Tilt angle measurement using accelerometer IC and CAN protocol implementation for data transmission

KRISHNAMURTHY BHAT CHAYALAKSHMI C.L.
Department of Instrumentation Technology
Basaveshwar Engineering College
Bagalkot, Karnataka State
INDIA

Abstract: - The paper presented here describes a method of real time measurement and transmission of tilt angle. MEMS based accelerometer sensor basically measures acceleration in the analog domain and an ARM processor built-in 10 bit ADC converts the analog data from accelerometer into digital number. This is processed and encoded by the same processor and sends the digital code to another ARM processor through a UTP cable. The receiving processor can be used for analysis, display and or control purpose. Transmission and reception of data is by a pair of sturdy CAN transceivers. ARM processor supports CAN transceiver. Since the tilt angle has a definite relationship with the measured acceleration, it is acquired and processed. Tilt angle in the range of $0\text{-}180^0$ can be measured using this method.

Key-Words: - Tilt, Accelerometer, CAN protocol, ARM processor,UTP cable.

1 Introduction

Recent advances in accelerometer sensor technology, especially with silicon micro machined types, have driven the cost of these devices down significantly. Measurement of acceleration or one of the derivative properties such as vibration, shock, or tilt has become very common in a wide range of applications. These parameters are measured for analysis and further, if necessary, for controlling. There are many types of sensors that measure acceleration, vibration, shock, or tilt. These sensors include piezo-film, electromechanical, servo, piezoelectric, liquid tilt, bulk micro machined piezo resistive and capacitive sensors, as well as surface micro machined capacitive[9]. Each of these sensors has distinct characteristics in terms of output signal of the sensor, cost for development and type of operating environment. Measurement of acceleration can also provide velocity by single integration and position by double integration. Vibration and shock can be used for machine health determination as well as motion and shock detection for car alarms. Static acceleration due to gravity can be used to determine tilt and inclination provided that the sensor is responsive to static acceleration.

The advances in MEMS technology have presented varieties of on-chip accelerometer sensors, which are miniature and cost effective. This type of accelerometer IC is practically used in measuring various physical parameters. An effort is made here to acquire the tilt or inclination and then communicate these data to a distant processor for the obvious advantages.

2 Block Diagram

The complete block diagram of measurement and data communication scheme is shown in Figure 1.

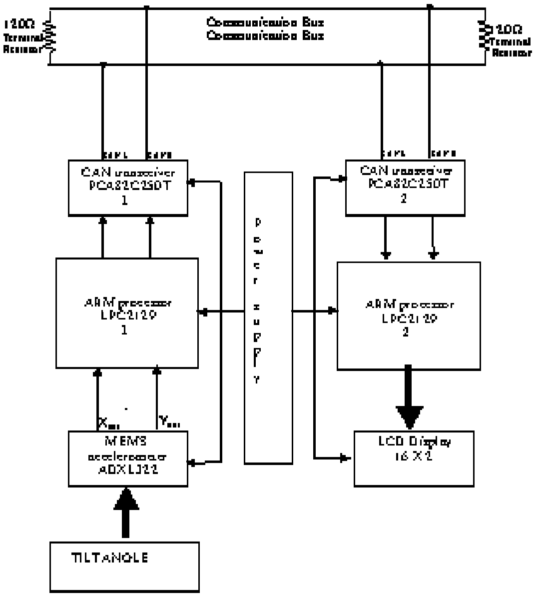

Figure 1. Block diagram

The tilt angle is measured using Analog Devices IC ADXL322. The output signal from this accelerometer IC is analog voltage. It can measure both static and dynamic acceleration also. The full-scale range of acceleration with which this IC can be used is ± 2 g.

The analog output of accelerometer IC is processed in digital domain. An ARM processor LPC2129 with built in 10 bit successive approximation ADC module suits this purpose, as the conversion time is adequate to measure tilt. The digital data equivalent of measured tilt is transmitted through CAN bus system to a remote processor. This processor, in turn, converts the received digital data into the corresponding tilt angle value and displays it on an LCD display.

3 The Hardware

The detail structure of hardware is shown in Figure 2.

