Kionix, Inc.

Wireless Demo Board Kit

User's Manual

September 21, 2007

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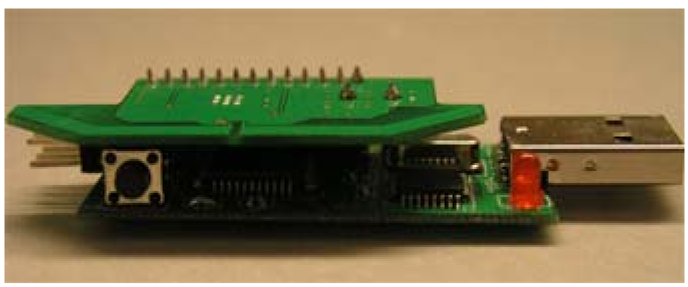
I. Zigbee™ - IEEE 802.15.14 wireless standard

Technical Overview

ZigBee™ is a new global standard for wireless connectivity, focusing on standardizing and enabling the interoperability of consumer electronic products as well as building automation and industrial control and monitoring. ZigBee™ is built on the robust radio (PHY) and medium access control (MAC) communication layers defined by the IEEE 802.15.4 standard. Above this, ZigBee™ defines mesh, star and cluster tree network topologies with data security features and interoperable application profiles.

The ZigBee™ specification provides a cost-effective, standards-based wireless networking solution that supports low data rates, low power consumption, security and reliability. ZigBee™ technology combines interoperable hardware and software to help make the design process easy and efficient. ZigBee™ technology is suited to a variety of markets including sensor networks.

Product Specifications

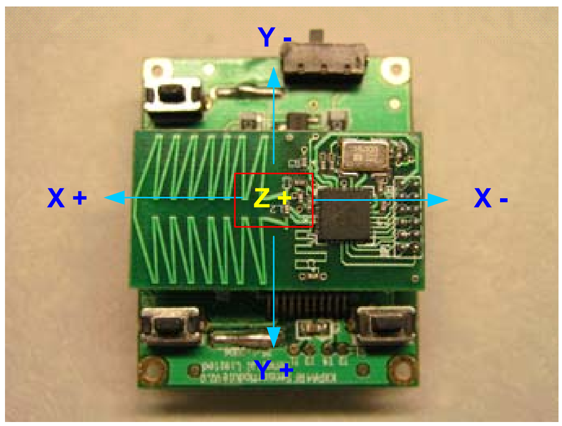


Kionix USB Transceiver

Features:	**Specifications:**
Freescale MC13191 chipset	16 RF channels
Seven general purpose input/output (GPIO) signals	Frequency: 2.4GHz to 2.4835GHz
DSSS Modulation	Indoor Range: 20–40 meters
13 I/O pins for MCU connection	Outdoor Range: 80-100 meters
Four internal timer comparators available to reduce MCU resource requirements	Supports 250 kbps O-QPSK in 5.0 Mhz channels and full spread-spectrum encode and decode
Programmable frequency clock output for use by MCU	RX sensitivity of -91 dBm (typical) at 1.0% packet error rate
Supports MC9S08GT16	Vdd = 3.3V
Supports point-to-point communication	Three power-down modes 0.2 µA Off current 2.3 µA Typical Hibernate current 35 µA Typical Doze current (no CLKO)

Features:	Specifications:
Supports point-to-multipoint communication	Physical / Environmental: Physical size (L * W * H): 52 * 22 * 6mm Operating temperature: -40 °C to 85 °C Storage temperature: -40 °C to 85 °C Humidity: 10% - 90%
Small 52x22x6 mm form factor	Power requirements: 500 µA Idle 30 mA Transmit mode 37 mA Receive mode

- The demo board is powered by a CR2450, 3 volt battery.
- The sensor runs at a bandwidth of 50Hz.
- The demonstration programs read samples at about 50 samples/second.

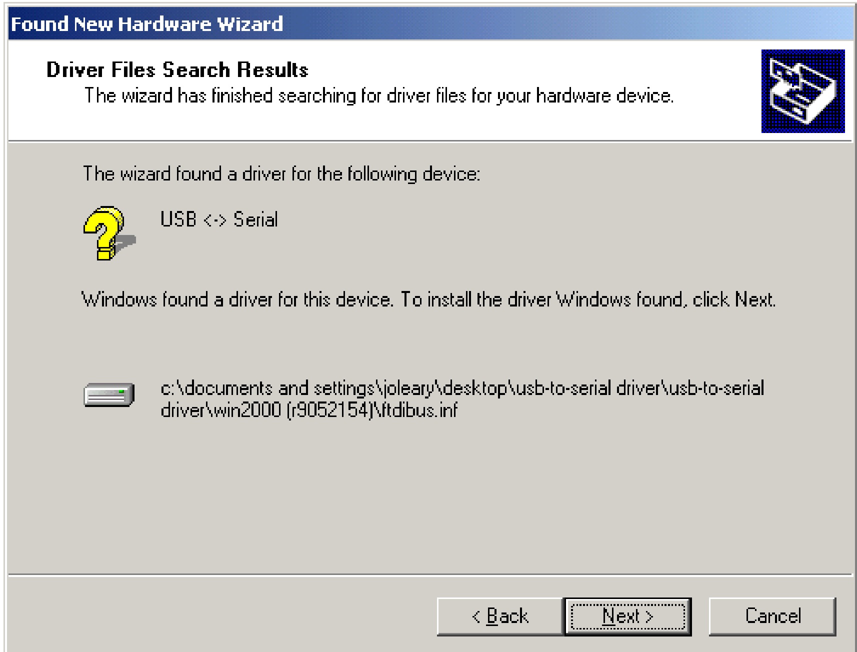


- S1 is a reset button for the module. S2 is a user configurable button (Button 1). S3 is another user configurable button (Button 2).

