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Bridge Monitoring System

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Abstract: *Bridge monitoring system is significant to health diagnosis of bridges and flyovers. This report is proposed and developed a novel architecture for large span bridge monitoring. A 3-level distributed structure is adopted in the monitoring system, which includes central server, intelligent acquisition node and local controller. Acquisition nodes are located across the bridge. One local controller manages all the acquisition nodes. Every acquisition node has 8 channels, which can sample displacement, acceleration and strain of bridge. To get high precision data, a 10 bits A/D converter. Compare to the traditional method, the proposed architecture has two features. First, the acquisition node is a smart device based on powerful DSP processor. Signals of field sensors are analyzed and real time compressed in the acquisition node. Only the processing results are sent to local controller through IEEE 802.11 wireless network. This operation can relieve load of central server and decrease demand of communication bandwidth. Second, 2G wireless network is utilized to provide enough bandwidth for real-time data transmission between local controller and central server. The intelligent monitoring system has run on a large span bridge for six months. Running results show that the proposed system is stable and effective.*

1. INTRODUCTION

Bridges and flyovers are critical in many regions, being used over several decades. It is critical to have a system to monitor the health of these bridges and report when and where maintenance operations are needed. Advancements in sensor technology have brought the automated real-time bridge health monitoring system. Many long span bridges in Korea and in Japan have adopted this real-time health monitoring system. However, current system uses complicated and high cost wired network amongst sensors in the bridge and high cost optical cable between the bridge and the management centre, which increases the overall cost of installation and maintenance cost of health monitoring system. The complicated wiring also makes the installation and repair/replacement process difficult and expensive.

In this project an idea of bridge health monitoring system using wireless is proposed. For short distance (among sensors in the bridge) IEEE 802.11 wireless communication, Zigbee is used as wireless network, and GSM is used for long distance (between the bridge and the management centre) data communication. This technology can be called MBM (Monitoring Based Maintenance) that enables the bridge maintenance engineers monitor the condition of the bridge in real time. The sensors installed on various parts of the bridge monitors the bend, traffic, weight of the vehicles etc. At any point of time if any of these parameters cross their threshold value the communication system informs the management centre giving an alarm for taking precautionary measures. The complete parameters of the bridge are taken by an ARM processor and sent to another module which is located in a short distance. Here the communication established is using Zigbee that uses wireless transmitter and receiver circuitry. The receiver module takes the parameters from the transmitter and sends a message with all the parameters to a database centre. The communication established between the intermediate module and the database centre is using GSM technology.

Fig 1: *The Humber Suspension Bridge*

2. LITERATURE SURVEY

[1] Roger W. Lockhart is vice president of DATAQ Instruments, “http://www.dataq.com/applicat/ articles/ bridge-structural-monitoring.html”

The collapse of the I-35W Mississippi River Bridge in Minneapolis, Minnesota on August 1, 2007 was a calamity of huge proportion. Carrying over 135,000 vehicles daily, the bridge failed during the evening rush hour resulting in thirteen fatalities and 145 injuries. Almost immediately plans were formulated for a replacement bridge, which subsequently opened on September 18, 2008. But unlike its ill-fated predecessor the new I-35W Saint Anthony Falls Bridge is designed with an integral state-of-the-art monitoring system that continuously assesses bridge integrity to ensure that a catastrophic failure will not repeat.

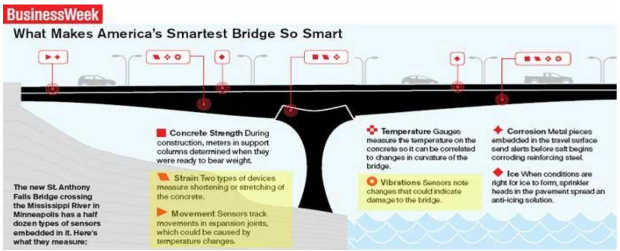


Fig 2: *New I-35W Saint Antony Falls Bridge*

[2] Peter FURTNER, Danilo DELLA CA', Chinmoy GOSH, "Structural Health Monitoring of Signature Bridge in Delhi - the Bridge - Structural - Health - Monitoring - System for the Wazirabad Bridge Project", http://www.brimos.com/Brimos/HTML/downloads/2013/Fullpaper_Furtner_2013.pdf

A new cable-stayed bridge is currently under construction across the River Yamuna in Wazirabad, Delhi. The bridge will have a total length of 675 m, with a main span of 251 m. Its steel-concrete composite deck, with a total width of 35.20 m, will carry four lanes of traffic in each direction. Its dramatic inclined steel pylon, with a height of 154 metres, and elegant stay cable design, will make it a particularly attractive and imposing addition to the Wazirabad skyline.

The bridge will be equipped with a sophisticated structural health monitoring system, supplied by a joint venture of Mageba India, Mageba Switzerland and Vienna Consulting Engineers.

The paper describes the purpose of the system and the requirements it will fulfil, and presents the general system layout, a description of the equipment and the technical solution for data transfer. A special focus is given to the subject of data management, which includes the archiving, analysis and presentation of the recorded data. In addition to the compulsory control room devices, the system will include a user interface which allows secure internet access to the monitoring data and results, from any location at any time.

[3] Client of NTT Data, Implementation of bridge monitoring system in Vietnam

With Japan facing the recent social infrastructure issue of aging infrastructure, NTT DATA developed a solution which remotely monitors bridges in real time to provide valuable information for maintaining bridge structures, and estimating the extent of structural fatigue.

NTT DATA helped the company by implementing the bridge monitoring system- BRIMOS with the support of ODA (Official Development Assistance) and successfully took the first step to expanding market share in South-East Asia.

Challenge:

The Cau Can Tho Bridge is a newly constructed bridge built over the Mekong Delta basin where the foundation is naturally very soft. The client was concerned about the possibility of adverse influences of ground subsidence on the bridge's foundations (such as unexpected large-scale deformation).

The bridge is used by a particularly high number of large vehicles carrying unusually heavy cargo as the logistics industry in vetnam that is still under development.

[4] Gethin Roberts , Xiaolin Meng , Michele Meo , Alan Dodson , Emily Cosser , Emanuela Iuliano, Alan Morris (2003), A REMOTE BRIDGE HEALTH MONITORING SYSTEM USING COMPUTATIONAL SIMULATION AND GPS SENSOR DATA.

The grant, entitled "A Remote Bridge Health Monitoring System Using Computational Simulation and GPS Sensor Data" is collaborative effort with Cranfield University, Railtrack, W S Atkins and Pell Freischman. The work expands and carries forward previous work started at the University of Nottingham in 1994. The work focuses on using kinematic GPS to create and validate finite element models of bridges, allowing the deflections and vibrations of the structures to be analysed for any uncharacteristic movements.

The paper details the progress of the work to date, including the way in which the field data gathered and analyzed by the Nottingham group is used by the Cranfield Group in order to assess the quality of structures. In addition, the use of a Cyrax laser scanner to create a finite element model of a bridge is discussed.

[5] Chae M.J.,Yo H.S., Kim J.R, Cho M.Y, 2006, Bridge Condition monitoring system using wireless network (Cdma And Zigbee)

In bridge health monitoring system, sensors and ZigBee modules are combined to be ubiquitous-node (u-node,) which are installed on the members of bridges and sends data to the u-gateway (ubiquitous gateway) that sends data to themanagement center wirelessly over CDMA technology. Based on the currently installed sensors on Yong-Jong Bridge, total 66 locations were carefully selected for four types of sensors.

[6] Ignacio González, Licentiate Thesis in Structural Engineering and Bridges Stockholm, Sweden 2011, Study and Application of Modern Bridge Monitoring Techniques

Railway and highway bridges are an important part of the transport infrastructure. They represent a major investment for society and an important part of that investment goes to inspection and maintenance. Bridges often constitute bottlenecks in the transport system with few practical alternative routes. As such, closing them for repair, inspection or replacement entails large costs for the users. Furthermore, safety levels in bridges are expected to be higher than in other parts of the transport system. This comes naturally due to the fact that failure of a bridge could have severe consequences in material damage and human lives. Introducing monitoring techniques in its different forms (damage detection, traffic monitoring, reliability assessment, etc.) can save costs by improving the understanding of the structure, thus reducing the need of overly safe assumptions and by granting the possibility to get early warnings of problems that develop.

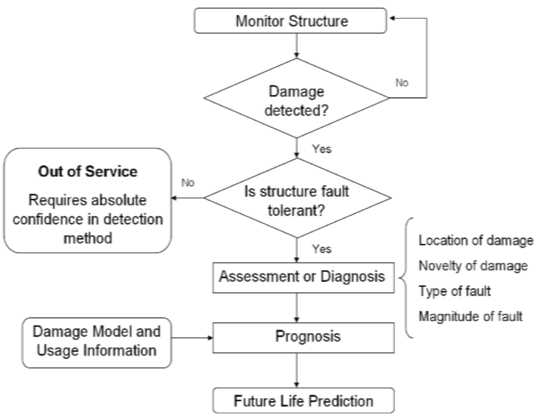


Fig 3: *A flow chart depicted for SHM system*

[7] A Bridge Health Monitoring System Based on NI Hardware and Software

Based on NI data acquisition hardware and related software, bridge health monitoring system has been set up. This system not only meets the functionality requirements of the monitoring task, but also endures the severe environmental conditions that a bridge usually faces. This article discusses the fundamentals of structure health monitoring (SHM) and describes how the Shanghai JUST ONE Technology company implements SHM on the Donghai Bridge, China's first sea-crossing bridge.

The wide geographical area that the bridge occupies separates the sensors with long inter-distances. Thus, the real-time requirements inherent with many of the measuring items call for certain advanced synchronization technique, one that works over a large geographical area. The traditional method by sharing sample clock signal via coaxial cables is no longer feasible. Global Positioning System (GPS) time synchronization, which requires no direct connection between the measurement subsystems, is ideal for this situation.

Situated into China East Sea, Donghai Bridge has to endure the erosion of the seawater, the impact of typhoons and earthquakes, and the gradual damages caused by the traffics on the bridge. So the measuring system must work under hostile environmental conditions with endurance. Also, because the monitoring is a long-term activity, the measuring system should be extremely reliable with minimum maintenance. These requirements are imposed on the whole measurement and data acquisition system.

