1. Introduction

3D tracking of a point in real-time has many applications in the world of simulators. Various readymade tracking systems are available which provide a high degree of accuracy but these are very costly. We have analyzed various cost-effective solutions available with which we could build such a tracking system. After a detailed analysis we propose a 3D tracking system for weapons using MEMS Linear Accelerometers and MEMS Gyroscope. The proposed model would provide 3D tracking of moving weapons in real-time, with a high degree of accuracy and that too on a Microsoft Windows XP platform.

1.1 Terms of Reference

The terms of reference of the project are:

- Real-Time 3D tracking of moving weapons by getting their orientation in space.
- Accuracy - at least 1mm on screen (maximum 10 m from weapon).
- Components should be COTS and readily available.
- Sensitivity
    - Linear Accelerometer – around 1000mV/g for 2g.
    - Gyroscope – around 12.5 mV/°/s at 150°/s
- Speed – Overall around 100-200 Hz
- Indigenous
- Easy to integrate and use

2. Study of various technologies available

The various technologies that were analyzed are:

- **Optical and IR**: Trackers can be built using cameras or other position-sensitive optical devices to track IRED beacons, and using laser range measurement techniques. Both methods tend to provide reasonable range, accuracy and resolution, but suffer from line-of-sight restrictions, reflections and very high cost. The light source generates light of a frequency that the light sensor is best able to detect, and that is not likely to be generated by other nearby sources. Infra-red light is used in most optical sensors. To make the light sensing system more foolproof, most optical proximity sensor light sources pulse the infra-red light on and off at a fixed frequency. The light sensor circuit is designed so that light that is not pulsing at this frequency is rejected.

- **Magnetic:** It does not have the line-of-sight problems of optical and ultrasonic systems. The biggest problems with magnetic systems are distortions caused by metal objects, and a very rapid decrease in accuracy and resolution with distance. Magnetic sensors emit pulses as they detect positional changes. Magnetic sensors consist of magnets embedded in the moving object, and stationary coils. The magnets might be in the vanes of a turbine flow meter or in the teeth of a gear. As the magnets move past the coils, they induce a voltage in the coil. A controller can count these pulses during a time interval to determine speed.

- **Ultrasonic and RF:** Time-of-flight trackers can have relatively large range at low cost, but are geometry specific and require a reference point to be defined. The need to wait for echoes to die out before initiating a new measurement can cause low update rates, particularly when tracking large volumes.

- **Semi-Magnetic Fluid:** These are less accurate than the MEMS based inertial sensors. A glass or plastic vial is filled with a conductive fluid; electrodes in the fluid are used to sense a resistance and as the device is tilted the resistance changes. One problem with these sensors is their sensitivity to shock, vibration and lateral accelerations. These signals cause the liquid to slosh around in the vial producing a non-usable signal from the tilt sensor. These sensors typically have a response as poor as 0.5 to 1hz, about 50 times less then required for quality input.

- **MEMS Linear Accelerometer:** It enables us to measure the accelerations of three orthogonal axes of vibration simultaneously on lightweight structures (Refer fig 1). The accelerations can be integrated to obtain the velocity and distance of the object and hence its position. The reference point problem is also solved as the previous point itself is the reference to the next point. It offers low jitter, fast response, increased range, and greatly reduced problems due to interference or line-of-sight occlusion. Accelerometers measure the force required to cause a mass to accelerate. The housing of the accelerometer is rigidly attached to the object that is being accelerated. Inside the housing, a known mass is centered by an arrangement of springs. Because of its inertia, the mass does not accelerate as fast as the housing, so there is a displacement of the mass from the accelerometer center. The amount of displacement, which is proportional to the acceleration moving the housing, can be measured with a position sensor.

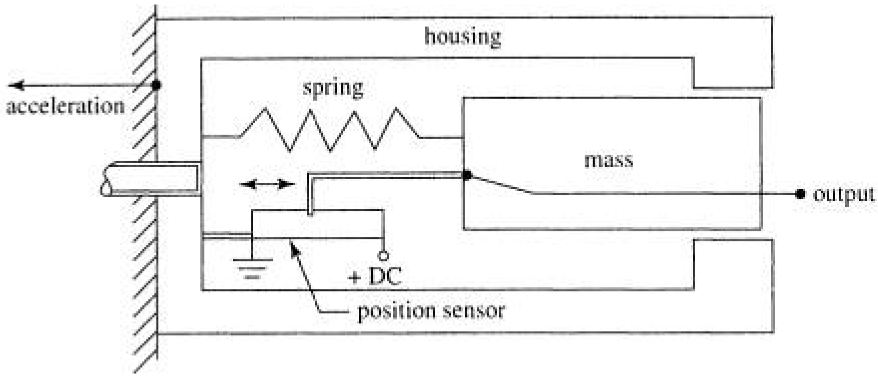


Fig 1
Overview of a Linear Accelerometer

- **MEMS Gyroscope:** Inertial angular rate sensors (gyroscopes(Refer fig. 2) for orientation tracking, offer great advantages as self-contained, fast and noiseless measurements can be made and the reference point problem can be removed. It is also desirable to track position, and the aforementioned advantages would theoretically apply as well to a 6-DOF tracking system built with gyros to determine orientation and accelerometers to measure changes in position.

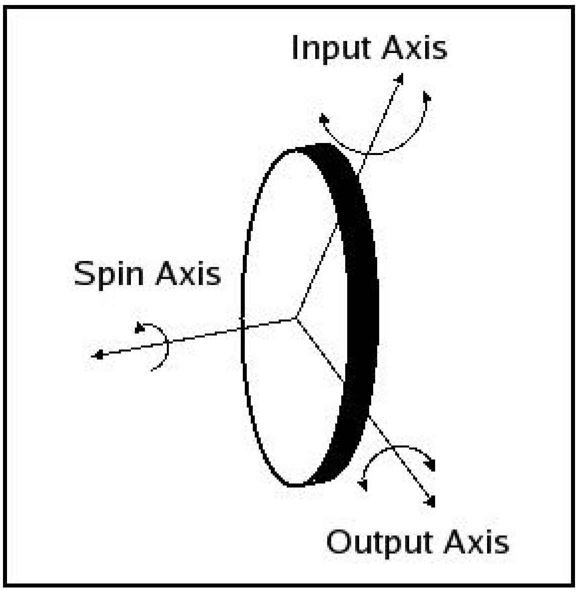


Fig 2
Overview of a Gyroscope

2.1 Products available for different Technologies

The following is a list of products available for various technologies:

Optical and IR:

- Laser BIRD2
- Hy-BIRD
- HiBall-3100
- Precise Position Tracker(PPT)

Magnetic:

- Liberty
- Fastrak
- pciBird
- Flock of Birds
- Flock of Birds ClassB
- Nest of Birds

Ultrasonic and RF:

- PCTracker
- Logitech
- Tracker
- IS-600Mark 2

MEMS Linear Accelerometer:

- ISOTRON - Bruel & Kjaer
- General Purpose Deltatron Accelerometers – Bruel & Kjaer
- i-TEDS Accelerometer – Bruel & Kjaer
- MA21, MA341, MA342 Single-axis – Honeywell Sensotec
- KXM52, KXP74, KXPA4 – Kionix

MEMS Gyroscope:

- KGF01 – Kionix
- ADXRS300/ADXRS150/ADXRS401 – Analog Devices
- InertiaCube2 – Inter Sense
- InertiaCube3- Inter Sense
- IS1200VisTracker- Inter Sense

2.2 Disadvantages of various Technologies

The disadvantages of the various technologies studied are described below:

- Optical and IR – Line of Sight Problem, Process Intensive, Expensive.
- Semi-Magnetic Fluid – Less accurate than Gyroscope and the spilling problem of the liquid.
- Magnetic – Low Range (Max 4ft) and Environment sensitive.
- Ultrasound and RF – Reference point required, Geometry-specific.