II. Driver Installation & Configuration

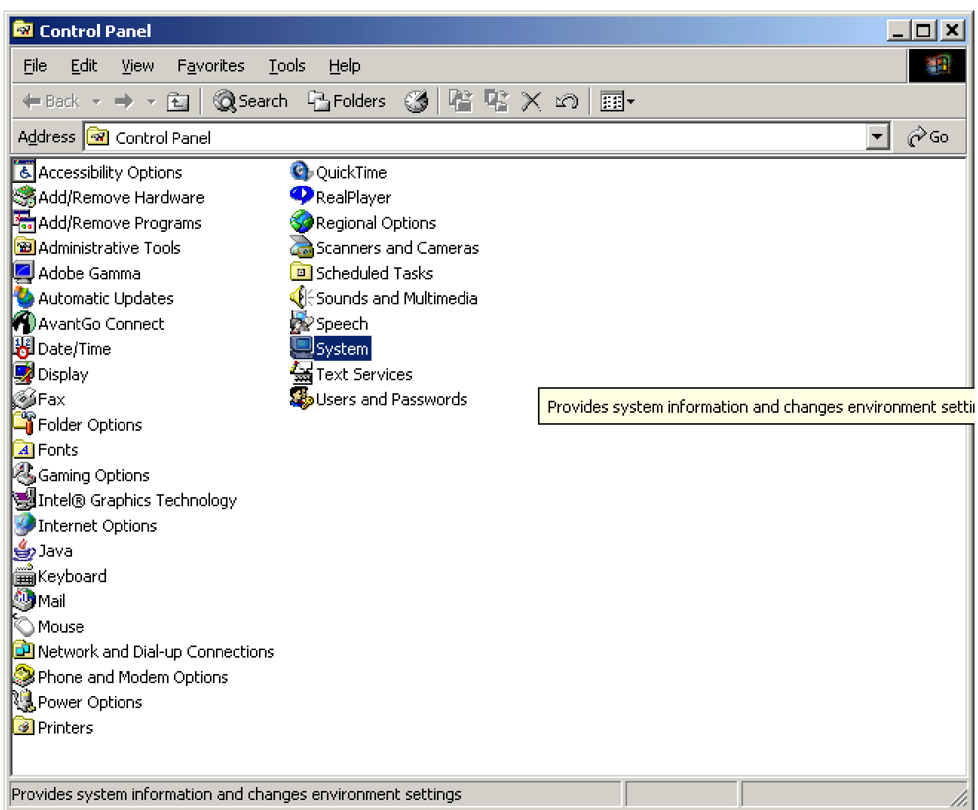
- The drivers for the transceiver are available from Future Technology Devices International, FTDI, as a free download: http://www.ftdichip.com/Drivers/VCP.htm
- Unzip the FTDI drivers into a new folder
- Connect the Transceiver to the USB port on the computer
- Windows will try to configure the device

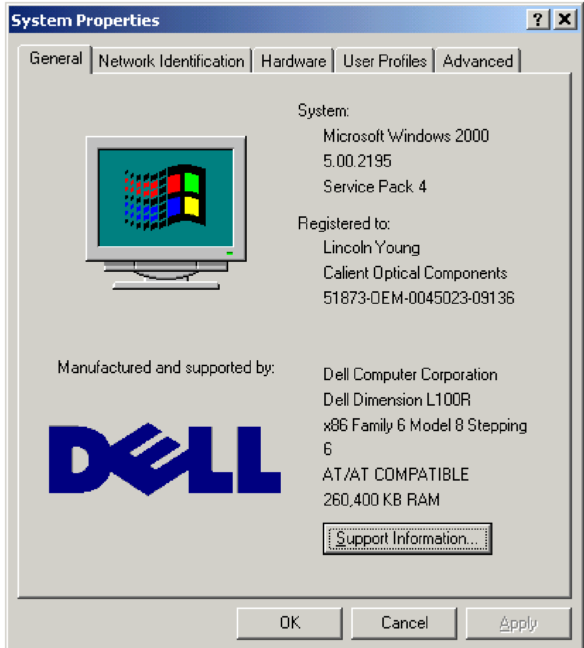
- Select the folder that contains the FTDI drivers