Fig 4: *Donghai Bridge, Shanghai*

[8] "Structural Monitoring: Making Bridges Safer Across the United States" (2008), Motorola Solutions

Bridge structures are key elements of the U.S. roadway system and vital assets for the nation's economy and security. Their functioning is critical, but opportunities for failure are many, including deteriorating materials, underlying construction issues and improper load ratings. At any given point in time, bridges may also be threatened by natural disaster, man-made events, defective materials or simply by long-term "wear and tear." Today, continuous structural health monitoring solutions that combine embedded sensor systems with wireless communications networks are helping to identify potentially dangerous structures, and to pinpoint conditions that can be repaired well before a bridge fails.

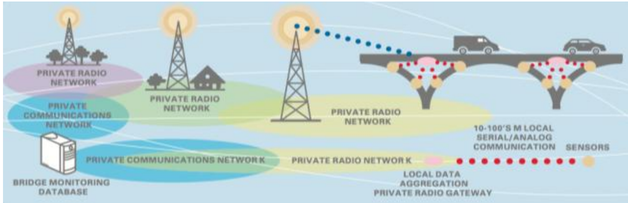


Fig 5: *Private Communication in the proposed model*

3. PROBLEM DEFINITION

Flyovers and highway bridge systems are critical in many regions, being used over several decades. It is critical to have a system to monitor the health of these bridges and report when and where maintenance operations are needed. Advancements in sensor technology have brought the automated real-time bridge health monitoring system. However, current system uses complicated and high cost wired network amongst sensors in the bridge and high cost optical cable between the bridge and the management centre. The complicated wiring also makes the installation and repair/replacement process difficult and expensive.

In this project an idea of bridge monitoring system using wireless is proposed. For short distance (among sensors in the bridge) Zigbee is used as wireless network, and GSM is used for long distance (between the bridge and the management centre) data communication. This technology can be called MBM (Monitoring Based Maintenance) that enables the bridge maintenance engineers monitor the condition of the bridge in real time. The sensors installed on various parts of the bridge monitors the bend, traffic, weight of the vehicles etc. At any point of time if any of these parameters cross their threshold value the communication system informs the management centre giving an alarm for taking precautionary measures.

The main objective of our project is to

- Monitor the traffic in the bridge.
- Monitor the load in the bridge.
- Indicates when there are earthquakes, cracks and bending in the bridges.

4. PROJECT OBJECTIVES

- Design of Bridge monitoring system.
- Analysis of bends, cracks and loads are done.
- Implementation of IR sensor, Load sensor, Flex sensor, Vibrator sensor, stepper motor. IR sensor detects the vehicles that enter the bridge and keeps count of the number of vehicles on the bridge. Load sensor detects the load on the bridge. Flex sensor detects the cracks and bending. Vibrator sensor detects extreme vibration on the bridge. Stepper motor acts as the gate in our bridge monitoring system
- We set up the test bed.

5. PROJECT DELIVERABLES

- Algorithm for monitoring the bridge
- Hardware of all the sensors.
- Software for burning the code on the chip.
- Firmware Development is been carried out.
- Code for all sensors and monitoring the bridge.
- User Manual for ARM 7 (LPC2148), GSM, and Zigbee were referred.

6. DESIGN

6.1. System Block Diagram

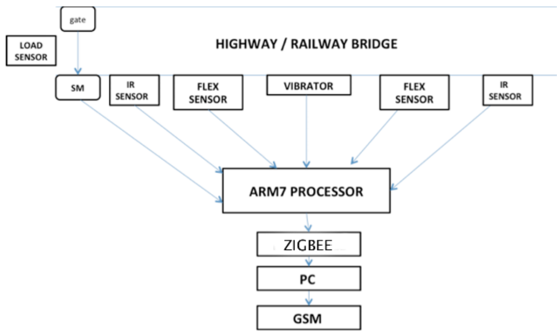


Fig 6: *System Block Diagram*

6.2. Block Diagrams

The sensors are installed on various parts of the bridge as shown in the above system block diagram, monitors the bend, traffic, weight of the vehicles etc. At any point of time if any of these parameters cross their threshold value the communication system informs the management centre giving an alarm for taking precautionary measures. The complete parameters of the bridge are taken by a ARM microcontroller and sent to another module which is located in a short distance. Here the communication established is using Zigbee that uses wireless Transmitter and Receiver circuitry. The receiver module takes the parameters from the transmitter and sends a message with all the parameters to a database centre. The communication established between the intermediate module and the database centre is using GSM technology. The sensory inputs are process to represent the condition of the bridge against seismic loads, loads etc.

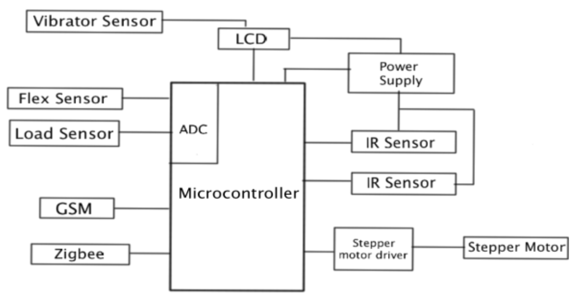


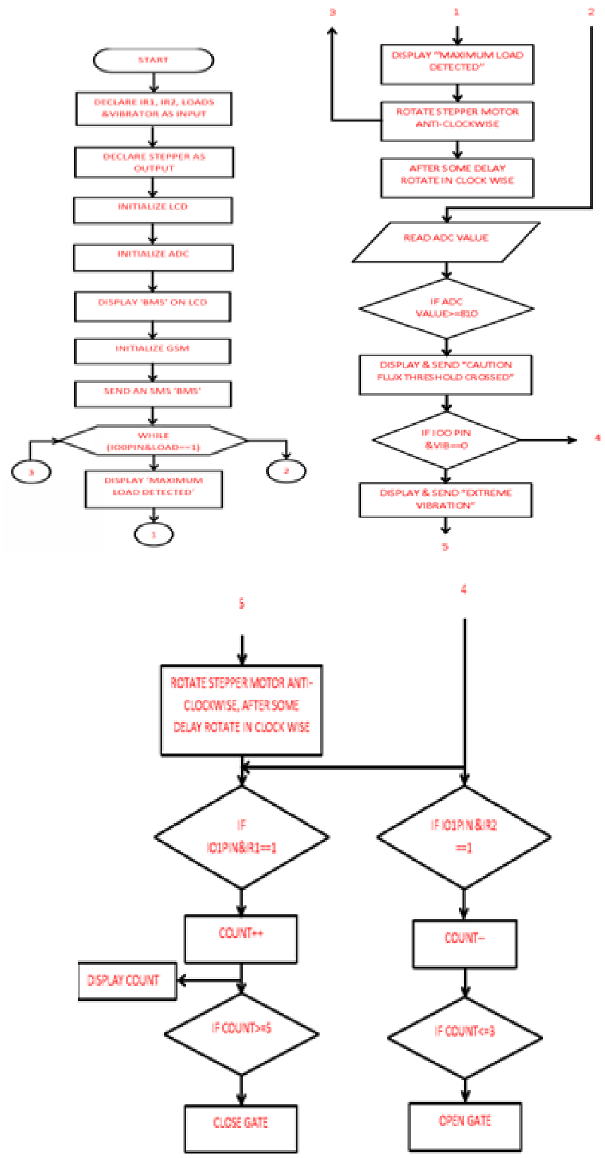
Fig 7: *Interfacing of sensor with the microcontroller*

The receiver module takes the parameters from the transmitter and sends a message with all the parameters to a database centre. The communication established between the intermediate module and the database centre is using GSM technology.

6.3. Algorithmic Details

- Declare the variables IR1, IR2, Loads and Vibrator as input.
- Declare stepper as output.
- Initialize LCD, ADC. Display Bridge Monitoring System.
- Initialize GSM and send sms as BMS.
- If maximum load is detected then display maximum load detected and stepper motor should rotate anti clockwise.
- If the flex sensor reaches the maximum threshold then display earthquake happening and send message to monitor house. The gate is closed and opened once we get message from the monitor house.
- If the load sensor senses the maximum load then the gate is closed.
- The IR sensor keeps count of the number of vehicles that enter the bridge and the count value is incremented.
- If the count of the vehicle increases the threshold then the gate is closed and the gate is opened once the vehicles are out of the bridge. The count is also decremented.
- The condition of the bridge is constantly displayed on the LCD.

6.5. Control Flow Diagram



6.6. Hardware Design

This chapter explains the concept and working of every component used in the project. First let us look at the various sensors used in the system. Then we will look at ARM processor which is used to program all the sensors and the stepper motor (for closing/opening the gate).Then we will look at the wireless transmission of data to database centre using GSM which is the most important aspect of this project.

6.6.1 IR sensor

The IR Sensor-Single is a general-purpose proximity sensor. Here we use it for collision detection. The module consists of a IR emitter and IR receiver pair. The high precision IR receiver always detects a IR signal. The module consists of 358 comparator IC. The output of sensors high whenever it IR frequency and low otherwise. The on-board LED indicator helps user to check status of the sensor without using any additional hardware. The power consumption of this module is low. It gives a digital output.

Application Ideas:

- Obstacle detection
- Shaft encoder
- Fixed frequency detection

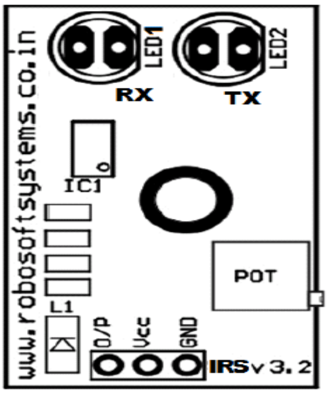


Fig 8: *IC of IR sensor*

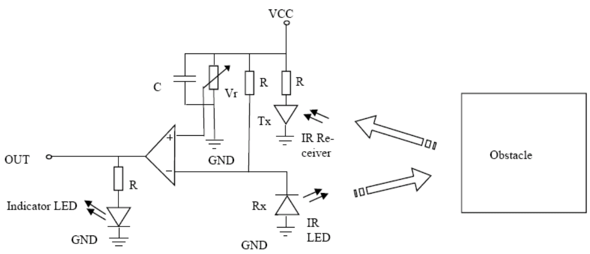


Fig 9: *Block Diagram of IR sensor*

Overview of Schematic

The sensitivity of the IR Sensor is tuned using the potentiometer. The potentiometer is tunable in both the directions. Initially tune the potentiometer in clockwise direction such that the indicator LED starts glowing. Once that is achieved, turn the potentiometer just enough in anti-clockwise direction to turn off the Indicator LED. At this point the sensitivity of the receiver is maximum. Thus, its sensing distance is maximum at this point. If the sensing distance (i.e., Sensitivity) of the receiver is needed to be reduced, then one can tune the potentiometer in the anti-clockwise direction from this point.