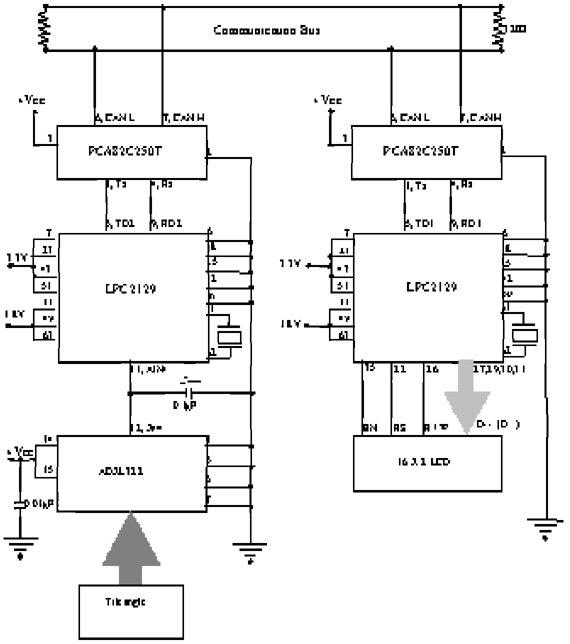

Figure 2 The Hardware

3.1 Accelerometer IC ADXL 322 :

ADXL 322 is a small, thin, low power, dual axis MEMS accelerometer IC. This IC is used as a sensor to measure the tilt of an object. The output signal from accelerometer IC is analog voltage. It can measure the acceleration with a full-scale range of ± 2 g with sensitivity of 420 mv/g at 3 V supply. Bandwidth is selectable between 50 Hz to 2.5 KHz. It is a product from Analog Devices Inc.

3.2 ARM processor LPC2129 :

The LPC 2129 is a 32-bit ARM 7TDMI-S CPU, with real time emulation and embedded trace support, together with 256 Kbytes of embedded high-speed flash memory. A 128-bit wide internal memory interface and unique accelerator architecture enables 32-bit code execution at maximum clock rate. It has 16 KB on-chip static RAM and 256 KB on-chip flash program memories, In-system programming (ISP) and In-application programming (IAP) via on-chip boot-loader software. Flash programming takes 1msec per 512 byte line.Full chip erase takes 400msec. The is chip has two interconnected CAN interfaces with advanced acceptance filters and four channel, 10-bit A/D converter with conversion time as low as 2.44msec. Operating clock of 1 MHz to 30 MHz is selectable. It is a product from Philips Corporation.

LPC 2129 processor is used to convert the analog signal received from the sensor ADXL 322 into a digital number using its built-in 10 bit ADC. It is then encoded in terms of gravimetric acceleration unit g before transmitted to the processor connected with the display unit. Conversion time of 2.44 μsec by the ADC is negligible in most of the practical applications.

3.3 Controller Area Network (CAN):

The controller area network module is a serial interface useful for communicating with other peripherals or micro-controller devices. This interface / protocol was designed to allow communications with in noisy environments. The LPC 2129 has two CAN controller modules. It can support data rate up to 1Mbits/sec. Each CAN controller has a register structure and the 8-bit registers of those devices have been combined into 32-bit words to allow simultaneous access in the ARM environment. CAN is better for communicating the signals in the automobiles, where the speed is at most important. PCA82C250T is the CAN transceiver IC used for the bus interfacing purpose.

On the receiver side there is one more CAN transceiver PCA82C250T, which receives the signal from the transmitter CAN transceiver. When the controller receives the message, then the data will be displayed on a 16x2 LCD display supported by an ARM processor.

4 The Software

The software has two parts: one for the transmitter side initialization and other for the receiver side.

4.1 Transmitter Side:

The appropriate algorithm required for sensing the analog input from accelerometer IC, converting it to digital equivalent data and then transmitting the same is shown in the proceeding section. In transmitter section, two main subroutines are used. Simply the main program calls the two subroutines. One subroutine is to initialize CAN as transmitter and the ADC module. The rate of transmission is selected as 125 kbps. This is sufficient for static tilt angle measurement. The other subroutine is to transmit the data using CAN through CAN transceiver PCA82C250T. In this subroutine, before transmitting, the digital data is obtained from ADC module of the ARM LPC2129 processor. Figure 3, Figure 4 and Figure 5 depict the flow chart for this part.