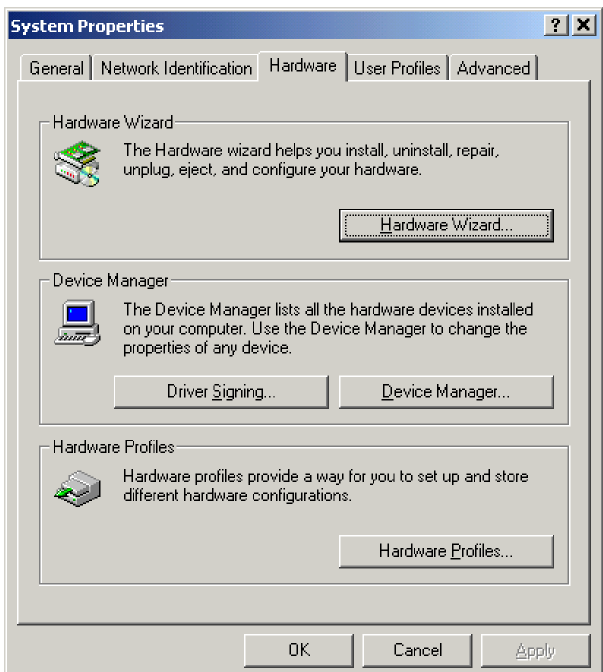
- Set the correct com port

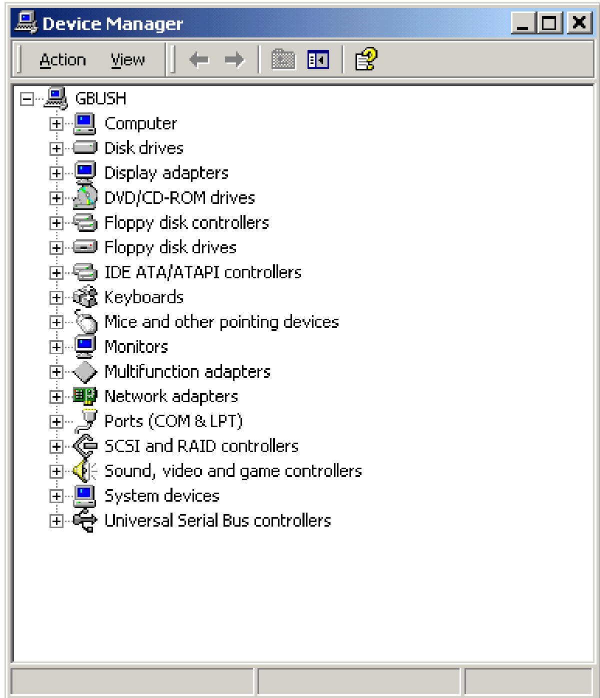
  From the **Start**, **Settings** menu:
  - Open **Control Panel**
  - Click on **System**



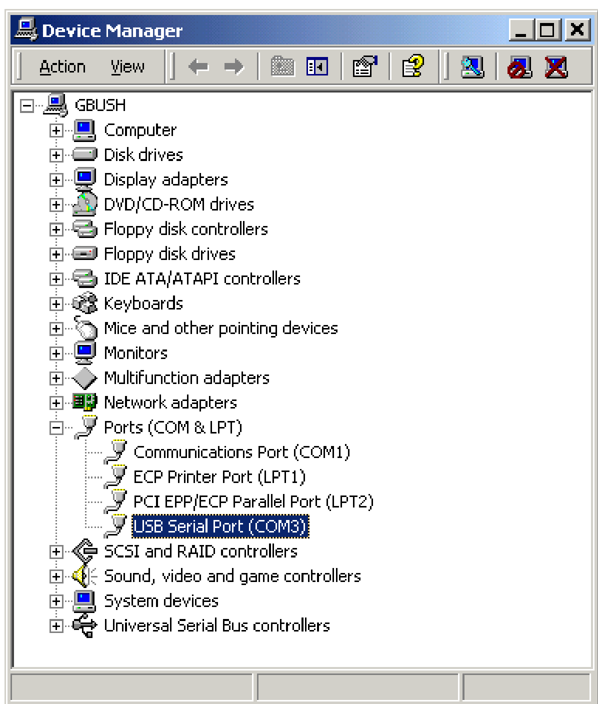


- Select **Hardware** and click **Device Manager**

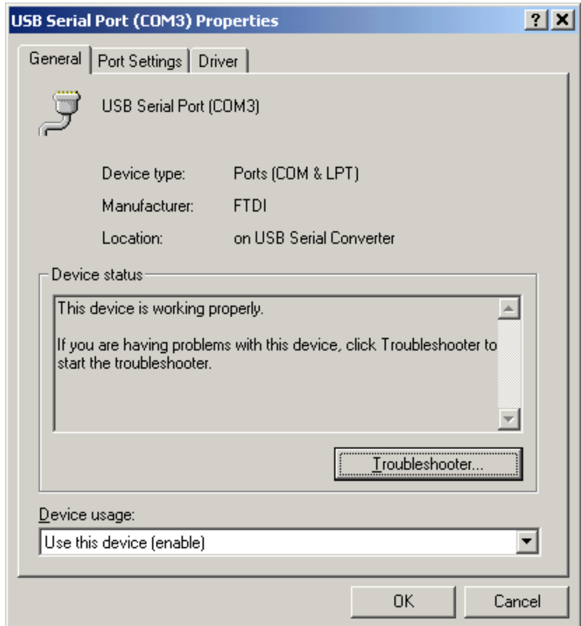


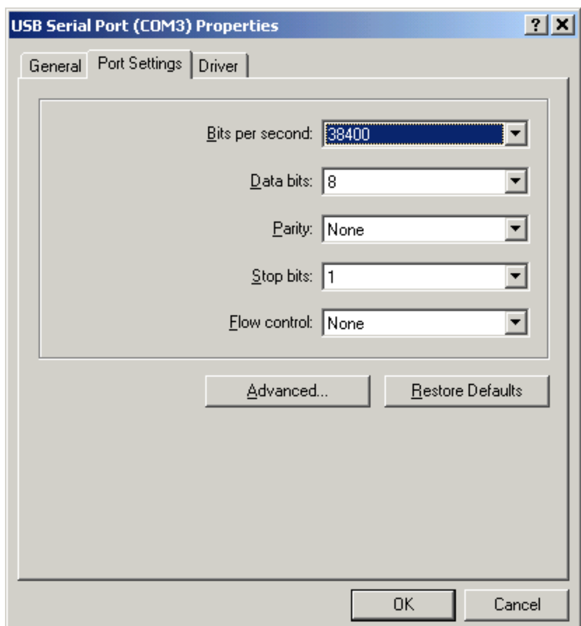


- Select **Ports** and double click **USB Serial Port (Com** ?**)**



- Select Port Settings





  - Bit per Second – 38400
  - Data bits – 8
  - Parity – None
  - Stop bits – 1
  - Flow control – None
- Click OK

III. Kionix Demo Software

Configure

Run the configure program to set the correct parameters for the demo board. The configuration program, shown in the figure below, will allow you to configure communication with the device.

1. **Interface** – The method used to communicate with the device. Currently the method is Streaming.
2. **Device** – The driver specific to the Kionix part being used. SengitalWireless is the correct device for the wireless demo board.
3. **Serial Port** – This selects the port to which the device is connected. Press “Scan” to limit the list to ports that can actually be accessed. A label to the right of the button will appear showing how many ports were found to be available. Then select the port to which the device is connected from the address pull-down above, and press “Test” to check that the device is connected properly. If it is, a label will appear to the right of the Test button confirming that the test was a success.
4. **Performance** – These boxes show the adjustments made to readings received. You may enter these manually if you wish, but it is easiest to lay the device flat, press “Calibrate” and accept the default settings.

