communication method by outside world which allows transferring data in the form of sequential making it to reach to large distance and it is represented in Fig 11.

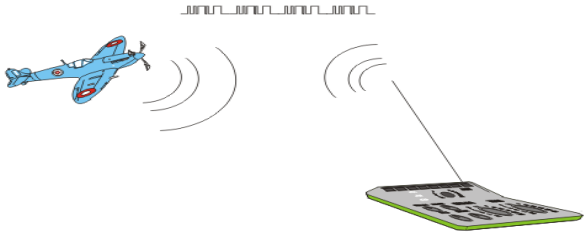

Fig.11. Transfer data to long distance

In normal computers there are restart button which is responsible to restart the computer as a result of stopping for any result. But in the microcontroller this button is not exist. So what is the solution?For that counter is added for writing zero times as a result of completed each step. When the program stops for any reason then it will not writing zero, for that the counter will stop and restart the microcontroller and doing the program again and it is show in Fig 12.

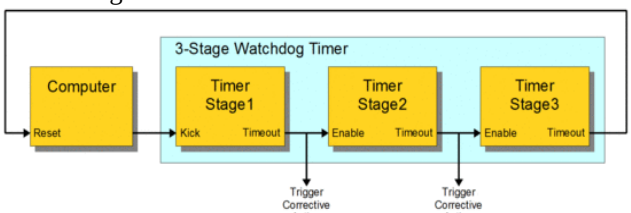

Fig.12. Watchdog flow chart

As we know, the microcontroller work by digital system, but there are some data coming by analog such the different speed for motors or temperature. So it is necessary to convert this data to signals which understands by microcontroller and this unit called ADC.

IV. MICROCONTROLLER PROGRAMMING

In the microcontroller program add code which is as a command for microcontroller device to transfer the command to other device. Fig 13shows the microcontroller program.

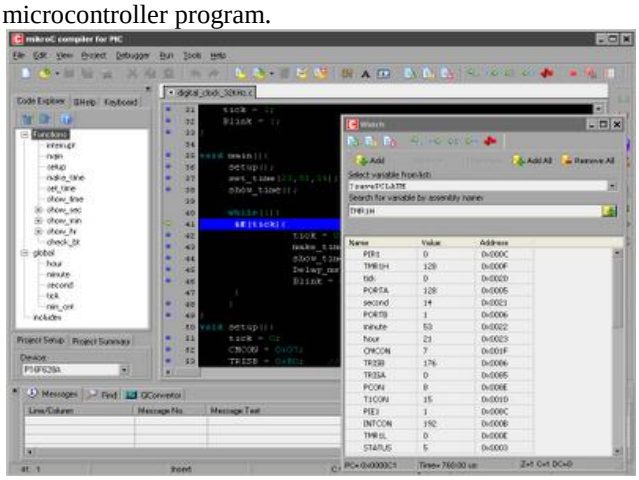

Fig.13. Microcontroller program

After make the circuits, open the microcontroller program and press get started button which is show in Fig 14 number1. It will open new window show in the same fig number2. In that window write the project information, the project name (robot), PIC number (16F628A) and microcontroller speed (4 MHZ).

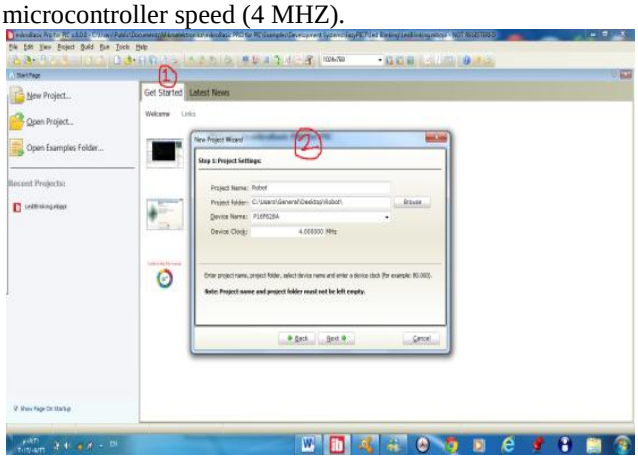

Fig.14. Microcontroller program

After that write the code which is considered the orders of microcontroller to identify trends and orders for robot. Where is that code converted to (.hex file) by build button to microcontroller understand it is show in Fig 15 Microcontroller (pic) which is in the transmitter board put in the programming board to be programmed. Connect the programming board which is show inFig 16 with computer and press programmable button to download the code to microcontroller show inFig 17.