Further, if the orientation of both Tx and Rx LED's is parallel to each other, such that both are facing outwards, then their sensitivity maximum. If they are moved away from each other, such that they are inclined to each other at their soldered end, then their sensitivity reduces.

Tuned sensitivity of the sensors is limited to the surroundings. Once tuned for a particular surrounding, they will work perfectly until the IR illumination conditions of that region nearly constant. For example, if the potentiometers tuned inside room/building for maximum sensitivity and then taken out in open sunlight, it will require retuning, since sun's rays also contain Infrared (IR) frequencies, thus acting as an IR source (transmitter). This will disturb the receiver's sensing capacity. Hence it needs to be returned to work perfectly in the new surroundings.

The output of IR receiver goes low when it receives IR signal. Hence the output pin is normally low because though the IR LED is continuously transmitting, due to no obstacle, nothing is reflected back to the IR receiver. The indication LED is off. When an obstacle is encountered, the output of IR receiver goes low; IR signal is reflected from the obstacle surface. This drives the output of the comparator low. This output is connected to the cathode of the LED, which then turns ON.

6.6.2. Vibration sensor

Product Description

This sensor buffers a piezoelectric transducer. As the transducer is displaced from the mechanical neutral axis, bending creates strain within the piezoelectric element and generates voltages.

Specifications

The Vibration Sensor Detector is designed for the security practice When Vibration Sensor Alarm recognizes movement or vibration, it sends a signal to either control panel Developed a new type of Omni-directional high sensitivity Security Vibration Detector with Omni-directional detection.

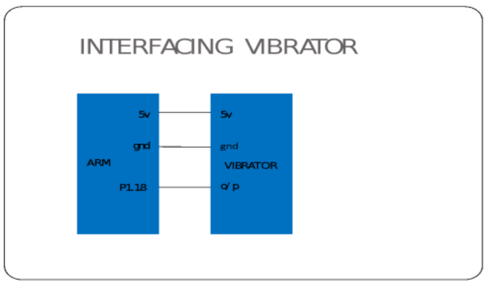


Fig 3: *Interfacing Vibrator Sensor*

6.6.3. Load sensor

A load cell is a "load transducer" which converts the weight or load acting on it into electrical signals. A load cell is composed of an aluminum alloy spring element, strain gauges (serving as sensors) and a bridge circuit. The strain gauges themselves are bonded onto four areas, which become considerably distorted in the spring element. The load cell detects the force of the distortion as voltage change.

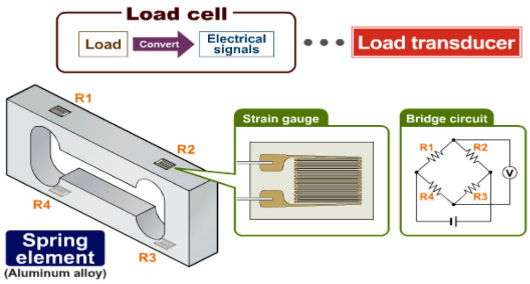


Fig 11: *Spring action in Load Sensor*

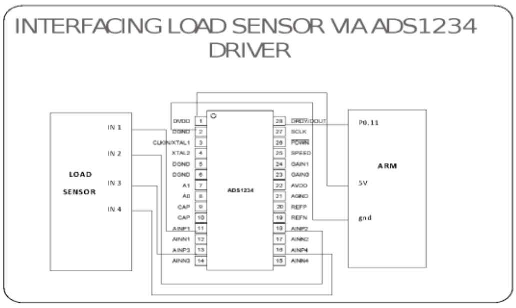


Fig 12: *Interfacing of Load Sensor*

6.6.4. Flex sensor

Flex sensors are sensors that change in resistance depending on the amount of bend on the sensor. They convert the change in bend to electrical resistance - the more the bend, the more the resistance value. They are usually in the form of a thin strip from 1" -5" long that vary in resistance.

Flex sensors are Analog resistors. They work as variable Analog voltage dividers. Inside the flex sensor are carbon sensitive elements within a thin flexible substrate, more carbon means less resistance. When the substrate is bent the sensor produces a resistance output relative to the bend radius.

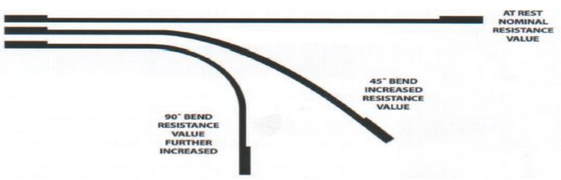


Fig 13: *Working of Flex Sensor*

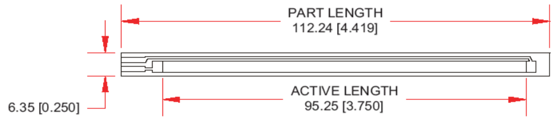


Fig 14: *Dimensional diagram of flex sensor*

Features:

- Angle Displacement Measurement
- Bends and Flexes physically with motion device
- Possible Uses
- Robotics
- Gaming (Virtual Motion)
- Medical Devices
- Computer Peripherals
- Musical Instruments
- Physical Therapy
- Simple Construction
- Low Profile

Mechanical Specifications

- Life Cycle: >1 million
- Height: 0.43mm (0.017")
- Temperature Range: -35°C to +80°C

Electrical specifications

- Flat Resistance: 10K Ohms
- Resistance Tolerance: ±30%
- Bend Resistance Range: 60K to 110K Ohms
- Power Rating: 0.50 Watts continuous. 1 Watt Peak

Fabrication of flex sensor:

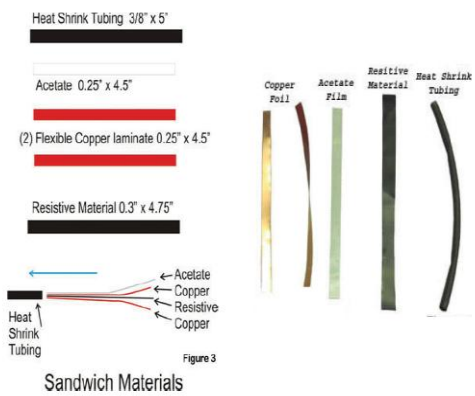


Fig 15: *Fabrication of Flex Sensor*

6.6.5. Stepper motor

Stepper motors fill a unique niche in the motor control world. These motors are commonly used in measurement and control applications. Sample applications include ink jet printers, CNC machines and volumetric pumps. Several features common to all stepper motors make them ideally suited for these types of applications.

These features are as follows:

1. **Brushless** – Stepper motors are brushless. The commutator and brushes of conventional motors are some of the most failure-prone components, and they create electrical arcs that are undesirable or dangerous in some environments.

2. **Load Independent** – Stepper motors will turn at a set speed regardless of load as long as the load does not exceed the torque rating for the motor.

3. **Open Loop Positioning** – Stepper motors move in quantified increments or steps. As long as the motor runs within its torque specification, the position of the shaft is known at all times without the need for a feedback mechanism.

4. **Holding Torque** – Stepper motors are able to hold the shaft stationary.

5. **Excellent response** to start-up, stopping and reverse.

Stepper Motor Theory of Operation:

Stepper motors provide a means for precise positioning and speed control without the use of feedback sensors. The basic operation of a stepper motor allows the shaft to move a precise number of degrees each time a pulse of electricity is sent to the motor. Since the shaft of the motor moves only the number of degrees that it was designed for when each pulse is delivered, you can control the pulses that are sent and control the positioning and speed. The rotor of the motor produces torque from the interaction between the magnetic field in the stator and rotor. The strength of the magnetic fields is proportional to the amount of current sent to the stator and the number of turns in the windings.

The stepper motor uses the theory of operation for magnets to make the motor shaft turn a precise distance when a pulse of electricity is provided. You learned previously that like poles of a magnet repel and unlike poles attract. Figure 1 shows a typical cross-sectional view of the rotor and stator of a stepper motor. From this diagram you can see that the stator (stationary winding) has eight poles, and the rotor has six poles(three complete magnets). The rotor will require 24 pulses of electricity to move the 24 steps to make one complete revolution. Another way to say this is that the rotor will move precisely 15° for each pulse of electricity that the motor receives. The number of degrees the rotor will turn when a pulse of electricity is delivered to the motor can be calculated by dividing the number of degrees in one revolution of the shaft (360°) by the number of poles (north and south) in the rotor. In this stepper motor 360° is divided by 24 to get 15°. When no power is applied to the motor, the residual magnetism in the rotor magnets will cause the rotor to detent or align one set of its magnetic poles with the magnetic poles of one of the stator magnets. This means that the rotor will have 24 possible detent positions. When the rotor is in a detent position, it will have enough magnetic force to keep the shaft from moving to the next position. This is what makes the rotor feel like it is clicking from one position to the next as you rotate the rotor by hand with no power applied.

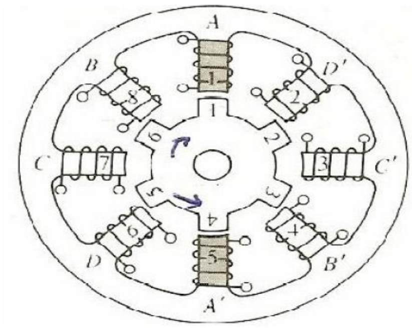


Fig 16: *Working of Stepper Motor*

When power is applied, it is directed to only one of the stator pairs of windings, which will cause that winding pair to become a magnet. One of the coils for the pair will become the North Pole, and the other will become the South Pole. When this occurs, the stator coil that is the North Pole will attract the closest rotor tooth that has the opposite polarity, and the stator coil that is the South Pole will attract the closest rotor tooth that has the opposite polarity. When current is flowing through these poles, the rotor will now have a much stronger attraction to the stator winding, and the increased torque is called holding torque.