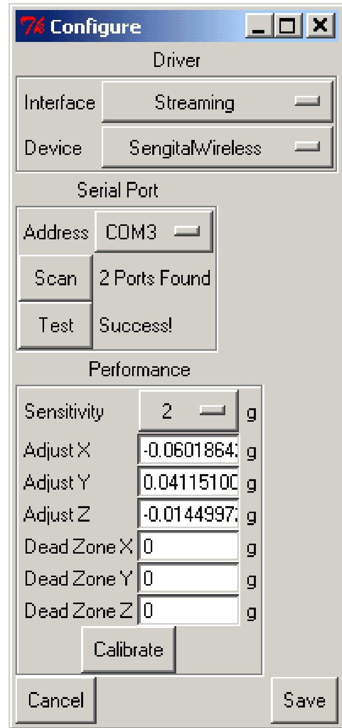


Figure 1 - configure.pl

Sensitivity – This is a pull down menu for selecting the sensitivity of the demo board. Sensitivity is set at the factory. You must select the correct g level for your board or the demos will not function properly. The default sensitivity is 2g.

Adjust X/Y/Z – These are the amounts by which each reading on the relevant axis is adjusted, in g's, before it is returned. This is to account for any slight variations in center the device might have.

Dead Zone X/Y/Z – This is the minimum absolute value a reading must reach before it is registered. If it is below this value, it will be read as zero. Having a dead zone can filter out noise, but at the cost of losing real readings if they are very small. The default of 0 is perfect for the demonstration programs.

When you are finished adjusting the settings press “Save” to save and exit the program.

1. Acceleration_Data

The Acceleration_Data demo shows the current readings of the device in the most raw form as is possible. For those interested in pure data, a device could be attached to a piece of memory to store a running log of all readings. The data could be retrieved later for analysis. The actual collection and processing of accelerometer data does not require very much processor power, and the sample rate of the device is very high, so an accelerometer can be added to almost any application while creating minimal overhead.

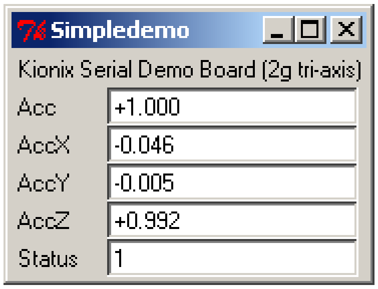


Figure 2 - Acceleration_Data

2. Oscilloscope

The Virtual Oscilloscope demo graphs data in a simple visual format to give the viewer a general idea of the pattens present in the motion of the device. By recognizing these patterns, such a device could become integral in several kinds of applications. A free-fall detector could be used to protect important data by spinning down a hard drive before it hits the ground. A jolt detector could create a record of package mishandling during shipping. A vibration detector could be placed on a piece of machinery to issue an alert if the pattern of movement changes significantly, indicating the possible need for maintenance.

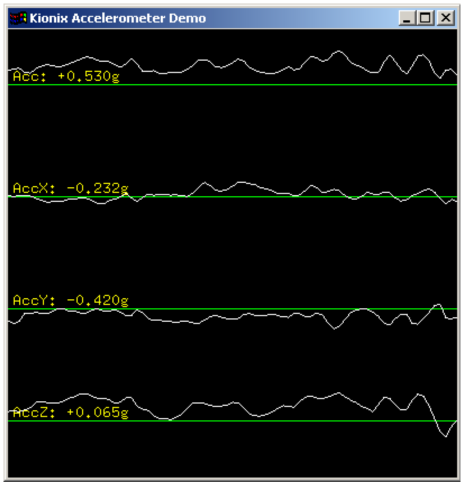
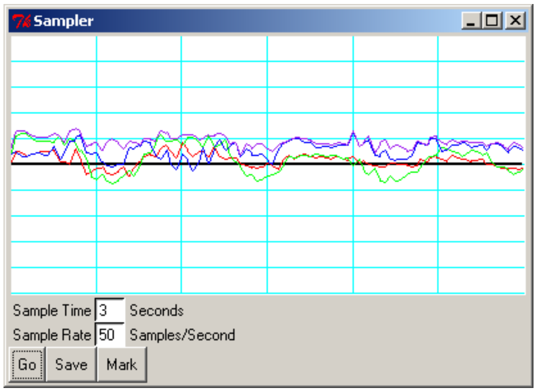


Figure 3 - Oscilloscope

3. Data_Logger

The data logger takes a constant stream of readings from the device and graphs them in real-time to the screen. Sampling is done by setting the time you wish to sample, the rate at which you wish to sample, and pressing “Go”. Note that the sample rate you specify is the target sample rate. If you specify a very high number, the program may read less samples than you expect. If you wish to save the data you collected, press “Save” to write the data to a CSV (comma-separated values) file. You can then use Excel, MatLab, etc. to analyze and graph the data.



4. 3D Ball

The 3D Ball demo is a simple demonstration of accelerometer-based controls in video games. By tilting the device, the user is able to roll the ball around the board and roll over the red target. Additionally, a strong bump applied to the z axis of the device will cause the ball to bounce into the air. A game development team could use this unique control scheme to add a new level of playability to games like the classic Marble Madness by Atari Games, or to create an entirely new game of their own. Other games which this could be used with include motorcycle, racing, snowboarding, skateboarding, and jet fighter games.

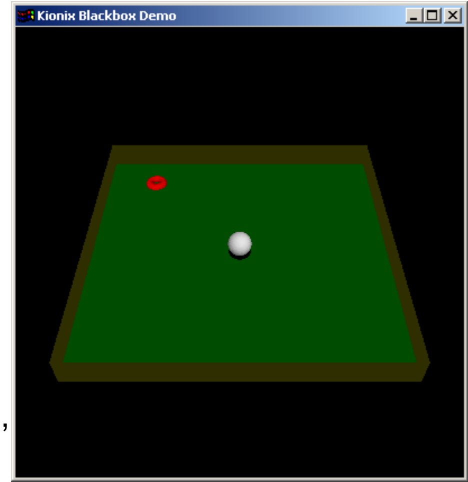


Figure 5 - 3D Ball

5. Cursor

The mouse cursor is a simple demonstration of the idea of a tilt mouse. After opening the program, the mouse cursor can be moved by tipping the device. To end this program press CTRL C.