3. System study

A through study of the proposed model has been done which is described below:

3.1 Study of the model used

Based on the specification required and the advantages and disadvantages of the various technologies the best suited for our design is the MEMS based linear accelerometer and gyroscopes (Refer fig 3). The linear accelerometers are available both in packages and also IC based. The requirement is to obtain the orientation of the moving weapon in terms of the 6 degree of freedom (i.e. x, y, z, Y, P and R), the tracking can be done by following methods:

- Using two linear accelerometers on both ends of the weapon.
- Using one linear accelerometer on one end and one gyroscope on the other end

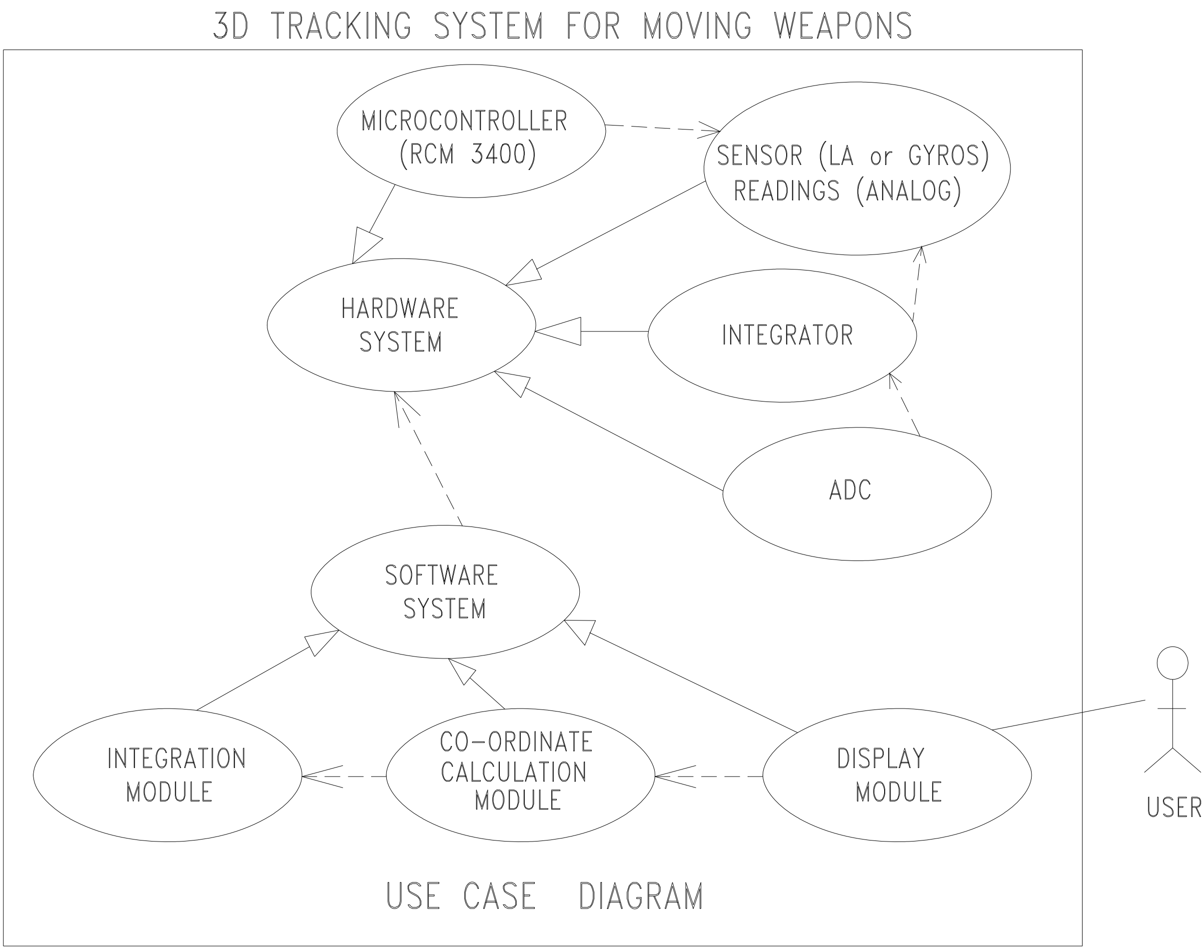


Fig 3
UML – Use Case Diagram of Proposed 3D Tracking System for Moving Weapons

3.2 Description of Design

The following methods will be followed in the implementation of this real-time system:

Method 1

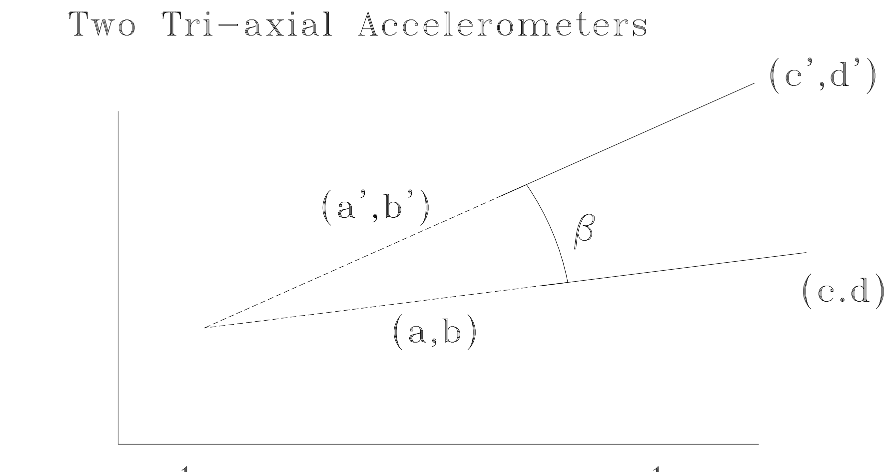
The default method we would use is to place two linear accelerometers on both ends (muzzle and butt) of the weapon. The acceleration (in terms of voltage) of the weapon given by the linear accelerometer can be integrated twice to get the distance and hence the position of the weapon (Refer fig 4). This double integration can be done by either an integrator circuit (using Op-amps) or by a micro-controller (Rabbit Core Module 3400) mounted on the weapon.

When using RCM 3400, appropriate programs would be written and compiled using Dynamic C for double integration of input analog signals and transmission of digital signals to a computer system using either Wi-Fi (wireless) or Ethernet 10/100 (wired).

When using an integrator circuit for double integration, the analog-to-digital conversion would be performed by an appropriate ADC circuit (ADI or Maxim ADC ICs) and then transmitted to a computer system through the serial port.

The conversion of signals from analog-to-digital form on the weapon (near the sensors), eliminates the use of any signal conditioning circuits. Also, the analog-to-digital conversion cannot take place at a place far away (e.g. in the computer system) from the sensor because the resistance of the wires will vary with the length and twists of the wires. The vacillation of the resistance will eventually induce errors in the voltage readings.