By changing the current flow to the next stator winding, the magnetic field will be changed 45°. The rotor will only move 15° before its magnetic fields will again align with the change in the stator field. The magnetic field in the stator is continually changed as the rotor moves through the 24 steps to move a total of 360°.

6.6.6. Zigbee

Fig 17: *Zigbee Module*

CC2500 ZIGBEE Module is a transceiver module, which provides easy to use ZIGBEE communication at 2.4Ghz. It can be used to transmit and receive data at 9600-baud rates from any standard CMOS/TTL source. This module is a direct line in replacement for your serial communication it requires no extra hardware and no extra coding tot works in Half Duplex mode i.e. it provides communication in both directions, but only one direction at same time

Features:

- Supports Multiple Baud rates (9600)
- Works on ISM band (2.4 GHz)
- No complex wireless connection software or intimate knowledge of ZIGBEE is required to connect our serial devices.
- Designed to be as easy to use as cables.
- No external Antenna required.
- Plug and play device.
- Works on 5 DC supply.

6.6.7. ARM 7 processor

Fig 18: *LPC2148 controller board (with ARM 7 processor)*

ARM Board-LPC214X is a breakout board for LPC2148 ARM7TMDI based microcontroller. The LPC2148 microcontroller has 512KB of internal flash and 32+8K RAM. Following are the salient features of the board.

- Two layer PCB (FR-4 material)
- Power: USB powered
- ISP and reset switch
- Test LED
- 32Khz crystal for RTC
- Connectors:

Extension headers for all microcontroller pins

1 RS232 connector for ISP

USB B-type connector with Link-LED

20pin - JTAG connector

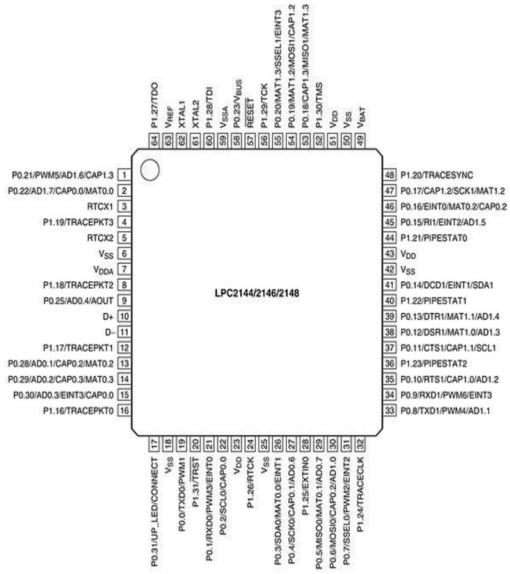


Fig 19: *Pin Diagram of ARM7 processor*

6.6.7.1. Features

- 16-bit/32-bit ARM7TDMI-S microcontroller in a tiny LQFP64 package.
- 8kB to 40kB of on-chip static RAM and 32kB to 512kB of on-chip flash memory.
- 128-bit wide interface/accelerator enables high-speed 60 MHz operation.
- USB 2.0 Full-speed compliant device controller with 2kB of endpoint RAM. In addition, the LPC2146/48 provides 8kB of on-chip RAM accessible to USB by DMA.
- One or two (LPC2141/42 vs. LPC2144/46/48) 10-bit ADCs provide a total of
- 6/14 analog inputs, with conversion times as low as 2.44us per channel.

- Single 10-bit DAC provides variable analog output (LPC2142/44/46/48 only).
- Up to 45 of 5 V tolerant fast general purpose I/O pins in a tiny LQFP64 package,.
- Up to 21 external interrupt pins available.
- 60 MHz maximum CPU clock available from programmable on-chip PLL with settling time of 100us.
- On-chip integrated oscillator operates with an external crystal from 1 MHz to 25 MHz
- Power saving modes includes Idle and Power-down.
- CPU operating voltage range of 3.0 V to 3.6 V (3.3 V ± 10 %) with 5 V
- Tolerant I/O pads.

6.6.7.2. On-chip flash memory

The LPC2148 incorporate a 512kB flash memory system respectively. This memory may be used for both code and data storage. Programming of the flash memory may be accomplished in several ways. It may be programmed In System via the serial port. The application program may also erase and/or program the flash while the application is running, allowing a great degree of flexibility for data storage field firmware upgrades, etc. Due to the architectural solution chosen for an on-chip boot loader, flash memory available for user's code on LPC2148 is 500kB respectively. The LPC2148 flash memory provides a minimum of 100,000 erase/write cycles and 20 years of data-retention.

6.6.7.3. On-Chip static RAM

On-chip static RAM may be used for code and/or data storage. The SRAM may be accessed as 32-bit. The LPC2148 provide 32kB of static RAM. An 8kB SRAM block intended to be utilized mainly by the USB can also be used as a general purpose RAM for data storage and code storage and execution.

6.6.7.4. Interrupt controller

The Vectored Interrupt Controller (VIC) accepts all of the interrupt request inputs and categorizes them as Fast Interrupt Request (FIQ), vectored Interrupt Request (IRQ), and non-vectored IRQ as defined by programmable settings. The programmable assignment scheme means that priorities of interrupts from the various peripherals can be dynamically assigned and adjusted.

Fast interrupt request (FIQ) has the highest priority. If more than one request is assigned to FIQ, the VIC combines the requests to produce the FIQ signal to the ARM processor. The fastest possible FIQ latency is achieved when only one request is classified as FIQ, because then the FIQ service routine does not need to branch into the interrupt service routine but can run from the interrupt vector location.

Vectored IRQs have the middle priority. Sixteen of the interrupt requests can be assigned to this category. Any of the interrupt requests can be assigned to any of the 16 vectored IRQ slots, among which slot 0 has the highest priority and slot 15 has the lowest. Non-vectored IRQs have the lowest priority.

The VIC combines the requests from all the vectored and non-vectored IRQs to produce the IRQ signal to the ARM processor. The IRQ service routine can start by reading a register from the VIC and jumping there. If any of the vectored IRQs are pending, the VIC provides the address of the highest-priority requesting IRQs service routine, otherwise it provides the address of a default routine that is shared by all the non-vectored IRQs.

6.6.7.5. 10-Bit ADC

The LPC2148 contain two analog to digital converters. These converters are single 10-bit successive approximation analog to digital converters. While ADC0 has six channels, ADC1 has eight channels. Therefore, total number of available ADC inputs for LPC2141/42 is 6 and for LPC2144/46/48 is 14. The features of ADC are as follows:

- 10 bit successive approximation analog to digital converter
- Measurement range of 0 V to VREF (2.0 V ≤ VREF ≤ VDDA).
- Each converter capable of performing more than 400,000 10-bit samples per second.
- Every analog input has a dedicated result register to reduce interrupt overhead.
- Burst conversion mode for single or multiple inputs.
- Optional conversion on transition on input pin or timer match signal.
- Global Start command for both converters (LPC2142/44/46/48 only).

6.6.7.6. UARTs

The LPC2148 each contain two UARTs. In addition to standard transmit and receive data lines, the LPC2148 UART1 also provides a full modem control handshake interface. Compared to previous LPC2000 microcontrollers, UARTs in LPC2148 introduce a fractional baud rate generator for both UARTs, enabling these microcontrollers to achieve standard baud rates such as 115200 with any crystal frequency above 2 MHz In addition, auto-CTS/RTS flow-control functions are fully implemented in hardware (UART1 in LPC2144/46/48 only). The features are as follows:

- 16 byte Receive and Transmit FIFOs.
- Register locations conform to '550 industry standard.
- Receiver FIFO trigger points at 1, 4, 8, and 14 bytes
- Built-in fractional baud rate generator covering wide range of baud rates without a need for external crystals of particular values.
- Transmission FIFO control enables implementation of software (XON/XOFF) flow control on both UARTs.
- LPC2144/46/48 UART1 equipped with standard modem interface signals. This
- Module also provides full support for hardware flow control (auto-CTS/RTS).

6.6.7.7. System control

Crystal Oscillator:

On-chip integrated oscillator operates with external crystal in range of 1 MHz to 25 MHz The oscillator output frequency is called fosc and the ARM processor clock frequency is referred to as CCLK for purposes of rate equations, etc. fosc and CCLK are the same value unless the PLL is running and connected.

PLL (Phase Locked Loop):

The PLL accepts an input clock frequency in the range of 10 MHz to 25 MHz The Input frequency is multiplied up into the range of 10 MHz to 60 MHz with a Current Controlled Oscillator (CCO). The multiplier can be an integer value from 1 to 32 (in practice, the multiplier value cannot be higher than 6 on this family of microcontrollers due to the upper frequency limit of the CPU). The CCO operates in the range of 156 MHz to 320 MHz, so there is an additional divider in the loop to keep the CCO within its frequency range while the PLL is providing the desired output frequency. The output divider may be set to divide by 2, 4, 8, or 16 to produce the output clock. Since the minimum output divider value is 2, it is insured that the PLL output has a 50 % duty cycle. The PLL is turned off and bypassed following a chip reset and may be enabled by software. The program must configure and activate the PLL, wait for the PLL to Lock, then connect to the PLL as a clock source. The PLL settling time is 100us.

Reset and wake up timer:

Reset has two sources on the LPC2148: the RESET pin and watchdog reset. The RESET pin is a Schmitt trigger input pin with an additional glitch filter. Assertion of chip reset by any source starts the Wake-up Timer (see Wake-up Timer description below), causing the internal chip reset to remain asserted until the external reset is de-asserted, the oscillator is running, a fixed number of clocks have passed, and the on-chip flash controller has completed its initialization.

When the internal reset is removed, the processor begins executing at address 0, which is the reset vector. At that point, all of the processor and peripheral registers have been initialized to predetermined values.

The Wake-up Timer ensures that the oscillator and other analog functions required for chip operation are fully functional before the processor is allowed to execute instructions. This is important at power on, all types of reset, and whenever any of the aforementioned functions are turned off for any reason. Since the oscillator and other functions are turned off during Power-down mode, any wake-up of the processor from Power-down mode makes use of the Wake-up Timer.