6. Freefall

The Free-fall Detector demo is an example of the free-fall detection algorithm described in Appendix B. It registers when it has been in free-fall for half a foot, then reports how far it fell when it reaches the bottom of its fall. Logging can be temporarily paused with the “Stop” button, or the log can be saved to a CSV (comma-separated values) file with the “Save” button. For more details on the algorithm, see Free-fall Detection in Appendix B.

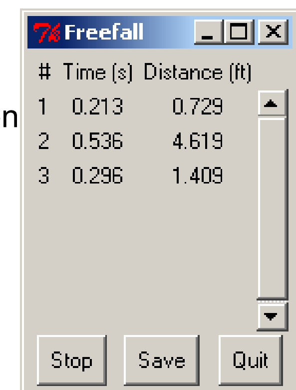


Figure 6 - Freefall

7. Spaceship

This Perl program demonstrates how an accelerometer can be used as a game controller. The tilt action is translated to control the movements of a virtual spaceship. Avoid the asteroids. If you crash into an asteroid the “game” will end and need to be closed and restarted to begin again.

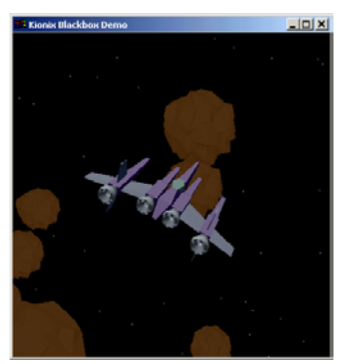


Figure 7 - Spaceship

8. Virtual Light Saber

The virtual light saber shows the unique values available from a tri axis accelerometer. The light saber is activated by picking up (or moving) the demo board. As you move the demo board the light saber will mimic your moves. Ten seconds of inactivity will cause the saber to “turn off”. Moving the demo board will again activate the light saber.

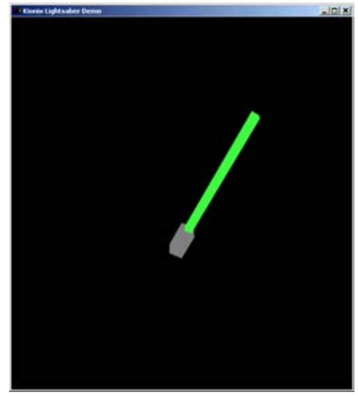


Figure 8 - Virtual Lightsaber

IV. Sengital Serial MSM Analyzer V4.1

Sengital Limited developed the wireless sensor module using KXPA4 for Kionix Inc. The Sengital software and manual have been included as another example of accelerometer analysis software. Use Serial_MSM_Analyzer V4.1 (2.7V).exe to start the Sengital program. The user manual details the connection procedure.

V. Appendices

Appendix A: Programmer's Manual

1. Perl API

The Perl API for the Kionix demo board provides an easy, object-oriented interface for a Perl programmer to access acceleration data. It is invoked in much the same way as any other Perl module, and returns an object which can be used to interact with the sensor.

Usage

Create a new Sensor object from scratch:

```
use Sensor;
my $Sensor = Sensor->new('Serial', 'TriAxis2g', 'Port' =>
'COM1');
$Sensor->open or warn "Failed to open sensor";
```

Create a Sensor object from an existing configuration file:

```
use Sensor;
my $Sensor = Sensor->newFromConfig('default.ini');
$Sensor->open or warn "Failed to open sensor";
```

Sensor Methods

The following methods are universal to all Sensor objects.

`Sensor->new($Interface, $Device, %Options)`

Create a new object based on the interface driver `$Interface` and the device driver `$Driver`. The `%Options` hash will be used to override default options if it is included.

`Sensor->newFromConfig($File, %Override)`

Create a new object, reading configuration options from `$File`. The `%Override` hash can be used to override options read from the configuration file.

`$Sensor->loadConfig($File)`

Load configuration options from `$File` and apply them to `$Sensor`.

`$Sensor->configure($Key, $Value)`

Sets a configuration option for the object. Valid options are detailed in "Configuration Options" below.

`$Sensor->open()`

Opens the sensor and prepares it for reading. Returns true or false, depending on if the open was successful.

`$Sensor->close()`

Closes the sensor. Returns true of false, depending on if the close was successful.

`$Sensor->canMeasure()`

$Sensor->canMeasure($Reading)
$Sensor->canMeasure(@Readings)

When called with no parameters, canMeasure returns a list of all the readings a sensor can return. When called with one parameter, canMeasure returns a true or false indicating if that reading can be returned. When called with multiple parameters, canMeasure returns a true or false value indicating if all of the readings can be returned.

$Sensor->status()

Returns the status of the device, 1 indicating a ready status and 0 indicating a bad status. If there is no way to determine the status of the device, this command returns `undef`.

$Sensor->$Reading()

Return the desired reading, as indicated by `$Reading`. `$Reading` can be any of the measurements returned by `$Sensor->canMeasure()`. For an example, see "Measurements Available From a TriAxis2g Sensor" below.

Measurements Available From a TriAxis2g Sensor

$Sensor->AccX()
$Sensor->AccY()
$Sensor->AccZ()

Returns acceleration on the X, Y, or Z axis. This value is in g's, the acceleration due to the Earth's gravity. That is, $1g = 9.8m/s^2$. For tilt calculations, $1g = 90°$. More information on using the values returned by an accelerometer can be found in Appendix B: Basic Concepts of Motion.

$Sensor->Acc()

Unlike the other readings, Acc is a calculated value. It is based on AccX, AccY, and AccZ, using the Pythagorean Theorem in three dimensions[1]. It is a measurement of the magnitude of the acceleration currently being applied to the accelerometer, without the direction. It is useful for applications such as jolt and free fall detection.