The conversion from voltage to distance and display of co-ordinates of the weapon would be done on a computer system using software written in C language (Refer fig 4 and fig 5).



$$\beta = \tan^{-1}[(d'-a')/(c'-b')] - \tan^{-1}[(d-a)/c-b)]$$

Fig 4
Geometrical Calculations in Method 1

Method 2

This method involves the use of one set of tri-axial linear accelerometers and one set of tri-axial gyroscopes on the muzzle side of the weapon. The linear accelerometers give the acceleration of the muzzle and the gyroscopes give the angular velocity of the muzzle (Refer fig 5). Double integration of the acceleration and single integration of the angular velocity would give the x, y and z co-ordinates and yaw, pitch and roll of the muzzle. This data can be used to compute the orientation of the weapon in space (Refer fig. 6 and fig. 7). The rest of the design of the system using this method is the same as that in the first method described above.

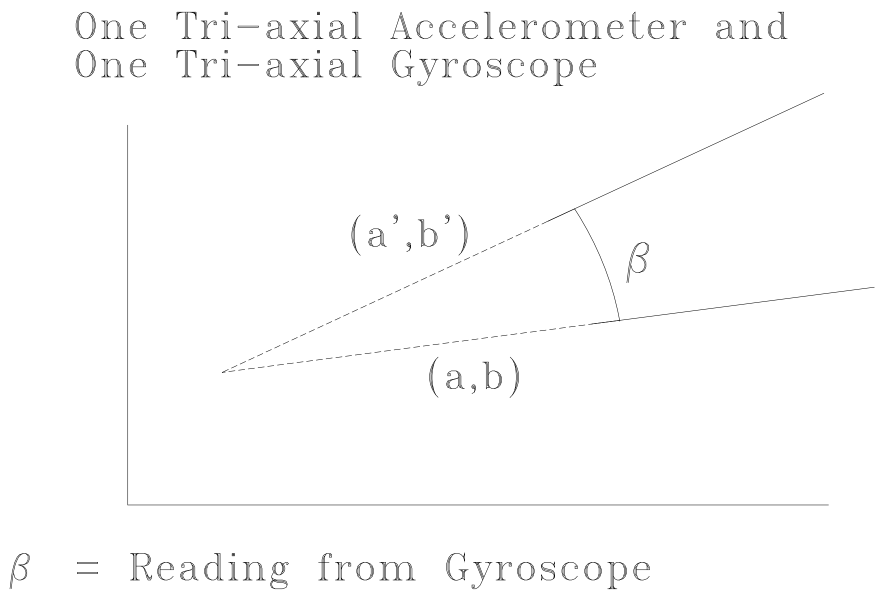


Fig 5
Geometrical Calculations in Method 2

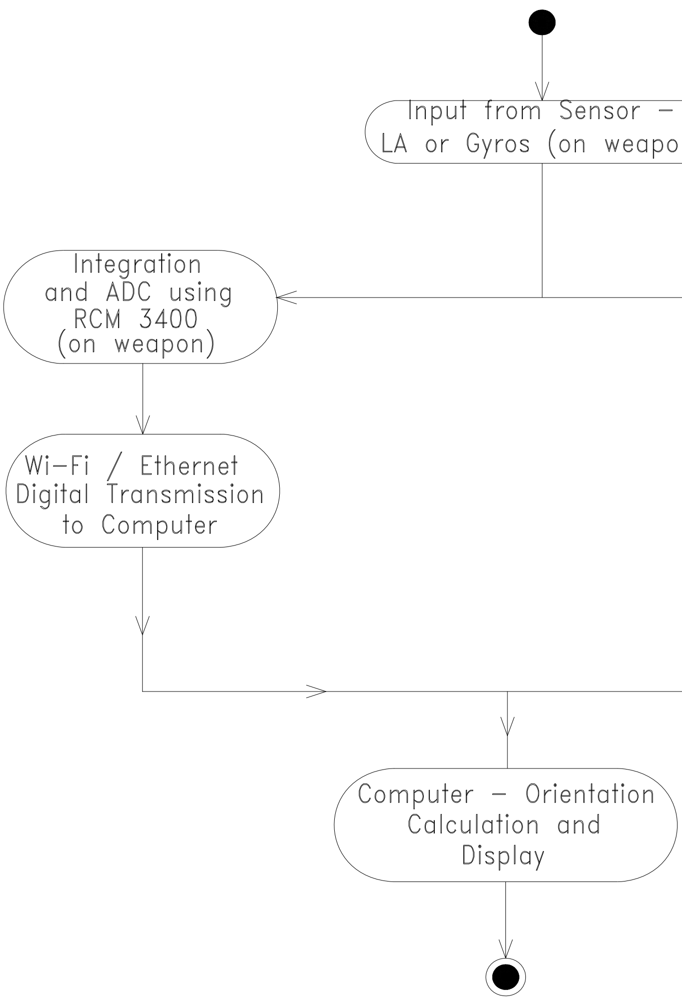


Fig 6
UML – Activity Diagram of Proposed 3D Tracking System for Moving Weapons

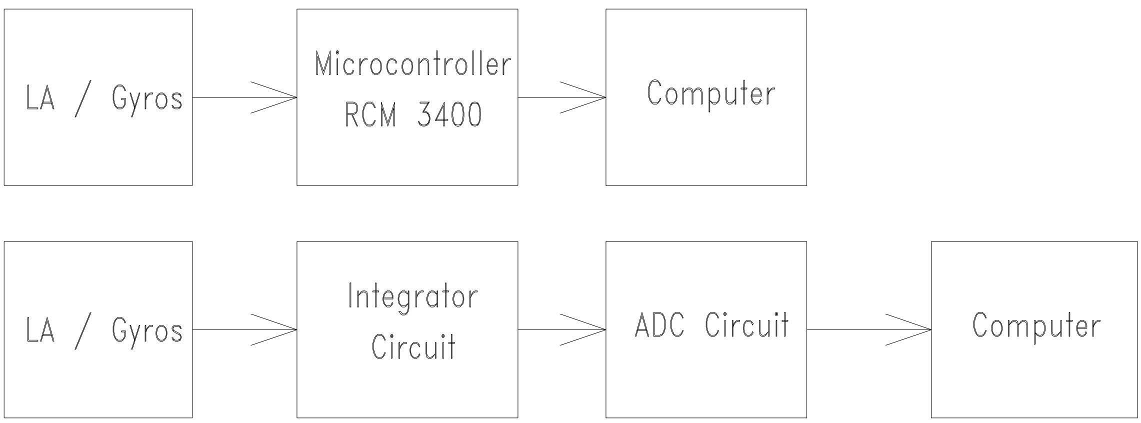


Fig 7
Overview of Components for Proposed 3D Tracking System for Moving Weapons

4. Description of components used

Various components which have been used in this project are described below:

4.1 ADIS16003 Linear Accelerometer

The ADIS16003 (Refer fig. 8) is a low cost, low power, complete dual-axis accelerometer with an integrated serial peripheral interface (SPI) [1]. An integrated temperature sensor is also available on the SPI interface. The ADIS16003 measures acceleration with a full-scale range of ±1.7 g (minimum) and it can measure both dynamic acceleration (vibration) and static acceleration (gravity).

- The typical noise floor is 110 μg/√Hz, allowing signals below 1 mg (60 Hz bandwidth) to be resolved.
- The bandwidth of the accelerometer is set with optional capacitors C X and CY at the XFILT and YFILT pins.
- An externally driven self-test pin (ST) allows the user to verify the accelerometer functionality.
- The ADIS16003 is available in a 7.2 mm × 7.2 mm × 3.6 mm, 12-terminal LGA package.