The Wake-up Timer monitors the crystal oscillator as the means of checking whether it Is safe to begin code execution. When power is applied to the chip, or some event caused the chip to exit Power-down mode, some time is required for the oscillator to produce a signal of sufficient amplitude to drive the clock logic. The amount of time depends on many factors, including the rate of VDD ramp (in the case of power on), the type of crystal and its electrical characteristics (if a quartz crystal is used), as well as any other external circuitry (e.g. capacitors), and the characteristics of the oscillator itself under the existing ambient conditions.

External interrupt inputs

The LPC2148 include up to nine edge or level sensitive External Interrupt Inputs as selectable pin functions. When the pins are combined, external events can be processed as four independent interrupt signals. The External Interrupt Inputs can optionally be used to wake-up the processor from Power-down mode. Additionally capture input pins can also be used as external interrupts without the Option to wake the device up from Power-down mode.

6.6.7.8. Emulation and debugging

The LPC2148 support emulation and debugging via a JTAG serial port. A trace port allows tracing program execution. Debugging and trace functions are multiplexed only with GPIOs on Port 1. This means that all communication, timer and interface peripherals residing on Port 0 are available during the development and debugging phase as they are when the application is run in the embedded system itself.

6.6.8. GSM module

6.6.8.1. Introduction

The GSM Modem comes with a serial interface through which the modem can be controlled using AT command interface. An antenna and a power adapter are provided. The basic segregation of working of the modem is as under:

- Voice calls
- SMS
- GSM Data calls
- GPRS

Voice calls

Voice calls are not an application area to be targeted. In future if interfaces like a microphone and speaker are provided for some applications then this can be considered.

SMS

SMS is an area where the modem can be used to provide features like: Pre-stored SMS transmission. These SMS can be transmitted on certain trigger events in an automation system. SMS can also be used in areas where small text information has to be sent. The transmitter can be an automation system or machines like vending machines, collection machines or applications like positioning systems where the navigator keeps on sending SMS at particular time intervals. SMS can be a solution where GSM data call or GPRS services are not available.

GSM data calls

Data calls can be made using this modem. Data calls can be made to a normal PSTN modem/phone line also (even received). Data calls are basically made to send/receive data streams between two units either PC's or embedded devices. The advantage of Data calls over SMS is that both parties are capable of sending/receiving data through their terminals.

Applications and facts about GSM data calls

- Devices that have communication on serial port either on PC or in the embedded environment
- Devices that want to communicate with a remote server for data transfer
- This capability of data transfer can help in reducing processing requirements of the device
- The basic aim is to provide a wireless solution keeping the existing firmware intact
- The clients firmware continues to work without any modifications (no changes in the existing software required)
- GSM data calls can be a good solution where data has to be transmitted from a hand-held device to a central server
- The interface on two sides can be between PC's as well as embedded devices
- Calls can be established by the terminals at either side to start data calls
- The Modem remains transparent during data transfer after the call is established.
- Call establishment utility to be provided in case PC terminals
- Call establishment to be automated in case of embedded terminals. GSM converter can be an option where intelligence of establishing calls has to be put in case of embedded devices. Concept of GSM converter is discussed

Dial-up networks using GSM data calls

Dial up networking is a utility available with Windows through a person can dial the Data call number of this modem from any PC and share the file system on either PC's. This can be a good utility where both terminals are PC based. Sharing the file system remotely enables monitoring of devices remotely. Thus the modem can act as a piece of device which acts as a spy in the system. Can be a good debugging utility wherein a person can configure/monitor a remote PC based system and even rectify it. Some companies do sell their products with a GSM modem inside it just for this handy feature which allows them to configure the machines sitting anywhere in the world.

GSM converter

GSM converter will be an add-on device to be attached between a terminal, which wants data transfer, and the GSM modem. This GSM converter will take care of call establishment where the embedded device cannot make a call. The converter will remain transparent throughout the call once call is established. The GSM converter will be a very small piece of hardware possibly embedded inside the cable itself.

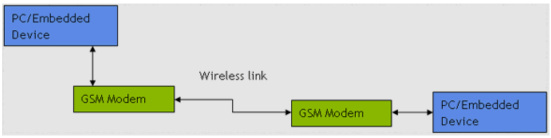


Fig 20: *Communication b/w GSM and System*

6.6.8.2. Working of GSM modem

Sending SMS messages from a microcontroller using a GSM modem

A GSM modem is a wireless modem that works with GSM wireless networks. A wireless modem is similar to a dial-up modem. The main difference is that a wireless modem transmits data through a wireless network whereas a dial-up modem transmits data through a copper telephone line. Most mobile phones can be used as a wireless modem.

To send SMS messages, first place a valid SIM card into a GSM modem, which is then connected to microcontroller by RS232 cable. After connecting a GSM modem to a microcontroller, you can control the GSM modem by sending instructions to it. The instructions used for controlling the GSM modem are called AT commands. GSM modems support a common set of standard AT commands. In addition to this common set of standard AT commands, GSM modems support an extended set of AT commands. The following table lists the AT commands that are related to the writing and sending of SMS messages:

Table 1: *AT commands*

AT command	Meaning
+CMGS	Send message
+CMSS	Send message from storage
+CMGW	Write message to memory
+CMGD	Delete message
+CMGC	Send command
+CMMS	More messages to send

GSM AT commands

One way to send AT commands to a GSM modem is to use a program. A program's function is like this:

It sends the characters you typed to the GSM modem. It then displays the response it receives from GSM modem on the screen.

Below shows a simple example that demonstrates how to use AT commands.

```
AT
OK
AT+CMGF=1
OK
AT+CMGW="9876543210"
> A simple demo of SMS text messaging.
+CMGW:
OK
AT+CMSS=1
+CMSS:
OK
```

Here is a description of what is done in the above example:

Line 1: "AT" is sent to the GSM modem to test the connection. The GSM modem sends back the result code "OK" **(line 2),** which means the connection between the program and the GSM modem works fine.

Line 3: The AT command +CMGF is used to instruct the GSM modem to operate in SMS text mode. The result code "OK" is returned **(line 4)**, which indicates the command line "AT+CMGF=1" has been executed successfully. If the result code "ERROR" is returned, it is likely that the GSM modem does not support the SMS text mode. To confirm, type "AT+CMGF=?" in the program. If the response is "+CMGF: (0, 1)" (0=PDU mode and 1=text mode), then SMS text mode is supported. If the response is "+CMGF: (0)", then SMS text mode is not supported.

Line 5 and 6: The AT command +CMGW is used to write an SMS text message to the message storage of the GSM modem . "+85291234567" is the recipient mobile phone number.

Line 7: "+CMGW: 1" tells us that the index assigned to the SMS text message is 1. It indicates the location of the SMS text message in the message storage.

Line 9: The result code "OK" indicates the execution of the AT command +CMGW is successful.

Line 10: The AT command +CMSS is used to send the SMS text message from the message storage of the GSM modem. "1" is the index of the SMS text message obtained from line 7.

Line 11: "+CMSS: 20" tells us that the reference number assigned to the SMS text message is 20.

Line 13: The result code "OK" indicates the execution of the AT command +CMSS are successful.

By using the above procedure message is sent by the GSM modem.

6.6.8.3. Characteristics of GSM standard:

- Fully digital system using 900,1800 MHz frequency band.
- TDMA over radio carriers (200 KHz carrier spacing.
- 8 full rate or 16 half-rate TDMA channels per carrier.
- User/terminal authentication for fraud control.
- Encryption of speech and data transmission over the radio path.
- Full international roaming capability.
- Low speed data services (up to 9.6 Kb/s).
- Compatibility with ISDN.
- Support of Short Message Service (SMS).

6.6.8.4. Advantages of GSM over analog system:

- Capacity increases.
- Reduced RF transmission power and longer battery life.
- International roaming capability.
- Better security against fraud (through terminal validation and user authentication).
- Encryption capability for information security and privacy.
- Compatibility with ISDN, leading to wider range of service.

6.6.9. Liquid crystal display

6.6.9.1. Introduction

An LCD is a small low cost display. It is easy to interface with a micro-controller because of an embedded controller (the black blob on the back of the board). This controller is standard across many displays (HD 44780), which means many micro-controllers (including the Arduino) have libraries that make displaying messages as easy as a single line of code. Hence it is very important device in embedded system. It offers high flexibility to user as he can display the required data on it

Major task in LCD interfacing is the initialization sequence. In LCD initialization you have to send command bytes to LCD. Set the interface mode, display mode, address counter increment direction, set contrast of LCD, horizontal or vertical addressing mode, color format. This sequence is given in respective LCD driver datasheet. Studying the function set of LCD lets you know the definition of command bytes. It varies from one LCD to another.

Next step after initialization is to send data bytes to required display data RAM memory location. Firstly set the address location using address set command byte and than send data bytes using the DDRAM write command. To address specific location in display data RAM one must have the knowledge of how the address counter is incremented.

6.6.9.3. Connections

A 14 pin access is provided having 8 data lines,3 control lines and 3 power lines. The function of each of the connections is shown in table 4.7.

Pin 1 and 2 are the power supply lines, VSS and VDD. The VDD pin should be connected to positive supply and VSS to 0V supply or ground. Although the LCD module data sheets specify a 5V DC supply. Supplies of 6V and 4-5V both work well, and even 3V is sufficient for some modules.

Pin 3 is a control pin, VEE, which is used to alter the contrast of the display. Ideally, this pin should be connected to a variable voltage supply.

Pin 4 is the (RS) register select line. When this line is low, data bytes transferred to the display are treated as commands and data bytes read from the display indicate its status.

By setting the RS line high, character data can be transferred to and from the module.

Pin 5 is read/write line. This line is pulled low in order to write commands or character data to the module, or pulled high to read character data or status information from its registers.

Pin 6 is the enable line. This input is used to initiate the actual transfer of commands or character data between the module and the data lines. When writing to the display, data is transferred only on high to low transition of this signal.

Pin 7 to 14 are data bus lines (D0 to D7). Data can be transferred to and from the display either as a single 8-bit byte or two 4 bit nibbles. The other two pins LED+ and LED- is used for back light of the LCD.