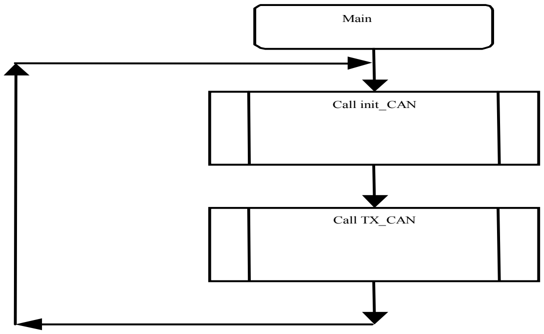

Figure 3. Main program for transmitter

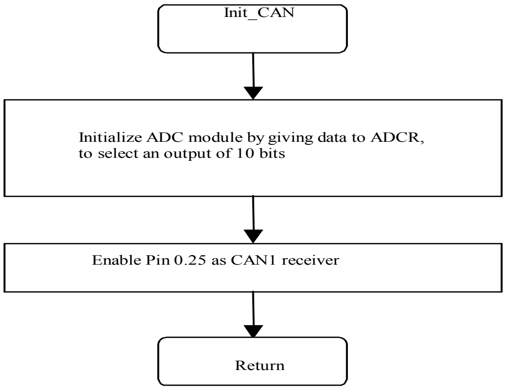

Figure 4. Subroutine to initialize CAN Controller of ARM processor

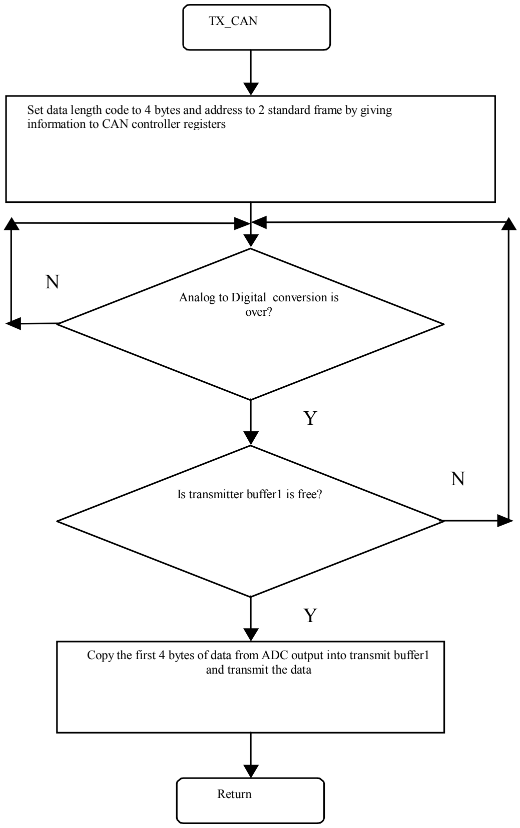

Figure 5. Subroutine to transmit ADC output

4.2 Receiver Side:

There are mainly two subroutines along with the main program. In the main program, the 16 x 2 LCD is initialized. Before initializing LCD, first it is necessary to configure the appropriate port pins as output. It is also done in the main program. Then the command words are given to LCD, to clear the display and to place the cursor in the home position, etc. The main program calls two subroutines. One for initializing CAN 2 module of second ARM processor LPC2129, which acts as receiver. Here also the baud rate of 125kbps is selected.

The other subroutine is used to receive the transmitted data, manipulate it in to the tilt angle value and then display it as tilt angle on the LCD. Figure 6, Figure 7 and Figure 8 depict the flow chart for this part.