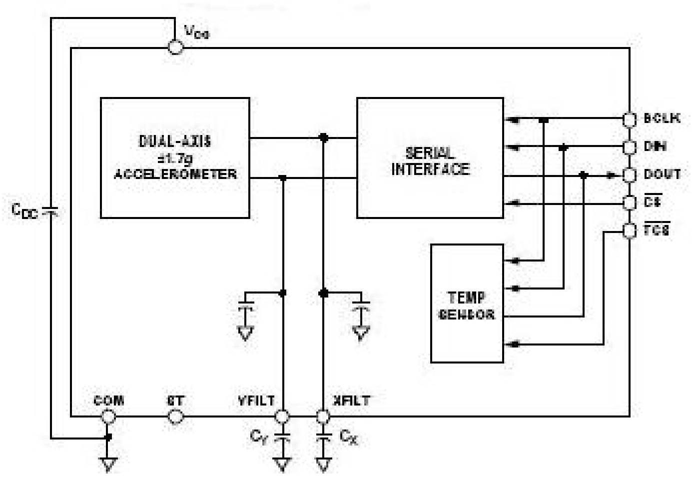


Fig 8
Functional Block Diagram of ADIS16003

4.1.1 Pin configuration and function descriptions

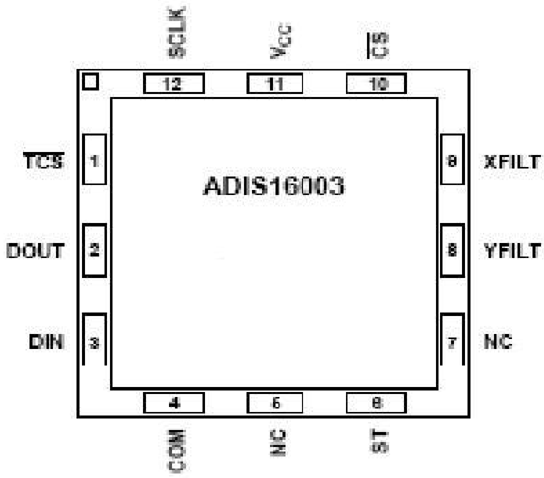


Fig 9
Pin configuration of ADIS16003

Table I
Pin Functional Description

Pin No.	Symbol	Description
1	TCS	Temperature Chip Select. Active Low logic input. This input frames the serial data transfer for the temperature sensor output.
2.	DOUT	Data Out, Logic Output. The conversion of the ADIS16003 is provided on this output as a serial data stream. The bits are clocked out on the falling edge of the SCLK input.
3.	DIN	Data In, Logic Input. Data to be written into the ADIS16003's control register is provided on this input and is clocked into the register on the rising edge of the SCLK input.
4.	COM	Common. Reference point for all circuitry on the ADIS16003.
5,7	NC	No Connection.
6.	ST	Self-Test Input. Active high logic input. Simulates a nominal 0.75 g test input for diagnostic purpose.
8.	YFILT	Y-channel Filter Node. Used in conjunction with an optional external capacitor to band-limit the ac signal from the accelerometer
9.	XFILT	X-channel Filter Node. Used in conjunction with an optional external capacitor to band-limit the ac signal from the accelerometer
10.	CS	Chip select. Active low logic input. This input provides the dual function of initiating the accelerometer conversions on the ADIS16003 and frames the serial data transfer for the accelerometer output.
11.	V_{oc}	Power Supply input. The V_{oc} range for the ADIS16003 is from 3.0V to 5.25V.
12	SCLK	Serial Clock, Logic Input. SCLK provides the serial clock for accessing data from the part and writing serial data to the control register. This clock input is also used as the clock source for the ADIS16003's conversion process.

4.1.2 Serial Interface

The serial interface on the ADIS16003 consists of five wires, CS, TCS, SCLK, DIN, and DOUT, with the temperature sensor's serial interface in parallel with the accelerometer's serial interface (Refer fig. 9 and fig. 10). The CS and TCS are used to select the accelerometer or temperature sensor outputs, respectively. CS and TCS cannot be active at the same time. The SCLK input accesses data from the internal data registers. The SCLK input accesses data from the internal data registers.

The Self-Test pin controls the self-test feature. When this pin is set to VCC, an electrostatic force is exerted on the beam of the accelerometer. The resulting movement of the beam allows the user to test if the accelerometer is functional. The typical change in output is 750 mg (corresponding to 614 LSB) for VCC = 5.0 V. This pin may be left open-circuit or connected to common in normal use. The ST pin should never be exposed to voltage greater than VCC + 0.3 V. If the system design is such that this condition cannot be guaranteed (for example, multiple supply voltages present), a low VF clamping diode between ST and VCC is recommended.

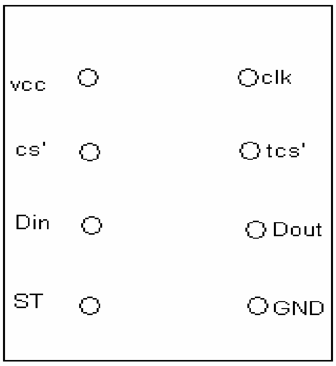


Fig 10
Pin configuration of evaluation board

Table II
Accelerometer control register

MSB							LSB
DONTC	ZERO	ZERO	ZERO	ADD0	ONE	ZERO	PM0

Accelerometer Control Register Bit Functions

Bit	Mnemonic	Comments
7	DONTC	Don't care. Can be one or zero.
6, 5, 4	ZERO	These bits should be held low.
3	ADD0	This address bit selects the x-axis or y-axis outputs. Zero selects the x-axis; one selects the y-axis.
2	ONE	This bit should be held high.
1	ZERO	This bit should be held low.
0	PM0	This bit selects the operation mode for the accelerometer; set to zero for normal operation and one for power down mode.

The serial clock provides the conversion clock. CS initiates the data transfer and conversion process and frames the serial data transfer for the accelerometer output. The accelerometer output is sampled on the second rising edge of the SCLK input after the falling edge of the CS. The conversion requires 16 SCLK cycles to complete. The rising edge of CS puts the bus back into three-state. If CS remains low, the next digital conversion is initiated.

4.2 Microcontroller – RCM3200

The RCM3200 Rabbit Core modules [5] are designed for use on a customer-supplied motherboard that supplies power and interfaces to real-world I/O devices. Their two 34-pin connection headers provide 52 parallel user I/O lines, shared with five serial ports, along with control lines. A sixth serial port and one additional I/O line are available on the programming header (Refer fig. 11).

The RCM3200 is equipped with

- 10/100Base-T Ethernet port,
- 512K flash memory,
- 512K program execution SRAM, 256K data SRAM
- Real time clock speed of 44.2MHz
- Watchdog supervisor

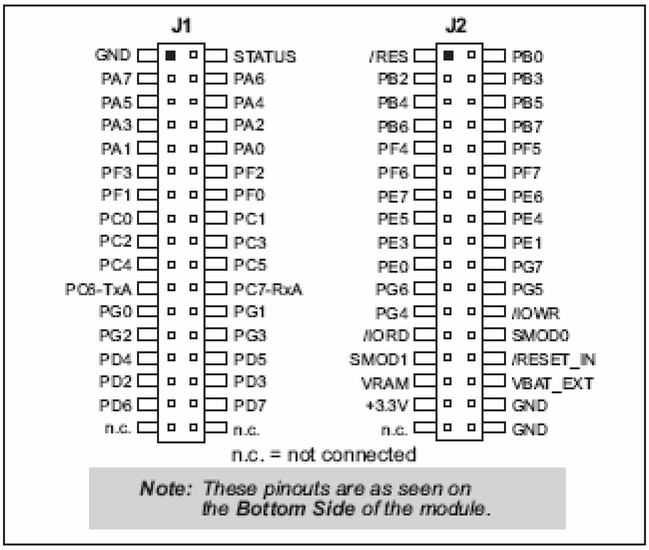


Fig 11
Headers J1 and J2 of RCM3400

The Prototyping Board included in the Development Kit makes it easy to connect an RCM3200 module to a power supply and a PC workstation for development. It also provides some basic I/O peripherals (switches and LEDs), as well as a prototyping area for more advanced hardware development.