Table 2: *Pin Details on an LCD module*

pin	name	function
1	Vss	Gnd
2	Vdd	+ve supply
3	Vee	contrast
4	RS	regester select
5	R/W	read/write
6	E	enable
7	D0	data bit0
8	D1	data bit1
9	D2	data bit2
10	D3	data bit3
11	D4	data bit4
12	D5	data bit5
13	D6	data bit6
14	D7	data bit7

6.6.9.4. Interfacing LCD with microcontroller

Interfacing LCD with microcontroller is very easy task. You just have to know the proper LCD programming algorithm. LCD used here has HD44780u dot matrix LCD controller. LCD module has 8-bit data interface and control pins. One can send data as 8-bit or in pair of two 4-bit nibbles.

To display any character on LCD micro controller has to send its ASCII value to the data bus of LCD. For e.g. to display 'AB' microcontroller has to send two hex bytes 41h and 42h respectively. LCD display used here is having 16x2 size. It means 2 lines each with 16 characters.

6.6.9.5. LCD initialization

This is the pit fall for beginners. Proper working of LCD depend on the how the LCD is initialized. We have to send few command bytes to initialize the LCD. Simple steps to initialize the LCD

1. Specify function set: Send 38H for 8-bit, double line and 5x7 dot character format.

2. Display On-Off control: Send 0FH for display and blink cursor on.

3. Entry mode set: Send 06H for cursor in increment position and shift is invisible.

4. Clear display: Send 01H to clear display and return cursor to home position.

Table 3: *LCD Pin Description*

Pin	Symbol	I/O	Description
1	Vss	-	Ground
2	Vcc	-	+5V Power Supply
3	Vee	-	Power Supply to contrast
4	RS	I	RS = 0 to select command register
5	R/W	I	RS = 1 to select data register
6	EN	I/O	Enable
7 to 14	D0 to D8	I/O	8 bit data bus

Table 4: *LCD command codes*

Code(HEX)	Command to LCD Instruction Register
1	Clear display screen
2	Return home
4	Decrement cursor (shift cursor to left)
6	Increment cursor (shift cursor to right)
80	Force cursor to the beginning of first line
C0	Force cursor to the beginning of second line
	2 lines and 5x7 matrix

6.6.10. Power supply

6.6.10.1. Introduction

The input to the circuit is applied from the regulated power supply. The AC input i.e., 230V from the mains supply is step down by the transformer to 12V and is fed to a rectifier. The output obtained from the rectifier is a pulsating DC voltage. So in order to get a pure DC voltage, the output voltage from the rectifier is fed to a filter to remove any AC components present even after rectification. Now, this voltage is given to a voltage regulator to obtain a pure constant dc voltage.

6.6.10.2. Transformer

Usually, DC voltages are required to operate various electronic equipment and these voltages are 5V, 9V or 12V. But these voltages cannot be obtained directly. Thus the a.c input available at the mains supply i.e., 230V is to be brought down to the required voltage level. A transformer does this. Thus, a step down transformer is employed to decrease the voltage to a required level.

6.6.10.3. Rectifier

The output from the transformer is fed to the rectifier. It converts A.C. into pulsating. D.C. The rectifier may be a half wave or a full wave rectifier. In this project, a bridge rectifier is used because of its merits like good stability and full wave rectification.

6.6.10.4. Filter

Capacitive filter is used in this project. It removes the ripples from the output of rectifier and smoothens the

D.C. Output received from this filter is constant until the mains voltage and load is maintained constant. However, if either of the two is varied, D.C. voltage received at this point changes. Therefore a regulator is applied at the output stage.

6.6.10.5. Voltage regulator

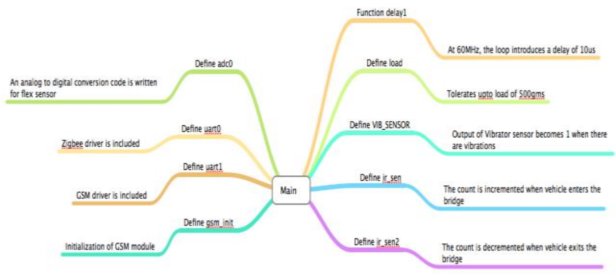
As the name itself implies, it regulates the input applied to it. A voltage regulator is an electrical regulator designed to automatically maintain a constant voltage level. In this project, power supply of 5V and 12V are required. In order to obtain these voltage levels, 7805 and 7812 voltage regulators are to be used. The first number 78 represents positive supply and the numbers 05, 12 represent the required output voltage levels.A variable regulated power supply, also called a variable bench power supply, is one where you can continuously adjust the output voltage to your requirements. Varying the output of the power supply is the recommended way to test a project after having double checked parts placement against circuit drawings and the parts placement guide.

The LM7805 is simple to use. You simply connect the positive lead of your unregulated. DC power supply (anything from 9VDC to 24VDC) to the Input pin, connect the negative lead to the Common pin and then when you turn on the power, you get a 5 volt supply from the Output pin.

6.6.10.6. Circuit features

- **Brief description of operation:** Gives out well regulated +5V output, output current capability of 100 mA
- **Circuit protection:** Built-in overheating protection shuts down output when regulator IC gets too hot.
- **Circuit complexity:** Very simple and easy to build.
- **Circuit performance:** Very stable +5V output voltage, reliable operation.
- **Availability of components:** Easy to get, uses only very common basic components.
- **Applications:** Part of electronics devices, small laboratory power supplies.
- **Power supply voltage:** Unregulated DC 8-18V power supply.
- **Power supply current:** Needed output current + 5 mA.
- **Component costs:** Few dollars for the electronics components + the input transformer.

6.8 Code Layout



7. TOOLS AND TECHNIQUES

7.1. Introduction to keilµVision3

The µVision3 IDE is a Windows-based software development platform that combines a robust editor, project manager, and make facility. µVision3 integrates all tools including the C compiler, macro assembler, linker/locator, and HEX file generator. The µVision3 IDE offers numerous features and advantages that help you quickly and successfully develop embedded applications. They are easy to use and are guaranteed to help you achieve your design goals.

7.1.1. Features

- The µVision3 Simulator is the only debugger that completely simulates all on-chip peripherals.
- Simulation capabilities may be expanded using the Advanced Simulation Interface (AGSI).
- µVision3 incorporates project manager, editor, and debugger in a single environment.
- The µVision3 Device Database automatically configures the development tools for the target microcontroller.
- The µVision3 IDE integrates additional third-party tools like VCS, CASE, and FLASH/Device Programming.
- The ULINK USB-JTAG Adapter supports both Debugging and Flash programming with configurable algorithm files.
- Identical Target Debugger and Simulator User Interface.
- The Code Coverage feature of the µVision3 Simulator provides statistical analysis of your program's execution.

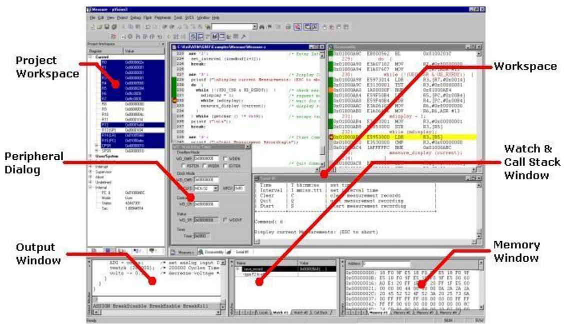


Fig 23: *Keil Window*

7.1.2. Software development cycle

When you use the Keil µVision3, the project development cycle is roughly the same as it is for any other software development project.

- Create a project, select the target chip from the device database, and configure the tool settings. Create source files in C or assembly.
- Correct errors in source files.
- Test the linked application.

The following block diagram illustrates the complete µVision3 software development cycle. Each component is described below.

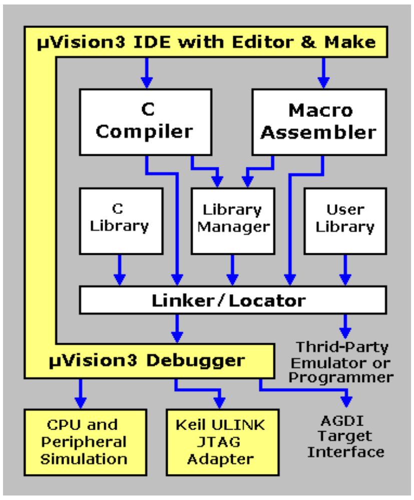


Fig 24: *Software Development Cycle using Keil uVision3*

7.1.3. µVision3 IDE

The µVision3 IDE combines project management, a rich-featured editor with interactive error correction, option setup, makes facility, and on-line help. Use µVision3 to create your source files and organize them into a project that defines your target application. µVision3 automatically compiles, assembles, and links your embedded application and provides a single focal point for your development efforts.

7.2. Flash magic

Flash Magic is Windows software that allows easy access to all the ISP features provided by the devices. Flash Magic provides a clear and simple user interface while Erasing /Programming / Reading Flash memory Under Windows, only one application may have access the COM Port at any one time, Flash Magic only obtains access to the selected COM Port when ISP operations are being performed. Hence applications that need to use the COM Port, such as debugging tools, may be used while flash magic is loaded.

7.3. Embedded C

When designing software for a smaller embedded system with the 8051, it is very commonplace to develop the entire product using assembly code. With many projects, this is a feasible approach since the amount of code that must be generated is typically less than 8 kilobytes and is relatively simple in nature. If a hardware engineer is tasked with designing both the hardware and the software, he or she will frequently be tempted to write the software in assembly language.

The trouble with projects done with assembly code can is that they can be difficult to read and maintain, especially if they are not well commented. Additionally, the amount of code reusable from a typical assembly language project is usually very low. Use of a higher-level language like C can directly address these issues. A program written in C is easier to read than an assembly program.

Since a C program possesses greater structure, it is easier to understand and maintain. Because of its modularity, a C program can better lend itself to reuse of code from project to project. The division of code into functions will force better structure of the software and lead to functions that can be taken from one project and used in another, thus reducing overall development time. A high order language such as C allows a developer to write code, which resembles a human's thought process more closely than does the equivalent assembly code. The developer can focus more time on designing the algorithms of the system rather than having to concentrate on their individual implementation. This will greatly reduce development time and lower debugging time since the code is more understandable.

By using a language like C, the programmer does not have to be intimately familiar with the architecture of the processor. This means that someone new to a given processor can get a project up and running quicker, since the internals and organization of the target processor do not have to be learned. Additionally, code developed in C will be more portable to other systems than code developed in assembly. Many target processors have C compilers available, which support ANSI C.

