



# WiTilt v3

## 1 Overview

The original WiTilt v1 started out as a controller for a toy robot. But it soon grew into a precision remote sensing device, giving 2 axes of acceleration measurement over a wireless link. However, growing customer need and popular demand spurred us on to continue the development of the WiTilt. The v2 series introduced the two and three axis accelerometers combined with a 2.4 GHz Bluetooth® link. WiTilt v3 continues to build on this wireless sensor concept.

The WiTilt v3 employs a Freescale MMA7260Q triple-axis accelerometer, a Melexis MLX90601 E2 150 degree/second gyroscope and a class 1 Bluetooth® link for robust communication over a universal platform.

Features on the WiTilt v3 include:

- Selectable channels for sampling (X,Y,Z and Rotation)
- Battery Monitoring capability
- Status LED's to indicate device activity
- Adjustable accelerometer range and calibration (1.5 g, 2 g, 4 g, 6 g)
- Raw, Binary and Calculated Output Modes
- New "Degree" Output Mode
- Output in Binary format
- Adjustable report threshold for accelerometer, gyroscope and battery voltage
- Adjustable output frequency
- 50 Hz max in degree mode
- 135 Hz max in gravity mode
- 220 Hz max in raw ADC mode
- 610 Hz max in binary mode
- Re-chargable LiPo Battery

## 2 Hardware Layout

There are only a few things that the reader should be familiar with before using the WiTilt v3 (indicated in figure 1).

## 3 Connecting to the WiTilt v3

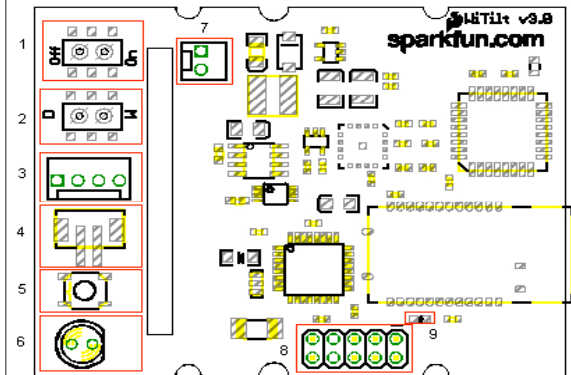
The WiTilt v3 may be connected either via a Bluetooth® interface, or hardwired directly to the device. Use the Debug/RF switch to decide which mode to use (M for Bluetooth®, D for hardwired).

### 3.1 Bluetooth®

Ensure that the Debug/RF switch is set to "M" for Bluetooth® mode and turn the unit on. From your base Bluetooth® device, connect to the WiTilt v3 in serial mode and open a terminal program to which ever port your Bluetooth® is set to. Set the connection speed of the

terminal, as well as the host Bluetooth® device, at 115,200 bps. Upon making the connection you should see the configuration menu come up. (Tip: If you are having trouble connecting to the device, try pressing the reset button.)

Figure 1: Overview



- 1) Power Switch
- 2) Debug/RF Switch (Switches the AtMega UART between the BlueTooth® module and the debug header)
- 3) Debug header (Note: This connector for this header is not populated. Use the silk screen designators to use this feature.)
- 4) Charging header (Connect a 5V DC power supply to charge the LiPO battery.)
- 5) uC Reset Button (button does not reset the Bluetooth module)
- 6) Charge Indicator LED
- 7) Battery Connector
- 8) AVR Programming Support
- 9) Bluetooth® Connection Indicator

### 3.2 Debug Header

The user has the option of connecting directly to the UART on the AtMega8. This is a TTL signal, not RS-232 so level conversion is necessary. Make sure the RF/Debug switch is set to "D" for Debug mode, and then connect a hard-line to the debug header at TTL levels. Start a terminal program with port settings of 115200/8/n/1. Once the terminal is open, hit the reset button on the WiTilt v3 and the configuration menu will come up. The unit will now ignore the Bluetooth® communication.

## 4 Configuration Menus

### 4.1 Top Menu and Start/Stop

The top-level menu for the WiTilt v3 can be seen in figure 2. To start the WiTilt v3, just press '1' and values will start pouring out according to the configuration settings. If running the WiTilt for the first time the user must first select the active channels, the display mode, and the output frequency. It is also recommended to calibrate the unit before running the device. Press any key to stop the process.