Prototyping Board Features:

- Power Connection

- Regulated Power Supply
- Power LED
- Reset Switch
- I/O Switches and LED
- Prototyping Area
- Master Module Connectors
- Slave Module Connectors
- Module Extension Headers
- RS-232
- Current Measurement Option
- Motor Encoder
- LCD/Keypad Module

4.3 DIO Card – PCI-1202

The OME-PCI-1202(H/L) is high performance, multifunction analog and digital I/O PCI boards for PC and compatible computers [6]. PCI-1202 boards provide a 110K samples/second acquisition rate and a 2Kword FIFO. The data acquisition will be under DOS and Windows 95/98/NT/2000/XP.

Features

The general features of PCI-1202/1602/1800/1802 series are given as follows:

- Bus: 5V PCI (Peripherals Component Interface) bus.
- A/D:
  - PCI-1202(/L): A/D converter = 110K samples/second
    PCI-1202(H): A/D converter = 44K samples/second

  - 32 single-ended / 16 differential analog inputs for PCI-1202H/L.
  - Three different A/D triggers: software, pacer and external trigger
  - Provides three different external triggers: pre-trigger, middle-trigger and post-trigger
  - Programmable input signal configuration.
  - Provides “MagicScan“ function
  - FIFO: 2K for PCI-1202(H/L)/1800(H/L)

- D/A:

  - Two channels independent 12 bits DACs.
  - Bipolar voltage output with +/-5V or +/- 10V jumper selectable.
  - High throughput: refer to chapter 10.

- DIO:

  - 16 channels TTL compatible DI and 16 channels TTL compatible DO .
  - High speed data transfer rate: refer to chapter 10.

- Timer:

    - Three 16-bits timer/counter (8254).
    - Timer 0 is used as the internal A/D pacer trigger timer.
    - Timer 1 is used as the external trigger timer.
    - Timer 2 is used as the machine independent timer for settling time delay.

5. Testing of the linear accelerometer – ADIS 16003

We have tested the sensor on various platforms. The method followed and results for each test are described below:

5.1 On C. R. O. (Oscilloscope)

1. Connected the SCLK to a 10 kHz clock signal from the breadboard.
2. Connected the DOUT as an input to the oscilloscope.
3. Connected DIN pin to 1 and 0 to see the output change.
4. Connected the common signal to ground of breadboard and oscilloscope.
5. Gave a constant logic low (0) signal to the CS pin.
6. Connected V_{cc} to 5V power supply.
7. Connected ST (self test) pin to 1 and 0 to see the change in output.
8. Connected TCS to high and low one after another to see the output change in the oscilloscope.

Expected Results:

- The output taken from DOUT pin and is displayed on the oscilloscope having 12 T states, followed with a stop and start bits.
- By giving self test as 1, the IC should simulate a nominal 0.75 *g* test input for diagnostic purpose.

Results observed:

- The DOUT signal is same as the clock signal with a frequency of 500 HZ.
- The Self-Test Pin when high simulates a nominal 0.75 g test input for diagnostic purpose.
- No output is obtained when the TCS pin is low.
- IC is disabled when CS signal is high.

5.2 On serial port

The following method was used to test the ADIS16003 IC on a computer through the serial port [2] using three serial port software applications, namely MTTY [4], Advanced Serial Port Monitor [3], and ActiveComport [7]:

- Make the null modem connection of the serial port with DTR, DSR, and CD short to each other, RTS and CTS short to each other, and SG connected to common ground (Refer fig. 12).

- From serial port connect the transmit data (TD) to DIN pin, and receive data (RD) to DOUT pin of the IC ADIS16003.

- Connect the evaluation board pins V_{cc} to 5V, clock to 10KHz, GND to common ground, chip select to logic high (binary 1) from bread board and leaving rest of the pins as NC.

- Use the RD to send activation data to the IC through the DIN pin. This activation data (10000100 or 00000100) is necessary to initialize the output from the IC.

- Then the output from the DOUT pin is displayed on the monitor using the above mentioned software.

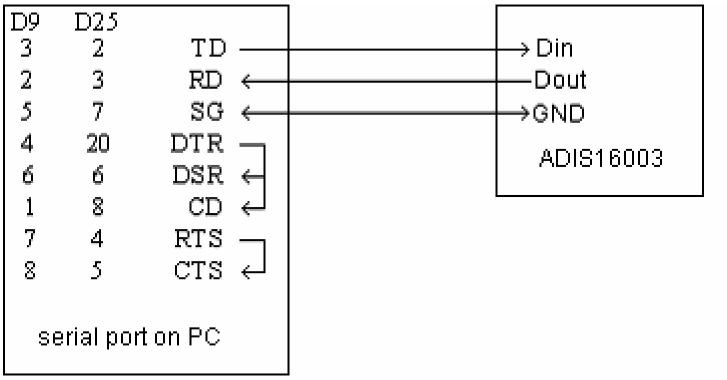


Fig 12
Null Modem Wiring Diagram

Data (10000100 or 00000100) for activating the IC is being sent successfully but in reality the IC is not getting activated at all as no output is being received from it. When the IC is connected with the serial port, all the pins of the serial port, except Receive data (Rxd), are active.

5.3 On the DIO card – PCI 1202

We also tried to test the ADIS16003 IC on a computer using a PCI 1202 DIO card. The following method was used for this test:

- Connect the V_{cc}, GND, DIN and DOUT pin of the IC to connectors CON1 and CON2 of the PCI 1202 DIO card
- Connect the evaluation board pins clock to 10 KHz clock and chip select to logic high (binary 1) from bread board and leaving rest of the pins as NC.

- The output is displayed on the PC monitor using the Visual C++ program we have written. This program makes use of PCI 1202 library and header files.

Code fragment for DIO through PCI 1202:

```
WORD P1202_Di(WORD *wDi)
{
*wDi=inport(wAddrDio)&0xffff;
return(NoError);
}
```

The above code fragment illustrates how the program reads input values of the IC through the PCI 1202 DIO card. The port address *wAddrDio* is used to read the input values into *wDi*.

The program we had written could not compile in Visual C++ due a corrupt library file of the DIO card. We could find a working version of the library file even after extensively searching on the internet and the resources at SDD. Moreover, sometimes even the DIO card was not being detected by the PC.

5.4 On RCM3200

The following method was used to test the ADIS16003 IC on a Rabbit Core Module (RCM) 3200 through the serial port using an appropriate program written in Dynamic C to interface the serial port:

- Install Dynamic C on a PC
- Attach the RCM 3200 to the prototyping board
- Connect programming cable to the prototyping board
- Attach the IC to the serial port (Serial port B) of the prototyping board by connecting transmit data (TD) of IC to receive data RD of Serial port B and RD of IC to TD of Serial port B.
- Connect the power cable of the prototyping board and provide power
- We have written a program in Dynamic C to interface the serial port. Thus, this program was run from the PC to read data from the IC and display on the PC monitor.

Code fragment for DIO through serial port of RCM 3200:

```
brdInit();                    //initialize board for this demo
serBopen(115200L);            //set the baud rate at 115.2 Kbaud
in1=serBgetc();               //receive data from ser port B
printf (“%c was received through Serial port B”, in1); //print data
```

The above code fragment illustrates how to read data from Serial port B of RCM 3200 and display on the monitor.