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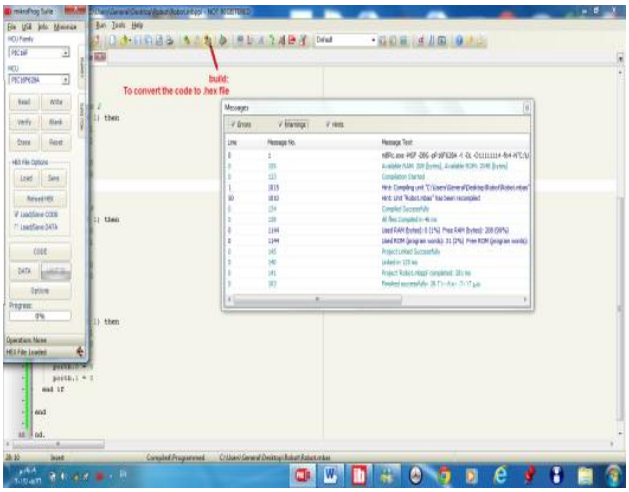

Fig.15. Convertingthe code to .hex file


Fig.16. Connecting the laptop with programming board

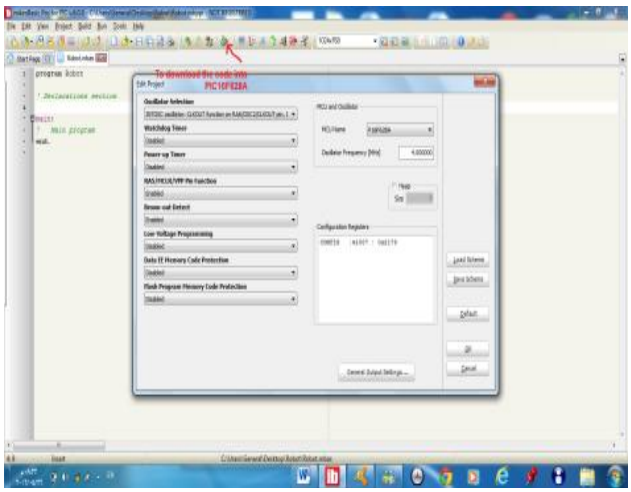
Fig.17. Download the code to PIC.

The concept of this work is microcontroller, the robot work by command from microcontroller. These commands programming by microcontroller program as a code. The **source code** is any collection of computer instruction written using some human-readable computer language usually as text shown in Fig 18.

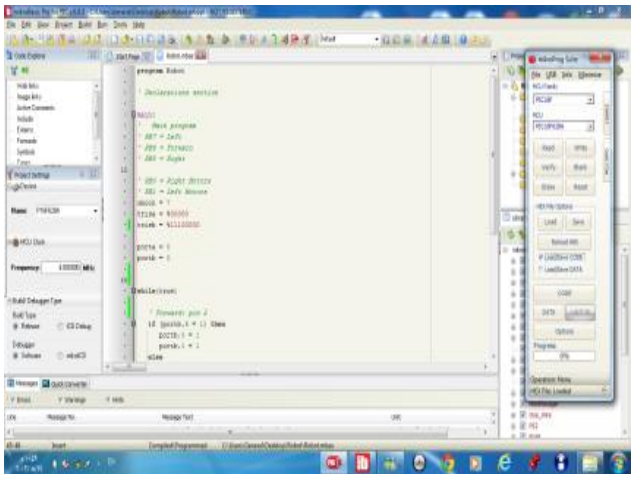
Fig.18. Source code written for control

In this work the camera which we used is mobile phone. We used two phones, in the first phone which will put on the robot and take the information will download in it the IP webcam program as shown in Fig 19and connect the internet from it to the receiver phone. In the camera phone capture will choose (start server) as shown Fig 20.