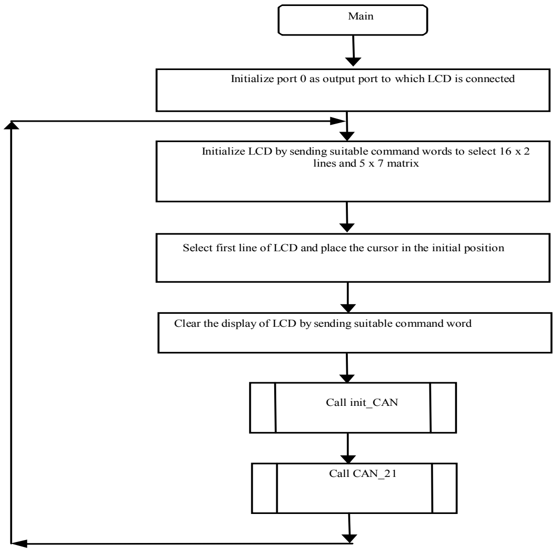

Figure 6. Main Program for receiver

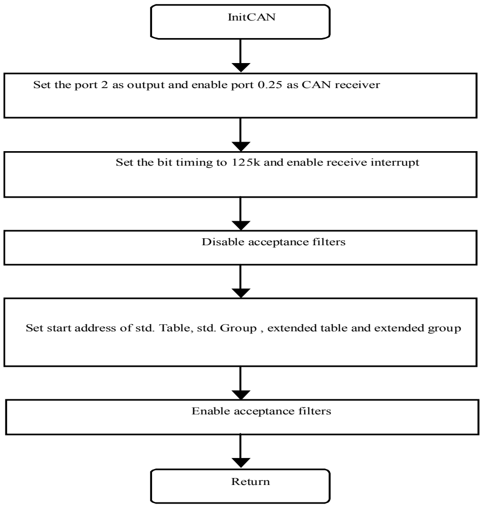

Figure 7. Subroutine to initialize CAN controller to receive the message

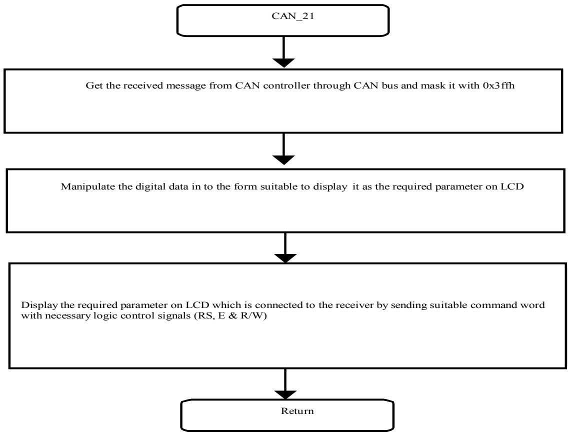

Figure 8. Subroutine to display the received information

5 Results

5.1 Tilt angle measurement:

The supply voltage for ADXL322 is 5 V.

The 0g point (when the accelerometer is oriented flat and parallel to ground) is V_{cc} /2 i.e. 2.5V. The sensitivity of ADXL 322 at 5V is 750mV/g. Yout is considered for calculation.

$A_{tilit} = Asin\{[V_m - V_{0g}] / S\}$ Where

A_{tilit} = Tilt angle in degrees.

V_m = Measured Voltage in volts (on Y_{out}).

V_{0g} = 0g point = V_{cc} /2 in volts.

S= accelerometer sensitivity in mV/g

5.2 Practical Observations:

A set of readings with the designed unit is as shown in Table 1.

Sl.No	Actual tilt angle (degrees)	Analog voltage (v)	ADC output (HEX)	Measured Tilt angle (Degrees)
01	00	2.91	0387	0.7
02	10	2.95	0393	9.99
03	20	2.99	03A0	20.09
04	30	3.03	03AD	30.26
05	40	3.08	03BA	40.52
06	50	3.11	03C6	50.12
07	60	3.16	03D3	60.6 8
08	70	3.2	03DF	70.62
09	80	3.23	03EB	80.80
10	90	3.27	03F6	90.08