This test shows abnormal output because usually serial port can take a maximum of 8 consecutive inputs of data bits but in this case the output of the ADIS16003 is 16 bits of data, as a result the format error occurs at the serial port. Moreover, there is no output coming from the sensor so we are not able to test its proper working even by receiving junk data from it.

6. Conclusions

The use of high accuracy MEMS based sensors would have made the whole system accurate and robust. Unfortunately, due to unavoidable circumstances (logistic problems in importing), we did not get the production version sensors we had asked for. Meanwhile, we received pre-release (experimental) free samples of sensors from Analog Devices which we thought would work according to our requirements. But no application note for the sensor was available and the data sheet that was available was incomplete and not comprehensive. Also the data sheet was changed after a month. Thus we were never sure about the proper configuration and setup of the sensor so that it would get initialized and start providing proper output.

Even then we tried to test the sensor (ADIS16003 IC) on an oscilloscope, serial port of a PC, PCI 1202 DIO card, and RCM 3200 but were able to get any output data from the sensor. The only success we had was that while testing on the serial port of a PC, we were able to send properly the initialization byte to the IC but never received any data from it.

The primary reason for the incomplete status of this project is our reliance on a non-reliable experimental sensor. We believe that we could have made a lot of progress in this project had we got the production (stable) IC and hope that the next batch gets to work with stable and not experimental ICs. In this connection, we are adding our observations here.

- When we look at performance, sensors of any type are not available locally or in India.
- When we start depending on importing sensors, hope does not exist in sight in getting those sensors before we reach our deadlines due to the delays involved in purchasing as well as the existing unpredictability of the local suppliers in procuring the same in time.
- We believe that getting these sensors is beyond our capabilities and we sincerely hope that concerned parties adapt planned strategies in meeting the basic needs of the coming interns.

Parametric Evaluation of Products

- Linear Accelerometer - ADI ADXL 203 / ADXL 204
    - Sensitivity - 1000 mV/g
    - Accuracy - 60 µg RMS
    - Error due to drift negligible (ambient temp around 25 °C)
    - In distance terms 0.006% (Refer fig below)

- Gyroscope - ADI ADXRS300 / ADXRS150 / ADXRS401
    - Sensitivity - 12.5 mV/°/s
    - Accuracy - In distance terms 0.006% (Refer fig 7); Error due to drift negligible (ambient temp around 25 °C)
    - Speed - 150°/s

- Microcontroller – RCM 3400
    - 8 channels single-ended (11-bit) or 4 channels differential (12-bit)
    - Programmable gain 1, 2, 4, 5, 8, 10, 16, and 20 V/V.
    - Speed - 2.5 KS/s
- Error calculation assuming the floor to be of 10m (max.) (Refer fig. 13).

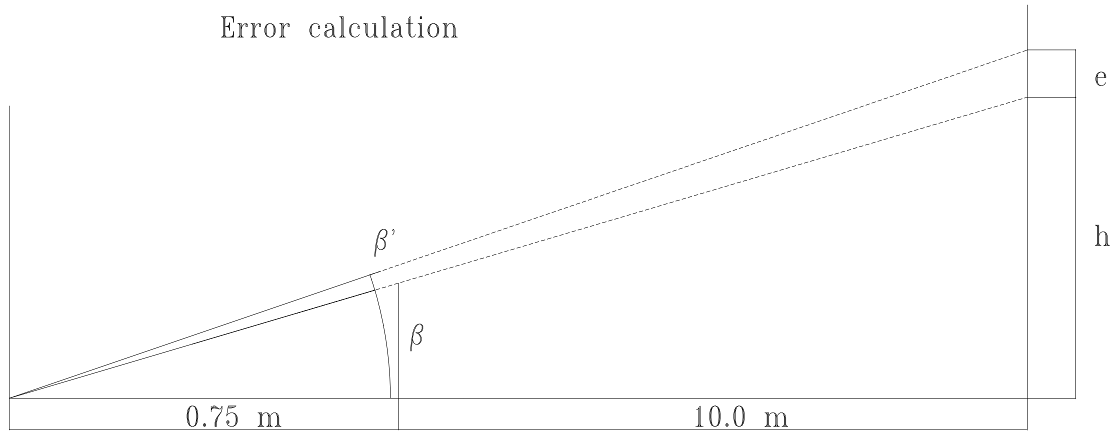


Fig. 13
Geometrical Analysis for Error Calculation

Appendix B

Components required

- IC based Linear Accelerometers (with Evaluation Boards) ADXL 203 / ADXL 204 of Analog Devices (ADI) or KXM52-1050 / KXP74-1050 / KXPA4-1050 (with Evaluation Boards) of Kionix Inc

- Package based Linear Accelerometers of Brüel & Kjær (B & K), Honeywell Sensotec (Model JTF) or Omni Instruments

- IC based Gyroscopes (with Evaluation Boards) ADXRS300 / ADXRS150 / ADXRS401 of Analog Devices (ADI) or KGF01-250 (with Evaluation Board) of Kionix Inc

- Package based Gyroscopes of Omni Instruments

- Rabbit Core Module (RCM 3400) Microcontroller Development Kit with Wi-Fi of ZWorld

- ADC ICs of Maxim or Analog Devices (ADI)

- Op-Amps (for Integrator circuits) of Analog Devices (ADI)

Appendix C

SWOT Analysis of the Project

Strength	High accuracy due to MEMS based Linear Accelerometer and Gyroscope
Weakness	Comprehensive packages do not meet all specifications and are very expensive
Opportunity	Opportunity to make advanced weapon tracking system
Threat	Lead time for required components

Appendix D

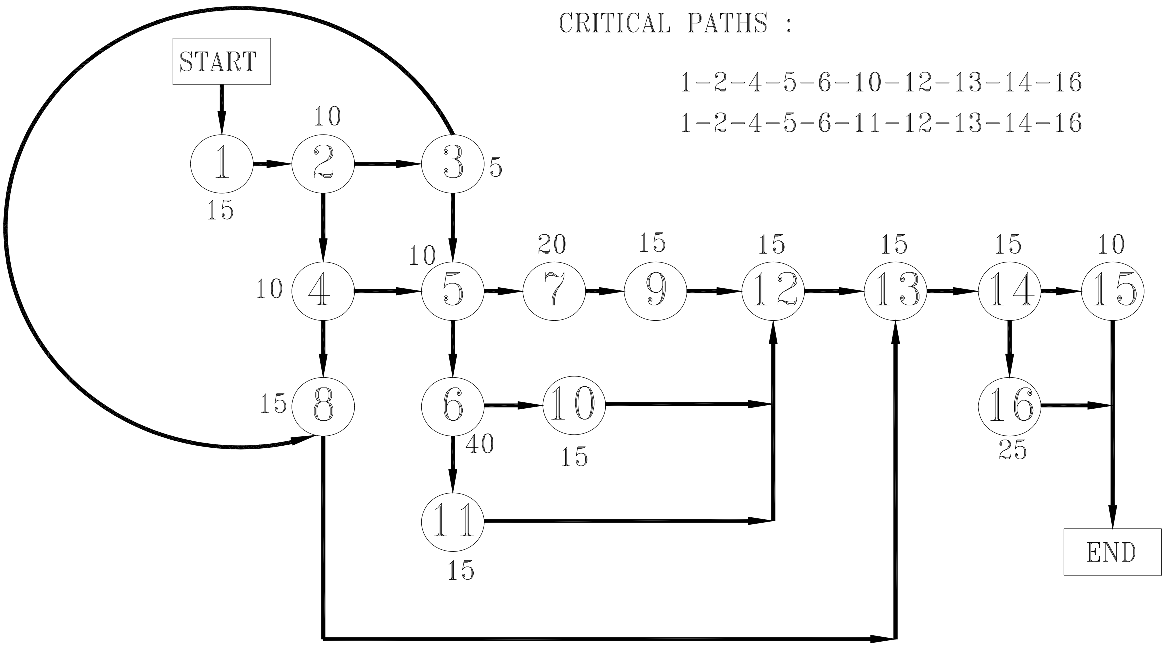
Gantt chart for execution of the project (15th June 2005 to 10th December 2005)