All of this is not to say that assembly language does not have its place. In fact, many embedded systems (particularly real time systems) have a combination of C and assembly code. For time critical operations, assembly code is frequently the only way to go. One of the great things about the C language is that it allows you to perform low-level manipulations of the hardware if need be, yet provides you the functionality and abstraction of a higher order language.

8. RESULTS AND DISCUSSIONS

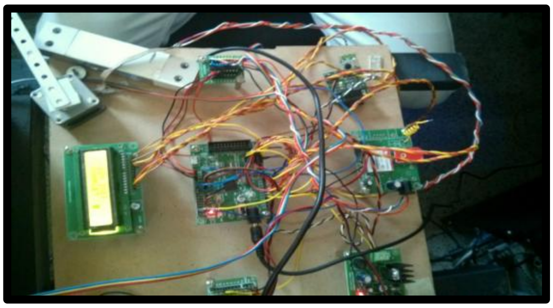


Fig 25: *The components of the Bridge Monitoring System*

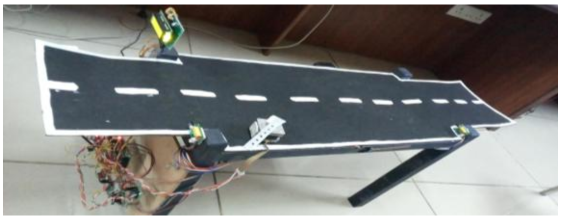


Fig 26: *Implemented Bridge monitoring system*

Fig 27: *The outputs of LCD*

Fig 28: *GSM output*

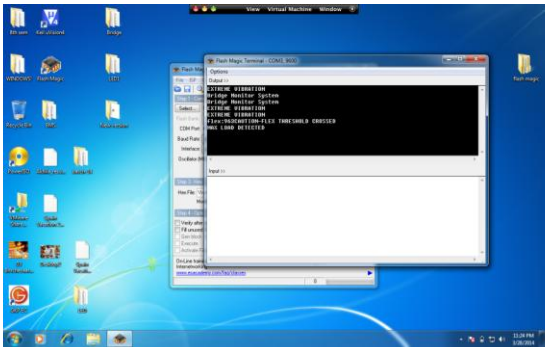


Fig 29: *Message to the Bridge Monitoring house via Zigbee*

The Bridge Monitoring System was designed and the hardware for the same was built. The above are the output obtained.

- When the system is powered up, there will be a display of "Bridge Monitoring System" on LCD. Also the information is sent to the monitoring house via Zigbee.

- Then the GSM initialization takes place and it searches for the signal. As the GSM initialization is completed, there will be a constant monitoring of flex sensor and the digital output value is displayed in the LCD, at the entrance of the bridge.

- There is an IR sensor at the entry of the bridge, which detects the vehicle and gives the incremented count of the number of vehicles on the bridge. If the number of vehicles exceeds the threshold value (i.e., 5), the gate is closed. There is an IR sensor at the exit of the bridge, which detects the vehicle and gives the decremented count of the number of vehicles on the bridge. The gate is opened if the number of vehicles is equal to 3.. If the monitoring head wants to know the number of vehicles on the bridge, he gets the same by sending a message "CNT".

- There is a vibrator sensor at the bottom of the bridge, which detects the earthquakes (heavy vibrations). The gate is closed when there are heavy vibrations. the information is sent to the monitoring house via Zigbee and the monitoring head via GSM. In order to open the gate, "K" command has to be sent by the monitoring house.

- There is a flex sensor beneath the bridge, which detects the cracks and bending. The gate is closed when the threshold value of flex exceeds 810. The information is sent to the monitoring house via Zigbee and the monitoring head via GSM. In order to open the gate, "K" command has to be sent by the monitoring house.
- There is a load sensor at the entry of the bridge, which detects the load on the bridge. The gate is closed when there are heavy loads. The information is sent to the monitoring house via Zigbee and the monitoring head via GSM. In order to open the gate, "K" command has to be sent by the monitoring house.

9. CONCLUSIONS AND SCOPE FOR FUTURE SCOPE

9.1. Conclusions

- Even in developed nations like USA, it has been found that more than one out of every four bridges are structurally deficient.
- This wireless technology could avert the kind of bridge collapse that killed 13 and injured 145 along Minneapolis on Aug. 1, 2007 at one-hundredth the cost of current wired systems.
- This system can help in monitoring the bridge in an efficient, cost effective and reliable manner.
- The immediacy, low cost, low energy and compact size add up to a revolution in bridge safety monitoring, providing a heightened level of early-warning capability.

9.2. Future Work

- Web camera can be fitted so that the density of the vehicles can be know by the people who enter the bridge. This can be done using MATLAB.
- Instead of using IR sensor, we can use UV sensor and more advanced sensor, which has high sensitivity.
- This project can be implemented in a two-way road bridges. But the complexity of the project increases.

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APPENDIX I: USER MANUAL

GSM USER MANUAL

GSM RS232 Modem from rhydoLABZ is built with SIMCOM Make SIM900 Quad-band GSM/GPRS engine, works on frequencies 850 MHz, 900 MHz, 1800 MHz and 1900 MHz. It is very compact in size and easy to use as plug in GSM Modem. The Modem is designed with RS232 Level converter circuitry, which allows you to directly interface PC Serial port .The baud rate can be configurable from 9600-115200 through AT command.

The modem needed only 3 wires (Tx, Rx, GND) except Power supply to interface with microcontroller/Host PC. The built in Low Dropout Linear voltage regulator allows you to connect wide range of unregulated power supply (4.2V -13V). Yes, 5 V is in between. Using this modem, you will be able to send & Read SMS, connect to Internet via GPRS through simple AT commands.

The features of GSM are:

- High Quality Product
- Quad-Band GSM
- 850/ 900/ 1800/ 1900 MHz
- Built in RS232 Level Converter (MAX3232)
- Configurable baud rate
- SMA connector with GSM L Type
- Built in Network Status LED
- Inbuilt Powerful TCP/IP protocol stack for internet data transfer over GPRS.
- Audio interface Connector
- Most Status & Controlling Pins are available at Connector
- Normal operation temperature: -20 °C to +55 °C
- Input Voltage: 5V-12V DC
- Built in SIM Card holder.

The specifications of GSM module are:

- Quad-Band 850/ 900/ 1800/ 1900 MHz GPRS multi-slot class 10/8
- GPRS mobile station class
- Weight: 3.4g
- Control via AT commands (GSM 07.07, 07.05 and SIMCOM enhanced AT Commands)
- Low power consumption: 1.0mA(sleep mode)
- Operation temperature: -40°C to +85 °C\

Specifications for Data

- GPRS class 10: max. 85.6 kbps (downlink) PBCCH support
- Coding schemes CS 1, 2, 3, 4
- CSD up to 14.4 kbps
- USSD
- Non transparent mode
- PPP-stack

Specifications for SMS via GSM

- Point to point MO and MT
- SMS cell broadcast
- Text and PDU mode

Software features

- 0710 MUX protocol
- Embedded TCP/UDP protocol
- FTP/HTTP

Special firmware

- MMS
- Java (cooperate with IA solution)
- Embedded AT

The GSM module is designed as a DCE (Data Communication Equipment), following the traditional DCE-DTE (Data Terminal Equipment) connection. The GSM Modem and the client (DTE) are connected through the following signal (as following figure shows). Auto baud supports baud rate from 1200bps to 57600bps.

Serial port

- TXD: Send data to the RXD signal line of the DTE
- RXD: Receive data from the TXD signal line of the DTE

SEND A TEXT MESSAGE

Goal: Send a text

AT+CMGF=1\r

Returns OK or ERROR

AT+CSCS="GSM"\r

Returns OK or ERROR

AT+CSCA="+13123149810" \r

Returns OK or ERROR. This number +13123149810 is the short

message center for AT&T/Cingular service. T-Mobile's is +12063130004 AT+CSMP=17,167,0,240\r

Returns OK or ERROR. These numbers refer to settings for text

message sending, keep them this way.

AT+CMGS="

AT+CMGS="1234567890"\r

Returns > , prompting what message to send. 1234567890 is the

phone number that the text message will be sent to.

Hello this is a message <Ctrl+z>

Type any message, and then press <Ctrl+z>. Returns confirmation message and Message ID number

SEND A TEXT MESSAGE

Goal: Read a Text

AT+CMGF=1\r

Returns OK or ERROR AT+CMGDA="DEL ALL"

Delete all text

AT+CNMI=0,0

Disable unsolicited error code AT+CMGR=1

Read Message #1

AT+CMGL="REC UNREAD"

Read all received unread messages

ZIGBEE USER MANUAL

ZigBee is a specification for a suite of high-level communication protocols used to create personal area networks built from small, low-power digital radios. ZigBee is based on an IEEE 802.15 standard. Though low-powered, ZigBee devices can transmit data over long distances by passing data through intermediate devices to reach more distant ones, creating a mesh network; i.e., a network with no centralized control or high-power transmitter/receiver able to reach all of the networked devices.

General characteristics of Zigbee are:

1) Dual PHY (2.4GHz and 868/915 MHz) , Data rates of 250 kbps (@2.4 GHz), 40 kbps (@ 915 MHz), and 20 kbps (@868 MHz) , Optimized for low duty-cycle applications (<0.1%) ,CSMA-CA channel access.