Fig.19. IP webcam used

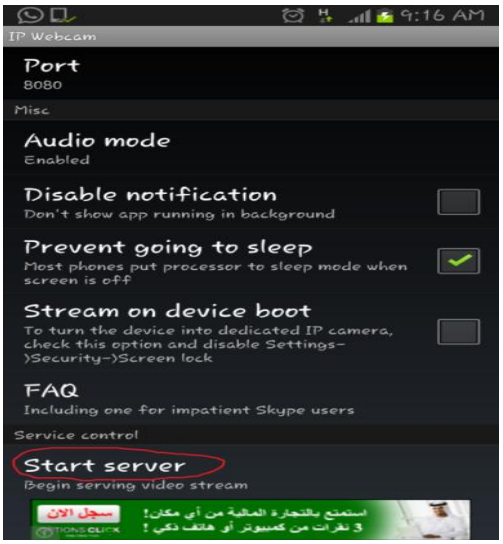

Fig.20. Start server applications

Then, the camera will open and will appear this link of website http://5.37.157.162:8080. In second phone open the internet and enter that link. Will view new window, from that window choose if you want to take photo or video, and it is shown inFig21.

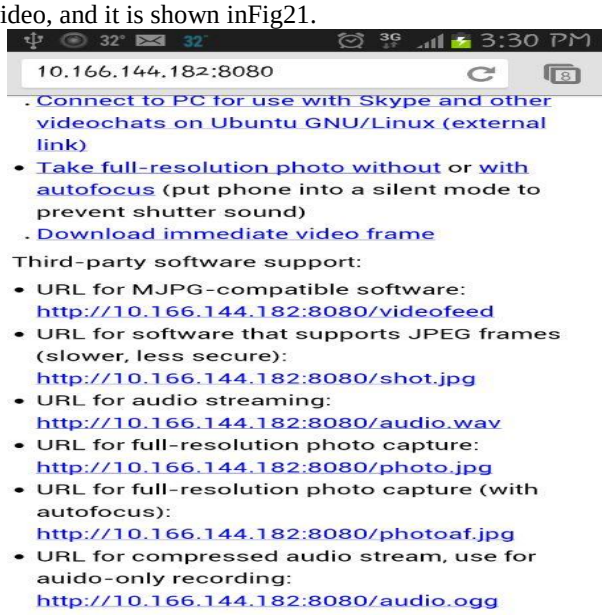

Fig.21. Camera options

IP camera is a camera that sends and receives photo, video and voice through network area. Moreover the idea for working this camera that is by IP (Internet Protocol) address. It is considered as surveillance cameras. Although photos can sends from camera (phone) to laptop, TV or other device. IP camera has many Features for example, this IP is like phone number but the difference is IP is not change but the phone number is change, we can put the camera in anywhere without cables, wires or anything, we can use more than one camera, also we can to use phone camera.The system of working IP camerais as shown in Fig 22.

- The camera turns video & audio into data
- The camera connects to your Network or direct your Router and transmits this data onto the network
- This data can then be viewed as high quality images, and audio on any authorized PC, Mac or Mobile Phone; on the local network, or over the internet
- The Recording Software supplied can be used to record and view up 64 cameras on any compatible Windows PC or Laptop

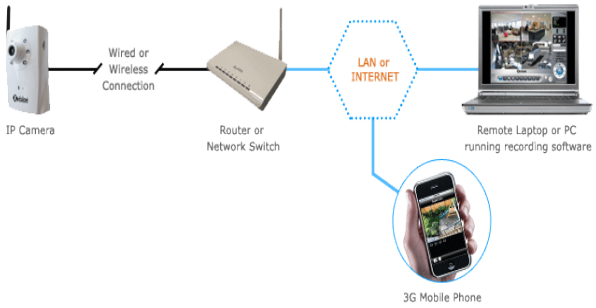

Fig.22. System of working principle of IP camera

V. FABRICATION AND TESTING OF ROBOT

After completion of all design work and selection of components, we started to fabricate the robot. The following figures explain the process of fabrication of robot.

Firstly we drawn the robot shape on the paper, and then according to the paper drawing it is cut in the piece of wood. We choose thin piece of wood in order to facilitate the free movement of robot.

The robot structure looks like a car as show in Fig23. It is having a length of 15 cm and width of 9 cm.

Fig.23. Robot structure made by wood

Then connected four pieces of wood and connecting together, then added 4 motors and fixing it by screws as show in Fig 24.

Fig.24. Robot design fitted with motors

The connected circuit and Controller board with motor is shown in Fig 25.

Fig.25. Insideview of circuit of robot

The final shape including Controller board with motor, transmitter, and receiver and attached with camera is shown in Fig 26 and Fig 27.