No.	Activity	Person/s	Est. time days	Prede-cessor	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1	Analysis of different technologies and respective products	All	15								
2	Detailed analysis and design of MEMS based systems with required accessories	All	10	1							
3	Feasibility presentation	AS	5	2							
4	Feasibility report	RA	10	2							
5	Quotation and Placement of order	AS	10	3, 4							
6	Procurement of components other than Op-Amps and RCM 3400		40	5							
7	Procurement of Op-Amps and RCM 3400		20	5							
8	Software development through simulated data	AN, AS	15	3, 4							
9	Installation and testing of Integrator and Amplifier Circuits	RA, PA	15	7							
10	Installation and testing of package based Accelerometers, Gyroscopes and RCM 3400	AS, AN	15	6							
11	Installation and testing of IC based Accelerometers, Gyroscopes, and ADC Converters	RA, PA	15	6							
12	Integration and testing of hardware components to implement the hardware system	All	15	9, 10, 11							
13	Finalization of software implementation with real data	AN, AS	15	8, 12							
14	Testing and evaluation of hardware and software systems, independently and as a whole	All	15	13							
15	Preparation of final Project Presentation	AS	10	14							
16	Preparation of final Project Report	RA, PA	25	14							

Legend: AS - Ashish, AN - Anand, RA - Ramvilas, PA - Pavan

Appendix 'E'

Pert Chart for execution of the project



No.	Activity
1	Analysis of different technologies and respective products
2	Detailed analysis and design of MEMS based systems with required accessories
3	Feasibility presentation
4	Feasibility report
5	Quotation and Placement of order
6	Procurement of components other than Op-Amps
7	Procurement of Op-Amps for Integrator and Amplifier Circuits
8	Software development through simulated data
9	Installation and testing of Integrator and Amplifier Circuits
10	Installation and testing of package based Accelerometers, Gyroscopes, and Micro-controllers
11	Installation and testing of IC based Accelerometers, Gyroscopes, and ADC Converters
12	Integration and testing of hardware components to implement the hardware system
13	Finalization of software implementation with real data
14	Testing and evaluation of hardware and software systems, independently and as a whole
15	Preparation of final Project Presentation
16	Preparation of final Project Report

Appendix 'F'

Pricing, availability and vendor contact Details of components required

Order of listing: **Devices, Manufacturers, Models, No of pieces, Pricing, Lead-times and Vendors/Distributors**

Accelerometers:

Manufacturer: **Brüel & Kjær (B & K)**

Models (all package based): In order of preference

4326A
4326A-001
4506
4506B
4506B 001
4506B 002
4506B 003
4513-002
Endevco 63C12
4511-001
4513-001
4513
Endevco 63C13
Endevco 35A

Number of pieces: 4 (any one model)

Price and Lead Time: Please consult vendor

Vendor: Suresh Kolathur
Company Name: Josts Engineering Company Limited
Company Address: 160-D, Patny Nagar Sardar Patel Road Post Box 2106
Zip Code: 500 003
City: Secunderabad
Country: India
Company Phone: +91 40 2790 0300
Company Fax: +91 40 2790 7555
E-Mail: sales@hyd.josts.com, kolathur_suresh@yahoo.co.in
Company Web page: http://www.josts.com

Manufacturer: Omni Instruments, Summit Instruments

All models listed in order of preference.

Models (all package based): Omni Instruments AR02-0300S050
Omni Instruments AR02-0150S050

Number of pieces: 4

Price: GBP 695

Models (all package based): Omni Instruments MAG02-0300S050
Omni Instruments MAG02-0150S050

Number of pieces: 4

Price: GBP 750

Model (package based): Summit Instruments 34203A

Number of pieces: 4

Price: GBP 695 or USD 1095

Model (package based): Summit Instruments 35203A

Number of pieces: 4

Price: GBP 595 or USD 1295

Model (package based): Summit Instruments 23200B

Number of pieces: 8

Price: GBP 249 or USD 325

Model (package based): Summit Instruments 13203B

Number of pieces: 12

Price: GBP 179 or USD 285

Lead-time: Please consult the company

Vendor:

Omni Instruments
UK / Europe Office
Tel +44 (0)8700 43 40 40
Fax +44 (0)8700 43 40 45
info@omniinstruments.co.uk

East Kingsway Business Centre
Mid Craigie Trading Est., Mid Craigie Rd
Dundee, DD4 7RH Scotland UK

And

Omni Instruments
Australia / Asia Pacific Office
Tel +61 (0)894 888 960
Fax +61 (0)894 888 965
info@omniinstruments.com.au
PO Box 105, Leederville
Western Australia, 6902

And

Summit Instruments, Inc
2236 N Cleveland-Massillon Rd
Akron, OH 44333
(330) 659-3312
Email: Sales & Support
Fax: (330) 659-3286

Manufacturer: Honeywell Sensotec

Model (package based): JTF

HONEYWELL SENSOTEC GENERAL PURPOSE ACCELEROMETER

Type: Screw Mount
Order Code: AG 111
Range (In Peak g): 0.5 to 500
Non Linearity and Hysteresis: 1% F.S
Operating Temperature: - 40° F to 250° F
Compensated Temperature: 70°F to 200° F
Excitation: 5 VDC
Triaxial Mounting Block AA235
Electrical Termination: Teflon Cable 5'

Number of pieces: 4

Price: Rs 34,500

Lead time: Immediate

Vendor: ANAND CHITGOPEKAR
Sr. EXECUTIVE – MARKETING
AIMIL LIMITED,
502 BABUKHAN ESTATE,
BASHEERBAGH, HYDERABAD-500 001

Please note: AIMIL Ltd carries Tri-axial Accelerometers of other companies also. Details of these Accelerometers can be had from Mr Anand Chitgopekar, AIMIL Ltd, Hyderabad.

Manufacturer: **Kionix Inc**

Models (all IC based): KXM52-1050 / KXP74-1050 / KXPA4-1050
and Evaluation Boards EVAL-74 / EVAL-1050 / EVAL-A4

Number of pieces: 4

Price and Lead Time: Please consult vendor

Vendors: Beijing Northking Electronic Technology Development Co. Ltd.
No. 6 Jia, Kang Ding Street
Beijing Economic-Technological Development Area, Beijing
100176, China
Tel: 86-10-6785 6600
Fax: 86-10-6785 6123
sales@northking.com or sales@sensors.com.cn
www.northking.com

Corporate Headquarters
Kionix, Inc.
36 Thornwood Drive
Ithaca, NY 14850, USA
Tel 607-257-1080
Fax 607-257-1146
info@kionix.com
www.kionix.com

Note: Please read the accompanying letter (email) from Kionix Inc, USA regarding the export restrictions that apply to them.

Manufacturer: **Analog Devices**

Models (all IC based): ADXL 203 / ADXL 204
and Evaluation Boards ADXL203EB / ADXL204EB.