$Sensor->AccAll()

Returns an array of the X, Y, and Z accelerations. Note that because all three of these are sampled anyway each time any one reading is taken, using this method is three times faster than calling AccX, AccY, and AccZ in succession.

Configuration Options

The following options can be passed to the `configure()` method.

`Port`

This option is accepted by any object using the Serial interface driver. It specifies which COM port the sensor is plugged into.

`AdjustX, AdjustY, AdjustZ`

[1]Specifically, the calculation used to get overall acceleration is:

$$a = \sqrt{x^2 + y^2 + z^2}$$

These options are accepted by sensors which can return AccX, AccY, and AccZ respectively. They are the amount by which the reading is adjusted to account for slight offsets in the “zero” position of the sensor. These are usually set during a calibration process, like the one in the configure.pl example script.

`DeadZoneX, DeadZoneY, DeadZoneZ`

These options are accepted by sensors which can return AccX, AccY, and AccZ respectively. They specify a minimum absolute value above which each reading must be. If the reading is within the dead zone for the axis, it is simply returned as zero. These are usually set to filter out noise when the device is level.

2. Communication

For those who wish to communicate with the device in their own program or programming language of choice, this section details how communication with the demo board takes place.

Commands

The following commands can be issued to the demo board once communication has been established.

Code	***Description***	***Return***
X	Get X-axis acceleration.	X (2-byte integer)
Y	Get Y-axis acceleration.	Y (2-byte integer)
Z	Get Z-axis acceleration.	Z (2-byte integer)
A	Return all three axes.	XYZ (three 2-byte integers)
T	Echo a 'T', useful for checking board status.	T (1-byte character 0x54)

Return Values

The value returned for an axis reading is stored as a 2-byte integer in little-endian (least significant byte first) order. That is, the value can be calculated with the following equation:

$$Reading = FirstByte + (SecondByte * 256)$$

The resulting value represents a number on an arbitrary scale set by the analog-to-digital converter taking the reading. To convert this value to millivolts, the following equation is used:

$$Millivolts = (Reading * 1000) / 1241.2121$$

Finally, to change the reading in millivolts into the acceleration in g's, subtract the 0g offset or center (usually Vdd/2, or 1650mv for a 3.3V part). Then, divide by the sensitivity rating of the part in mv/g. This demo board uses a device with a sensitivity of 660 mv/g, thus:

$$Acceleration = (Millivolts - Center) / 660$$

The resulting number is the acceleration value returned by the sensor in g's.

Appendix B: Basic Concepts of Motion

The concepts discussed in this section are widely available and are a part of any Physics course, but they have been reproduced here both as a refresher and as a quick reference useful to anyone working with accelerometer data. There is also a discussion of the limitations of these methods when used to determine the position or tilt of a device using a tri-axis accelerometer.

1. Calculating Velocity and Distance From Acceleration

Given an acceleration (a) and a period of time (t), it is possible to calculate the change in velocity during the relevant time period. If the original velocity is also available, the velocity at the end of the time period and the change in position over the time period can be calculated. Lastly, if the original position is available, the position at the end of the time period can be calculated. This can be done according to the steps below.

Calculating Change in Velocity

Given a, the acceleration applied on the axis.

Given t, the time period for which the acceleration was applied.

$$\Delta v = at$$

Results in Δv, the change in velocity during the time period.

Calculating Final Velocity

Given Δv from the previous equation.

Given v_0, the velocity at the start of the time period.

$$v = v_0 + \Delta v$$

Results in v, the velocity at the end of the time period.

Calculating Change in Distance

Given v_0 , v, and t from previous equations.

$$\Delta d = \frac{(v_0 + v)}{2} * t$$

Results in Δd, the change in distance during the time period.

Calculating Final Distance

Given Δd from the previous equation.

Given d_0, the distance at the start of the time period.

$$d = d_0 + \Delta d$$

Results in d, the distance at the end of the time period.

Conclusion

At the end of these equations, we have both the final velocity (v) and the final distance (d). This information can be used to determine the same values in the next time period, resulting in a continuous flow of acceleration, velocity, and distance data.

2. Calculating Angle of Tilt From Acceleration

The acceleration data can also be used to find how far the device is tilted. This can be done because the Earth is always pulling on the device with 1g of acceleration. If the device is put on a flat surface and is completely still, all of that acceleration is on the Z axis. The acceleration on the X and Y axes will be zero. If the object is put on its side, whichever axis is pointed toward the earth will read 1g. Getting the angle from the readings on an axis can be done two different ways. The simplest way, although it is not very exact, is to multiply the acceleration on the axis by 90:

$$= \quad *$$

For a much more exact value, take the inverse sine of the acceleration:

$$= \quad (\quad)$$

For more information see Kionix Application Note AN005 on Tilt Sensing

http://www.kionix.com/sensors/application-notes.html

3. Free-fall Detection

A tri-axis accelerometer can be used to detect when an object is in free-fall. The first step is to calculate the overall magnitude of the acceleration being applied to the object. This is done with the Pythagorean Theorem:

$$a = \sqrt{x^2 + y^2 + z^2}$$

If the object is in free-fall, the value will be very close to zero. Depending on the rotation of the object, however, it may be a somewhat higher number (see “Limitations of These Methods” below for details). The distance the object fell can be calculated by using gravity ($g = 9.8\ m/s^2$) as acceleration (a) in the equation for calculating distance (d) from acceleration (a) and time (t):

$$d = \frac{1}{2}at^2$$

Note that this calculation will produce the wrong number if the object has been thrown upward or downward. Again, see “Limitations of These Methods” below for more details.

4. Limitations of These Methods

While these equations are effective for many applications, there are several limitations and “gotchas” that one has to watch for when using the data returned by the accelerometer.