Fig.26. Front side of inspection robot

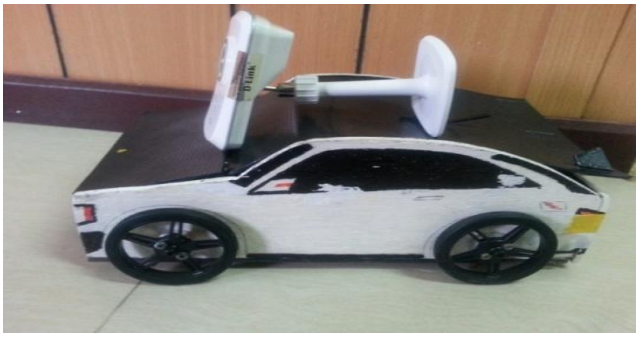

Fig.27. Left side of inspection robot

The Fig 28shows 3D of Robot prepared using Crocodile technology 609 programme software.

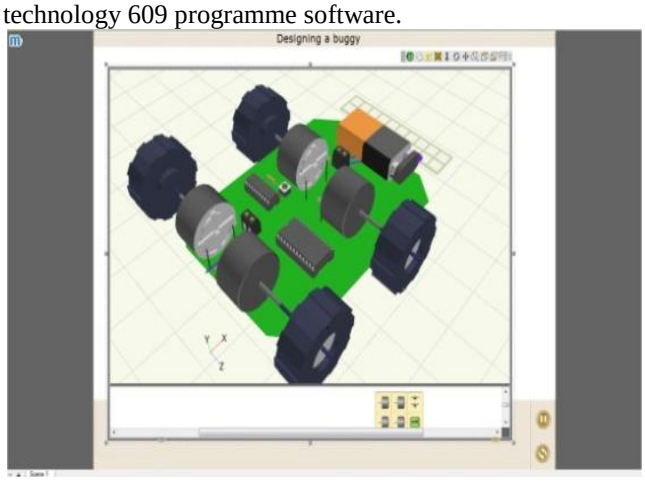

Fig.28. 3D Inspection Robot design

Pipeline inspection robot is used to detect any abnormality inside the pipeline and take pictures of it so we can see if there is a crack, deposit or any malfunction in the pipe. This robot consists of two RF transmitters, RF receiver.

Controller board which is shown in Fig 29 receives the signal from receiver and converts it to movement. ControllerBoard consists of relay which is working to move the motors right, left, reverse and forward. Also it is converting from high voltage to low voltage or vice.

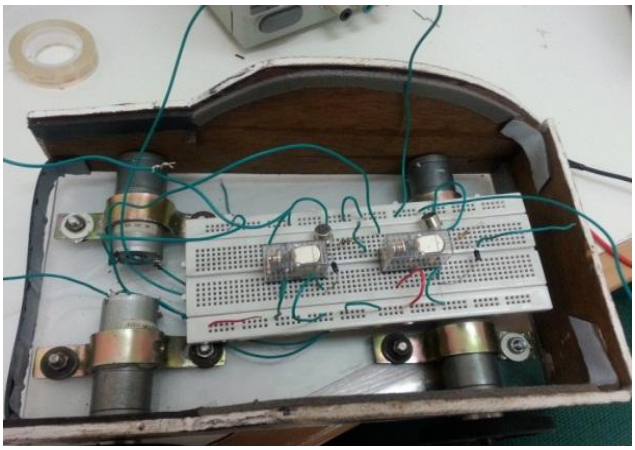

Fig.29. Testing of Controller board for wheel movement

Inspection pipeline robot has four motor, two motor fixed in the front and other two motor in the rear. The positive side of the motor connected together and negative side of the motors connected together. When connect the battery to the positive side of motors and negative side the motor robot will start to move. Moreover need to use the transmitter and receiver to send and receive the signal. Finally write the source code in the microcontroller program.

The design of the robot is looks like a car as shown in Fig 30 consisting of four motors and wireless camera above it. The robot will move by remote control. We can to use phone camera.It will capture and transfers the photo and video by wireless to computer by IP webcam.

Figure 30Prototype robot design

The robot can move inside the pipeline where it is difficult for human, the movement of robot inside the pipeline is controlling by remote. This robot moves straight forward, left direction and right direction according to the direction of pipeline. The pipeline inspection robot checks the pipeline from any crack, deposit, leakage, bending or any abnormality things in the pipes. Above the robot a wireless camera is fitted to take photo, video or voice for the pipeline and transfer the photo directly to laptop by IP webcam. This is will communicate to computer or phone device which is operated. Inside repot there is receiver to receive the signal from transmitter and send to controller board, by relay and the motors will move.