Number of pieces: 8

Price: USD 12.00
Evaluation Boards USD 30.00

Lead Time: 4-6 weeks

Vendors: BBS Electronics PTE. LTD.
#3005, Emerald House
S.D. ROAD
SECUNDERABAD, 500 003
India.
Tel : (9140) 3090 4074/5533 5402

Fax : (9140) 5533 5403

And

EXCELPOINT SYSTEMS PTE LTD
M/S. MARUTHI CORPORATE POINT
#217, SWAPNALOK COMPLEX S.D. ROAD,
SECUNDERABAD-3 HYDERABAD, 500 003
India
TEL 91 40 5531 9898 TEL2 91 40 2781 1216
FAX 91 40 2781 3456

Gyroscopes

Manufacturer: Omni Instruments

Model (package based): TriRate - Triaxial Gyro

Number of pieces: 4

Price: GBP 535

Lead-time: Please consult the company

Vendor:

UK / Europe Office
Tel +44 (0)8700 43 40 40
Fax +44 (0)8700 43 40 45
info@omniinstruments.co.uk
East Kingsway Business Centre
Mid Craigie Trading Est., Mid Craigie Rd
Dundee, DD4 7RH Scotland UK

And

Australia / Asia Pacific Office
Tel +61 (0)894 888 960
Fax +61 (0)894 888 965
info@omniinstruments.com.au
PO Box 105, Leederville
Western Australia, 6902

Analog Devices

Models (all IC based): ADXRS300 / ADXRS150 / ADXRS401
and Eval Boards ADXRS300EB / ADXRS150EB / ADXRS401EB.

Number of pieces: 12

Price: Approx USD 30.00 / USD 30.00 / USD 22.00
Eval Boards USD 50.00

Lead Time: 4-6 weeks

Vendors: BBS ELECTRONICS PTE. LTD.
#3005, EMERALD HOUSE
S.D. ROAD
SECUNDERABAD, 500 003
India.
Tel : (9140) 3090 4074/5533 5402
Fax : (9140) 5533 5403

And

EXCELPOINT SYSTEMS PTE LTD
M/S. MARUTHI CORPORATE POINT
#217, SWAPNALOK COMPLEX S.D. ROAD,
SECUNDERABAD-3 HYDERABAD, 500 003
India
TEL 91 40 5531 9898 TEL2 91 40 2781 1216
FAX 91 40 2781 3456

Manufacturer: Kionix Inc

Models (IC based): KGF01-250

Number of pieces: 12

Price and Lead Time: Please consult vendor

Vendors: Beijing Northking Electronic Technology Development Co. Ltd.
No. 6 Jia, Kang Ding Street
Beijing Economic-Technological Development Area, Beijing
100176, China
Tel: 86-10-6785 6600
Fax: 86-10-6785 6123
sales@northking.com or sales@sensors.com.cn
www.northking.com

Corporate Headquarters

Kionix, Inc.
36 Thornwood Drive
Ithaca, NY 14850, USA
Tel 607-257-1080
Fax 607-257-1146
info@kionix.com
www.kionix.com

Analog-to-Digital Converter (IC-based)

Manufacturer: Analog Devices

Models: In order of preference

Model	Cost
AD 7738	USD 7.77
Evaluation Board EVAL-AD7738EB	USD169.00
AD7739	USD 7.77
Evaluation Board EVAL-AD7739EB	USD169.00
AD7856	USD 11.65
EVAL-AD7856CB evaluation board package	Please consult vendor

Number of pieces: 10 (any one model), Evaluation Boards - 5

Lead Time: 2-4 weeks

Vendors: BBS ELECTRONICS PTE. LTD.
#3005, EMERALD HOUSE
S.D. ROAD
SECUNDERABAD, 500 003
India.
Tel : (9140) 3090 4074/5533 5402
Fax : (9140) 5533 5403

And

EXCELPOINT SYSTEMS PTE LTD
M/S. MARUTHI CORPORATE POINT
#217, SWAPNALOK COMPLEX S.D. ROAD,
SECUNDERABAD-3 HYDERABAD, 500 003
India
TEL 91 40 5531 9898 TEL2 91 40 2781 1216
FAX 91 40 2781 3456

Manufacturer: Maxim-ic

Models: In order of preference

Model	Cost
MAX1168	USD 9.60
MAX1149	USD 8.55
MAX1148	USD 8.55
MAX1257	USD 30.00
MAX1258	USD 30.00
MAX1221	USD 30.00
MAX1220	USD 30.00
Max1400	USD 20.84

Number of pieces: 6 (any one model)

Lead Time: Please consult vendor

Vendors: **Hyderabad Office**

Arrow Electronics India Pvt. Ltd.,
Chamber #505 , V Floor
3-6-322, Mahavir House
Basheerbagh
Hyderabad - 560 029
India

Tel: (91) 40 5577 4146
Fax: (91) 40 5577 4138

Head Office - Bangalore

Arrow Electronics India Private Ltd.
#26, 4th Floor, Akshaya Commercial Complex,
Victoria Road,
Bangalore - 560047,
India

Tel: (91) 80 5135 3800
Fax: (91) 80 5112 7784

Op-Amps (for Integrator and Amplifier Circuits)

Manufacturer: Analog Devices

Models: In order of preference

Product code	# Amplifiers in Pkg	Vos	Ib	-3dB Bandwidth	V_{cc}-V_{ee} Supply(V)	Iq per Amplifier(max)	Packages	Price(000-4999)
AD8574	4	1µV	10pA	1.5MHz	2.7 to 6	975µA	SOIC, SOP	$3.05
AD8554	4	1µV	10pA	1.5MHz	2.7 to 6	975µA	SOIC, SOP	$3.02
AD8609	4	12µV	0.2pA	400kHz	1.8 to 6	40µA	SOIC, SOP	$1.83
OP2177	2	15µV	500pA	1.3MHz	5 to 36	500µA	SOIC, SOP	$1.51
OP4177	4	15µV	500pA	1.3MHz	5 to 36	500µA	SOIC, SOP	$3.56

Lead Time: 2-4 weeks
Number of pieces: 20

Vendors: BBS ELECTRONICS PTE. LTD.
#3005, EMERALD HOUSE
S.D. ROAD
SECUNDERABAD, 500 003
India.
Tel : (9140) 3090 4074/5533 5402
Fax : (9140) 5533 5403

And

EXCELPOINT SYSTEMS PTE LTD
M/S. MARUTHI CORPORATE POINT
#217, SWAPNALOK COMPLEX S.D. ROAD,
SECUNDERABAD-3 HYDERABAD, 500 003
India
TEL 91 40 5531 9898 TEL2 91 40 2781 1216
FAX 91 40 2781 3456

Microcontroller based Analog-to-Digital Converters

Manufacturer: ZWorld

Models (all IC based): Rabbit Core Module (RCM) 3400 with Wi-Fi attachment

Number of pieces: 2

Price and Lead Time: Please consult vendor

Vendor: Mr.Shiva

Analogic Controls
India Ltd.
#6-1-190/25, Padmarao Nagar
Secunderabad - 500 025
India
Phone: 0091-40-27506102 / 27505768
Fax : 0091-40-27504776

References

1) ADIS16003 Data Sheets (Both old and the newer version)
2) Interfacing the Serial / RS232 Port by Craig Peacock
3) Advanced Serial Port Monitor Reference Manual
4) MTTTY Reference Manual
5) RCM 3200 Reference Manual
6) PCI 1202 DIO card Reference Manual
7) ActiveComport Reference Manual.