Noise In Acceleration -> Velocity -> Distance Calculations

All measurements contain a small amount of background noise. Unfortunately, in an acceleration reading, noise can disrupt the apparent velocity of the device. This difference will become more apparent over time as the “phantom” velocity pushes the distance measurements farther and farther from reality. This change will be relatively slow, however, due to the low-noise nature of the device. The difference can also be made less visible by taking an average of several readings instead of acting on each reading as it arrives. A dead zone can also be implemented, risking the possible loss of the actual readings if they are very small.

Differentiating Between Tilt and Motion

While the ability to measure either motion or tilt is very useful, it comes with the unfortunate disadvantage of not being able to easily differentiate between the two. The z-axis of this device may make this distinction possible on the x and y axes by watching the effect of the acceleration in question on the z axis, and the acquired data could be applied to future demos. Of course, associated equations will also be made available.

Rotation and Center of Mass in Free-fall Detection

Centripetal acceleration, present if the object is rotating, can throw off free-fall detection by causing the overall acceleration of the object to be significantly higher than zero even when the object is actually in free-fall. This effect can be reduced by putting the device in a heavy casing, positioning the accelerometer as close as possible to the device's center of mass, and allowing a range of values to represent free-fall. 0.0 to 0.5g is usually a safe range to use.

Free-fall Time When an Object is Thrown

An object is in free-fall as soon as no forces except for gravity are acting on it. That means that if you throw the device upward, it will be in free-fall even when it is “falling” upward. Similarly, being thrown downward will shorten the time the object is in free-fall before it hits the ground. Either of these events will throw off the equation presented in “Free-fall Detection” above, which assumes that the object was released into free-fall with a velocity of zero. This limitation is not an issue for applications such as hard drive protection, as they are only concerned with the fact that the object has been dropped, but can adversely affect applications in which the distance the object fell is important. In these cases, it may be better to use an accelerometer with a higher range and implement impact detection instead of using a low-range accelerometer for detecting free-fall.