VI. CONCLUSION

The Robots in these days is very common in use. These robots can take the place of human in dangerous area. Inspection and performing the maintenance work in pipeline is very dangerous for human because, the pipeline is very long, narrow and maybe it is because choking. So, the robot will replace the human in doing inspection.

The designed and fabricated Pipeline inspection robot can move forward straight, right direction and left direction and has a wireless camera to monitor the pipeline from any crack, leakage, deposit or any abnormality things. The camera will take the picture of any crack in the pipe and transfer the data to the computer. This data is very useful to monitor the pipe line. The microcontroller (PIC16f628A) which is used is controlled by program to give the robot command. This will reduce the time consuming for work, to reduce the cost of man power and minimize potential risks..

Further improvement can be done in the pipeline inspection robot by adding sensors to avoid collision the walls. Also we can add timer and to measure distance travelled in the pipeline to know the location of crack.

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REFERENCES

[1] Yunwei. Zhang and Guozheng Yan, “In-pipe inspection robot with active pipe-diameter adaptability and automatic tractive force adjusting”, Mechanism and Machine Theory Journals & Magazines, 2007, vol. 42(12), pp. 1618–1631.

[2] Young-Sik Kwon; Byung-Ju Yi, "Design and Motion Planning of a Two-Module Collaborative Indoor Pipeline Inspection Robot," *Robotics, IEEE Transaction*, June 2012, vol.28, no.3, pp.681-696.

[3] K. Suzumori, T. Miyagawa, M. Kimura, and Y. Hasegawa, "Micro inspection robot for 1-in pipes," *Mechatronics, IEEE/ASME Transactions*, Sep 1999, vol.4, no.3, pp.286-292.

[4] Se-gon Roh and Hyouk-Ryeol Choi, "Differential-drive in-pipe robot for moving inside urban gas pipelines," *Robotics, IEEE Transactions*, Feb. 2005, vol.21, no.1, pp.1-17.

[5] T. Fukuda, Kawamoto, Atsushi,F. Arai, and H. Matsuura, "Mechanism and swimming experiment of micro mobile robot in water," *Micro Electro Mechanical Systems, 1994, MEMS '94*, 1994, *Proceedings, IEEE Workshop*, pp.273-278.

[6] C. Anthierens, A. Ciftci, and M. Betemps, "Design of an electro pneumatic micro robot for in-pipe inspection," *Proceedings of the IEEE International Symposium on Industrial Electronics, ISIE '99*, Kitakyushu, Japan1999, vol.2, no., pp. 968-972.

[7] H. Nishikawa, T. Sasaya, T. Shibata, T. Kaneko, N. Mitumoto, S. Kawakita and N. Kawahara, "In-pipe wireless micro locomotive system," *Proceedings of International Symposium on Micromechatronics and Human Science, 1999. MHS '99*,Nagoya, Japan,1999, pp.141-147.

[8] S. Aoshima, T. Tsujimura, and T.Yabuta, “A Miniature Mobile Robot using Piezo Vibration for Mobility in a Thin Tube”, *ASME Journal of Dynamic Systems, Measurement, and Control*, June 1993, vol.115, pp. 270-278.

[9] Shigeo Hirose, Hidetaka Ohno, Takeo Mitsui, Kiichi Suyama, “Design of In-Pipe Inspection Vehicles for ø25, ø 50, ø150 Pipes”,*Journal of Robotics and Mechatronics* 12, 3, pp. 310-317.

[10] F. Pfeiffer and T. Rossmann, “Control of a Tube Crawler,” *Proceedings of the Fourth InternationalConference on Motion and Vibration Control, 1998*, Vol. 3, pp. 889-894.

[11] JGC Corporation, “Inspection Robots in Nuclear Power Plants” *Robotics in Nuclear Facilities,”* Special issue for the exhibition of the 11th *International Conference on Structural Mechanics in ReactorTechnology (SMIRT II)*, 1991,Tokyo.

[12] Glolab Corporation, “Electronic Kit Manual”, 307 Pine Ridge Drive, Wappingers Falls, New York, USA.

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