2) Yields high throughput and low latency for low duty cycle devices like sensors and controls

3) Low power (battery life multi-month to years)

4) Multiple topologies: star, peer-to-peer, mesh

5) Addressing space of up to: 18,450,000,000,000,000,000 devices (64 bit IEEE address) and 65,535 networks

6) Optional guaranteed time slot for applications requiring low latency

7) Fully hand-shake protocol for transfer reliability

8) Range: 50m typical (5-500m based on environment)

LPC2148 User Manual

LPC2148 has two I/O ports namely PORT0 and PORT1. Each PORT has 32 IO pins. In PORT0 pins P0.24, P0.26 and P0.27 are not available. In PORT1 pins 0 to 15 are not available. Each Port Pin has multiple functions. These functions can be selected by using Pin Connect Block. Pin Connect Block contains three 32-bit registers namely **PINSEL0**, **PINSEL1** and **PINSEL2.**

Pin Function Select Registers (PINSEL)

To enable you to select which pin functions you would like to use, you need to use one of the three **PINSEL** registers: PINSEL0, PINSEL1 and PINSEL2. Which register you use depends on which pin you want to modify. While you can find a complete and detailed list of all of the pins and their functions in Chapter 7 of the LPC2148 User's Manual, you can summarize the pin organization as follows:

PINSEL0 contains GPIO pins 0.0 to 0.15

PINSEL1 contains GPIO pins 0.16 to 0.31

PINSEL2 is a special case, and is used to control whether pins 1.16.31 are used as GPIO pins, or as a Debug port in combination with hardware JTAG debugger. Since we are using hardware JTAG debugger in all of these tutorials, these pins will not be available to use as GPIO during testing and development (they are used by the JTAG device itself).

Each pin can be IOPIN or IODIR or IOSET or IOCLR

- **IOPIN (IO0PIN** for **PORT0** and **IO1PIN** for **PORT1):**

GPIO Port Pin value register**.** The current state of the GPIO configured port pins can always be read from this register, regardless of pin direction. This register has the current status of the corresponding port.

- **IODIR (IO0DIR** for **PORT0** and **IO1DIR** for **PORT1):**

GPIO Port Direction control register. This register individually controls the direction of each port pin. This register is used to set each port pin as either input or output. If '0', the port pin is considered as input and if '1', then the port pin is considered as output.

- **IOSET (IO0SET** for **PORT0** and **IO1SET** for **PORT1):**

GPIO Port Output Set register. This register controls the state of output pins in conjunction with the IOCLR register. Writing ones produces highs at the corresponding port pins. Writing zeroes has no effect.

- **IOCLR (IO0CLR** for **PORT0** and **IO1CLR** for **PORT1):**

GPIO Port Output Clear register. This register controls the state of output pins. Writing ones produces lows at the corresponding port pins and clears the corresponding bits in the IOSET register. Writing zeroes has no effect.

APPENDIX II : DETAILED CODE

CODE LISTING

```
int main (void)
{
	unsigned char
addr[30]={0xc0,0xc1,0xc2,0xc3,0xc4,0xc5,0xc6,0xc7,0xc8,0xc9,0xca,0xcb,0xcc,0xcd,0xce,0xcf};
	int i,j;
	IO1DIR &= ~IR1;
	IO1DIR &= ~IR2;
	IO0DIR &= ~LOAD0;
	IO1DIR &= ~vibrator;
	IO0DIR|=(STEPPER1|STEPPER2|STEPPER3|STEPPER4);
	IO1CLR |=  IR1|IR2|LOAD0;
	IO1SET|=  vibrator;
	init_adc0();
		// Initialize ADC
	init_lcd();
	uart0_init();
		// Initialize LCD
	uart1_init();
	uart0_puts("Bridge Monitor System\r\n");
	lcd_putstring(LINE1,0," Bridge Monitor");
	lcd_putstring(LINE2,0,"    System    ");
	delay(20000);
	lcd_clear();
	lcd_putstring(LINE1,0,"Searching Signal...");
	for(j=0;j<3;j++)
	{
			for(i=0;i<16;i++)
			{
	lcd_command_write(addr[i]);
				lcd_data_write('>');
				delay(1200);
			}
			for(;i>0;i--)
			{
	lcd_command_write(addr[i]);
				lcd_data_write('<');
				delay(1200);
			}
	}
	intGsm();
	lcd_clear();
	lcd_putstring(LINE1,0,"   GSM INIT ");
	lcd_putstring(LINE2,0,"   COMPLET  ");
	sendSMS("8867279301","BRIDGE
MONITORING SYSTEM");
	delay(30000);
	lcd_clear();
	while(1)
	{
		process_adc_flex();
		ir_control();
```

```
        Load_control();
        delay(200);
    }
}
void ir_control(void)
{
        if(IO1PIN&IR1)
        {
            count++;
            sprintf((char *)buf3,"Cnt:%d",count);
            lcd_putstring(LINE2,0,(char *)buf3);
            LCD_string("        ");
            if(count>=5)
            {
                if(stepper_branch == 0)
                {
    stepperanti_clock();
    stepper_branch = 1;
                }
            }
            delay(12000);
        }
        if(IO1PIN&IR2)
        {
            count--;
            sprintf((char *)buf3,"Cnt:%d",count);
            lcd_putstring(LINE2,0,(char *)buf3);
            LCD_string("        ");
            if(count<=0)
            {
                count=0;
            }
            if(count<=3)
            {
                if(stepper_branch == 1)
                {
                  stepper_clock_1();
    stepper_branch = 0;
                }
            }
            delay(12000);
        }
}
void Load_control(void)
{
        while(IO0PIN & LOAD0)
        {
            lcd_putstring(LINE2,0,"MAX LOAD DETCD");
            uart0_puts("MAX LOAD DETECTED\r\n");
stepperanti_clock();
            delay(30000);
            while(uart0_getkey () != 'K');
            stepper_clock_1();
            lcd_command_write(1);
        }
        if(!(IO1PIN & vibrator))
        {
    lcd_putstring(LINE2,0,"EXTREME VIBRATION");
            uart0_puts("EXTREME VIBRATION\r\n");
stepperanti_clock();
```

```
        sendSMS("8867279301","EXTREME
VIBRATION");
                        delay(30000);
                        while(uart0_getkey () != 'K');
                        stepper_clock_1();
                        lcd_command_write(1);
                }
}
void LCD_string(unsigned char *temp)
{
        while(*temp)
        lcd_data_write(*temp++);
}
void delay9(unsigned int count)
{
 int j=0,i=0;
 for(j=0;j<count;j++)
 {
  /* At 60Mhz, the below loop introduces
  delay of 10 us */
  for(i=0;i<1000;i++);
 }
}
```

APPENDIX III : ENVIRONMENTAL SETUP

Flash Magic Setup

Step 1. Visit Flash Magic website **http:// www. flashmagictool.com/** and download the file FlashMagic.exe.

Step 2. Execute the downloaded file FlashMagic.exe, and follow the instructions.

Step 3. Start Flash Magic by selecting it from the Start Menu. In the Flash Magic windows select Options > Advanced Options ... menu item. In the window that appears enable the check box that says Use DTR and RTS to control RST and P0.14, and click on Ok.

When this option is enabled, during code download, the flashing tool will automatically switch the device into ISP mode. For more information on this, see the board user manual.

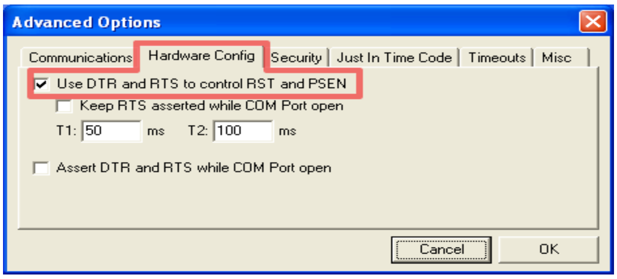

Figure 30: *Flash Magic Advanced Options*

Keil uVision 4 Installation

Please check the minimum hardware and software requirements that must be satisfied to ensure that your Keil development tools are installed and will function properly. Before attempting installation, verify that you have:

Keil products are available on CD-ROM and via download from **www.keil.com**. Updates to the related products are regularly available at **www.keil. com/ update**.

Single-User License is available for all Keil products. A Single-User License grants the right to use a product on a maximum of two computers to one user. Each installation requires a license code that is personalized for the computer on which the product is installed. A Single-User license may be uninstalled and moved to another computer.

Floating-User License is available for many Keil products. The Floating- User license grants the right to use that product on several computers by several different developers at the same time. Each installation of the product requires an individual license code for each computer on which the product is installed.

A standard PC running Microsoft Windows XP, or Windows Vista 1GB RAM and 500 MB of available hard-disk space is recommended 1024x768 or higher screen resolution; a mouse or other pointing device A CD-ROM drive

Installation using the web downloads

1. Downloadtheproductfrom**www.keil.com/demo**

2. Run the down loaded executable

3. Follow the instructions displayed by the **SETUP** program

Installation from CD-ROM

1. Insert the CD-ROM into your CD-ROM drive. The CD-ROM browser should start automatically. If it does not, you can run **SETUP.EXE** from the CD-ROM.

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2. Select **Install Products & Updates** from the CD Browser menu
3. Follow the instructions displayed by the **SETUP** program

Procedure for connecting controller pins to the sensors:

Detailed procedure to connect controller board to the sensors is as follows:

Table 5: *Connections b/w controller and sensors*

Input/output	Pin no. on controller board
Entry IR sensor	P1.16
Exit IR sensor	P1.17
First coil of stepper motor	P1.4
Second coil of stepper motor	P1.5
Third coil of stepper motor	P1.6
Fourth coil of stepper motor	P1.7
Load sensor	P1.12
Vibrator sensor	P1.24
Analog to Digital convertor	AD0.1
LCD D4	P1.18
LCD D5	P1.19
LCD D6	P1.20
LCD D7	P1.21
LCD RS	RS of controller
LCD RW	RW of controller
LCD EN	EN of controller
Zigbee Tx	Rx of controller (UART 0)
Zigbee Rx	Tx of controller (UART 0)
GSM Tx	Rx of controller (UART 1)
GSM Rx	Tx of controller (UART 1)

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Mr.Anand Kumar Jha is currently working as a software engineer at Manhattan Associates,Bangalore.He has got overral 2 years of IT Industry experience (**Supply Chain**). He is an alumini of PESIT,2010-2014th Batch.

He has completed his engineering in Electronics & Communication in 2014 with 8.15 CGPA from PES INSTUTUTE OF TECHNOLOGY(PESIT),Bangalore.

During this four year tenure,he has done extremely well both in academics and co-curricular activities.

He has secured top grades(**S**) for his final year project(**Bridge Monitoring System**) and reprented it at various levels.

Anand has participated in various co-curricular activities during the year and was also a part of **CORI**(Cruscible of Research & Innovation) team(PESIT) in building small nano satellite during first year of engineering which got appreciation from ISRO and about to get launched soon.

He is also an active volunteer of World Vision India and have sponsored a girl child regarding her education and overral development.