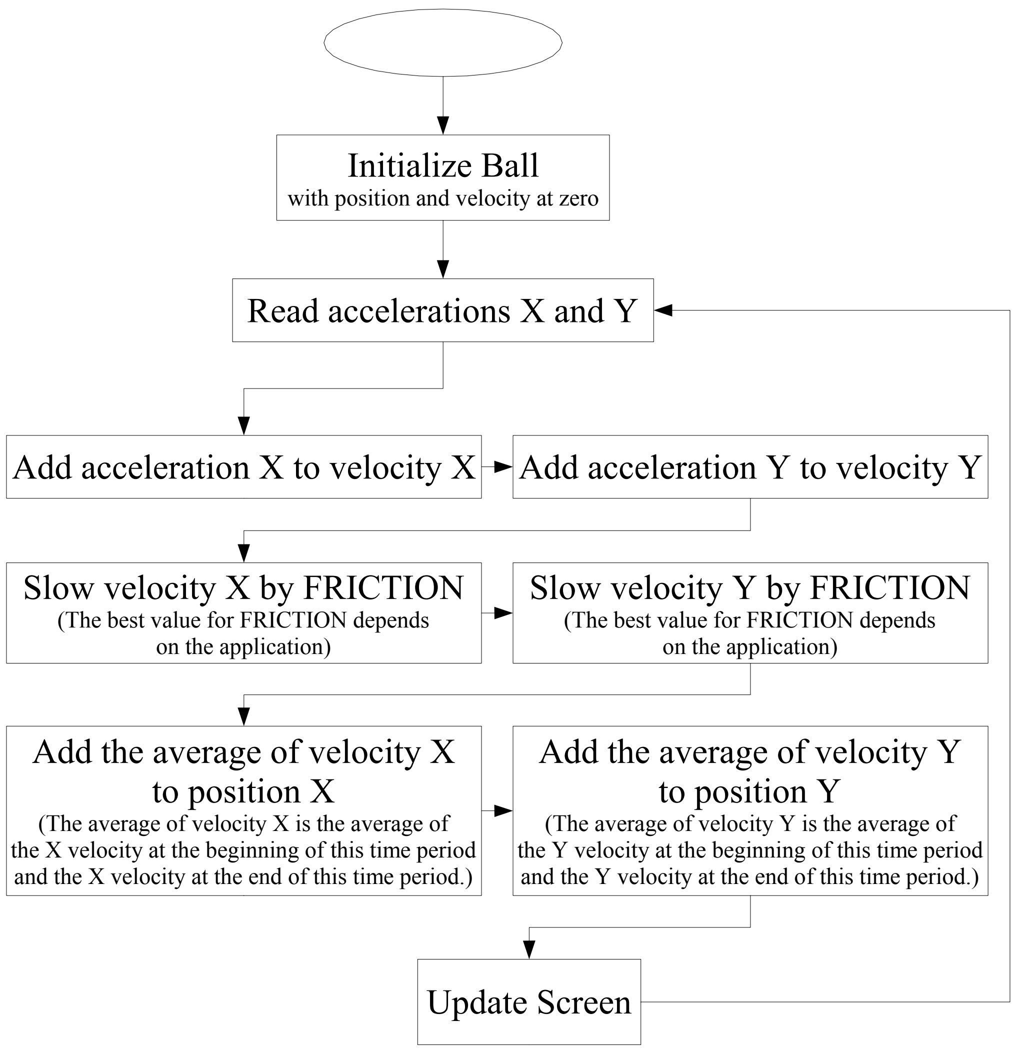
Appendix C: Algorithm References

1. Converting From Acceleration to Tilt

$$\text{roll:}\quad \phi = \arctan\left(\frac{X}{\sqrt{Y^2 + Z^2}}\right)$$

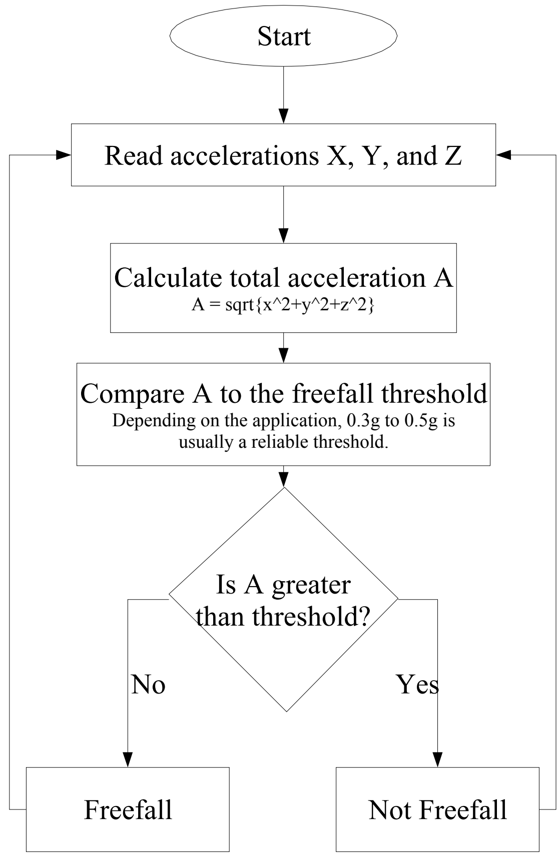
$$\text{pitch:}\quad \rho = \arctan\left(\frac{Y}{\sqrt{X^2 + Z^2}}\right)$$

2. Controlling a Rolling Ball by Tilting



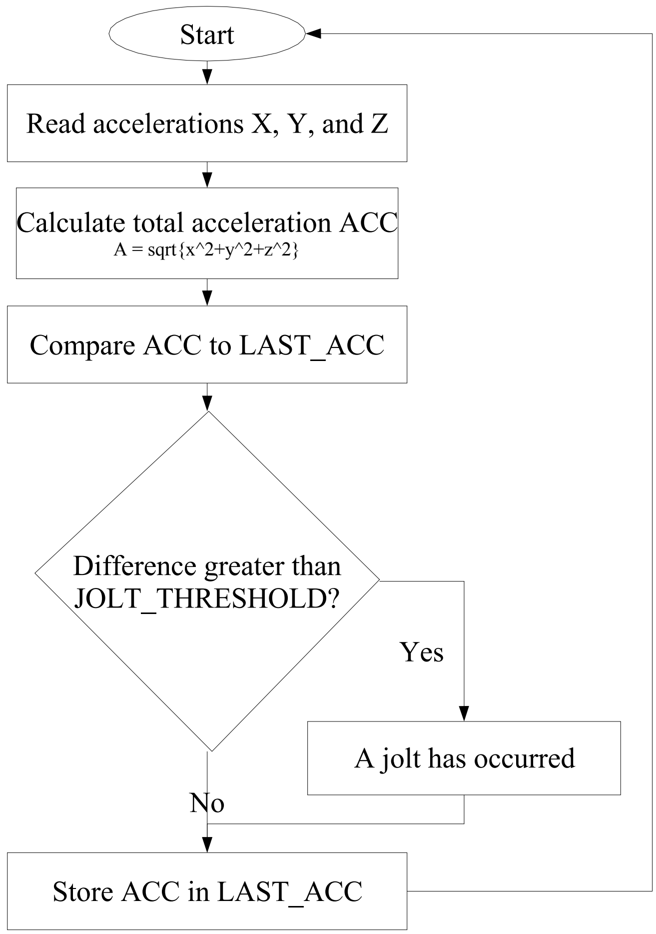
```
ball.positionX = 0
ball.positionY = 0
ball.velocityX = 0
ball.velocityY = 0

while running
     (ACCX, ACCY, ACCZ) = sensor.allreadings
     OLDVELX = ball.velocityX
     OLDVELY = ball.velocityY
     // Add acceleration to velocity
     ball.velocityX = ball.velocityX + ACCX
     ball.velocityY = ball.velocityY + ACCY
     // For a better feel, the following implements
     // friction. The best value for FRICTION depends on
     // the application.
     if absolute_value(ball.velocityX) < FRICTION then
          ball.velocityX = 0
     else
          if ball.velocityX > 0 then
               ball.velocityX = ball.velocityX - FRICTION
          else
               ball.velocityX = ball.velocityX + FRICTION
          end if
     end if
     if absolute_value(ball.velocityY) < FRICTION then
          ball.velocityY = 0
     else
          if ball.velocityY > 0 then
               ball.velocityY = ball.velocityY - FRICTION
          else
               ball.velocityY = ball.velocityY + FRICTION
          end if
     end if
     // Add average velocity to position
     ball.positionX = ball.positionX + average(
          ball.velocityX, OLDVELX)
     ball.positionY = ball.positionY + average(
          ball.velocityY, OLDVELY)
end while
```

3. Detecting Free-fall




```
FREEFALL = 0.3 g // Threshold under which the object is
                 // considered to be in free-fall
IN_FREEFALL = false // Stores whether or not the device is
                    // falling
while running
     (ACCX, ACCY, ACCZ) = sensor.allreadings
     TOTAL_ACC = square_root(ACCX ^ 2 + ACCY ^ 2 + ACCZ ^ 2)
     if TOTAL_ACC < FREEFALL then
          IN_FREEFALL = true
     else
          IN_FREEFALL = false
     end if
end while
```

4. Jolt Detection




```
JOLT_THRESHOLD = 1 g // Amount by which the overall
                     // acceleration reading must change
                     // between readings to be considered a
                     // jolt

(ACCX, ACCY, ACCZ) = sensor.allreadings
LAST_ACC = square_root(ACCX ^ 2 + ACCY ^ 2 + ACCZ ^ 2)

while running
     (ACCX, ACCY, ACCZ) = sensor.allreadings
     ACC = square_root(ACCX ^ 2 + ACCY ^ 2 + ACCZ ^ 2)
     JOLT = absolute_value(ACC - LAST_ACC)
     if JOLT >= JOLT_THRESHOLD then
          // A jolt has occurred
     end if
     LAST_ACC = ACC
end while
```