Table 1. Tilt measurement

6 Conclusion:

The case presented here is a real-world problem to measure/transmit the tilt angle. Tilt angle measurement is most common in applications such as robotic angular movements, navigations, avionics, head lamp leveling/ wheel alignment and so on. Analog Device's ADXL322 is quite suitable and affordable for this task as it has a range of ±2g with 2mg resolution, output voltage of Vs/2 at 0g irrespective of supply voltages, selectable bandwidth to suit the application. The tilt angle values are calibrated using a set of known angles from 0^0 to ± 90^0. The observed error is less than ± 1^0 in the measured value. It is within the acceptable range for most of practical application. The same module can be used for tilt angles more than 90^0 (± 180^0), but such cases are rare in real time applications. Further, the pitch angle measurement is identical to roll angle if the Y-output is replaced by the X-output in calculation/

encoding. Hence with the same set up can be modified to ensure the measurement of tilt in two axes. The resolution of 10 bit for ADC is quite adequate for converting the analog voltage into digital data. In many of practical applications it is also necessary to transmit the data acquired to a distant receiver where it is displayed and analyzed, if required.

References:

[1] Chayalakshmi C.L., Krishnamurthy Bhat, B.G.Sheepermatti, "Acceleration & tilt angle measurement using ARM processor and CAN protocol implementation for data transmission", 3rd national control instrumentation system conference, Nov. 03-04-2006, pp. 85-88.
[2] S. Furber, Book on "ARM system-on-chip architecture", 2nd edition, Addison-Wesley, 2001
[3] John Catsoulis, Book on "Designing embedded hardware",O'Reilly, 2005
[4] Michael Bazzarelli, Nelson G.Durdle, Edmond Lou, J.James Raso, "A wearable computer for physiotherapeutic scoliosis treatment", IEEE trans. Inst. & measurement, Vol.52,No.1,Feb.2003, pp.126-129.
[5] John Leavitt, Athanasios Sideris, James E.Bobrow, "High bandwidth tilt measurement using low cost sensors", http://gram.eng.uci.edu/~bobrow/papers_files/J36.pdf
[6] S.J.Sherman, W.K.Tsang, T.A.Core, D.E.Quinn, "A low cost monolithic accelerometer", 1992 IEEE symposium on VLSI circuits digest of technical papers, pp.34-35.
[7]Rodger Richey, "Measure tilt using PIC16F84A & ADXL202", Microchip Technology Inc, 1999
[8]"Vehicle operator safety: The advantages of using electronic sensors in off- road vehicles", http://www.automation.com/sitepages/pid1641.php
[9] A report from Bruel & Kjaer, "Selecting a rightaccelerometer", http://www.bksv.com/default.asp?ID=3859
[10] Rahul Prakash Mundke, "Driver rating system usingb data recorder", Library Archives,IIT Bombay,India
[11] Timothy Liu, University of Queensland, October2001 "Interfacing of a tilt sensor to personal digital assistant", http://innovexpo.itee.uq.edu.au/2001/projects/s369518/thesis2.pdf
[12] Adrian David Cheok, Krishnamoorthy Ganesh Kumar and Simon Princ, "Microaccelerometer based hardware interfaces for wearable computer mixed reality applications", 6th International Symposium on Wearable Computers 2002, pp. 223-230
[13]Hung-Chi Chung, Tomoyuki Enomoto1, Masanobu Shinozuka, Pai Chou, Chulsung Park, "Real time visualization of structural response with wireless mems sensors", 13th World conference on earthquake engineering, Canada, 2004, pp.121 http://shino8.eng.uci.edu/Papers_2005/13WCEE_MEMS.pdf
[14] Bo Enstedt, Royal institute of technology, "Vehicle performance measurement using inertial navigation", http://www.ee.kth.se/php/modules/publications/reports/2003/IR-S3-EX-0310.pdf
[15] Vladimir Kozitsky , "Secure solar power source", http://instruct1.cit.cornell.edu/courses/eceprojectsland/STUDENTPROJ/2003to2004/vk44/Secure%20Solar%20Power%20Source.pdf
[16]http://www.analog.com/en/prod/0%2C2877%2CADXL322%2C00.html, for data sheets of ADXL322.
[17]http://www.arm.com/products/CPUs/ARM7TDMIS.htmlfor ARM 7TDMI-S
[18] http://www.nxp.com/pip/LPC2119FBD64.html, for ARM processor LPC 2129.
[19]http://www.keil.com/support/man/docs/mcb2100/mcb2100_examples.htm, for programming.