The Configuration menu shows a list of options available to the user. Many of the options include the current status of the configuration. In the "Active Channels" selection, X, Y, and Z correspond to the accelerometer channels, B indicates that the battery channel is active and R indicates that the Gyro channel is active. If the channels are not active, a '-' will be shown instead.

Figure 2: Main Menu

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WiTilt v3 Configuration Menu:

1) Start Tri-Ax detector.
   (Press any key stop)
2) Set active channels (XYZBR
   Active)
3) Calibrate
4) Sensor range (1.5 g)
5) Display mode (Gravity)
6) Set/View threshold values
7) Set output frequency
   (130Hz)

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### 4.2 Active Channel Select

Selection #2 is for setting the active channels that the unit will report. If the channel isn't active, no values will be generated. Pressing '2' from the main menu will enter the active channel select mode. You will be prompted for each channel (X, Y, Z and R) to be set, as well as the battery monitoring channel. The X, Y, and Z channels are for the respective axis on the accelerometer, while the R channel enables the values for the gyroscope. Press 'y' or 'n' to make your selection.

### 4.3 Calibrate

Press '3' from the main menu to enter calibration mode. Upon entering calibration, the X, Y and Z midpoint and 1 g width ADC count values will be displayed. These values can be used to manually calculate the g values of the axis, as well as the pitch and yaw degrees. (Formulas for the conversions are in the "Calculations" section of this datasheet.) By pressing the spacebar the user will continue on to the calibration process and will be prompted to manipulate the WiTilt device into various positions that maximize and minimize the readings and to press a key upon achieving those values.

Note: Calibration should be performed every time the sensor range is changed. Calculated values that the WiTilt uses depend on the calibration being correct.

### 4.4 Sensor Range

Press '4' from the main menu to enter the sensor range setting mode. You will be prompted to set the range of the MMA7260Q to +/- 1.5 g, +/- 2 g, +/- 4 g or +/- 6 g. You can also press 'x' to exit without changing the mode.

Note: Calibration should be performed every time the sensor range is changed. Calculated values that the WiTilt uses depend on the calibration being correct.

### 4.5 Display Mode

Press '5' from the main menu to set the display mode. You will be prompted to select either Gravity mode, Raw ADC mode, Binary Output mode or Degree mode. If Gravity mode is selected, the accelerometer channels (X, Y and Z) will be reported in the number of g's, while the gyroscope channel (R) will be reported in degrees/second. Battery Voltage will be displayed in Volts while running the unit in Gravity or Degree Mode. In Degree mode, the X and Y angles will be displayed in degrees along with the Rotational value and the Battery value if they are activated (Note: Because the X, Y and Z accelerometer values are required to compute the degrees, all three channels will be activated upon choosing the Degree Output Mode).

Note: Each display mode has a different maximum output frequency. After changing display modes, you should enter the output frequency mode. If the current value is too high for the given display mode, the unit will default to the maximum allowed value.

Raw ADC and Gravity values are output in ASCII format for ease of reading. For example, here's what you can expect to see in Raw mode with all channels active and threshold set to zero:

Inactive channels will simply be omitted from the display, as will any reading that does not meet a preset threshold.

Figure 3: Raw Data

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X=557Y=492Z=747B=782R=493
X=559Y=485Z=746B=785R=495
X=564Y=499Z=766B=781R=492
X=554Y=499Z=766B=781R=485
X=558Y=495Z=746B=782R=494
X=557Y=506Z=763B=781R=504
X=557Y=492Z=747B=781R=498
X=560Y=485Z=747B=782R=495

```

### 4.5.2 Binary Output Format

The WiTilt v3 has a 'Binary Mode' feature. In Binary mode, the output will behave much differently than in the Raw ADC or Gravity modes. Once the device is put into the 'Start' mode, the WiTilt v3 in Binary mode will broadcast the 'Ready' string(#R\$) and wait for one of three commands from the host:

- 1) Ready: Sending a capitol 'R' character (0x52) at any time will cause the WiTilt v3 to respond with the 'Ready' string: #R\$ once it has completed all current measurements.
- 2) Abort: Sending an 'A' character (0x41) will cause the WiTilt v3 to stop any data output and respond with the 'Ready' string: #R\$. From here, the space bar may be pressed to return to the main menu.
- 3) Start: Sending an 'S' character (0x53) will cause the WiTilt v3 to respond with the 'Ready' string (#R\$) and then begin to transmit the following data string: (See table 1).

The user should bear in mind that the length of the data can vary depending on the number of active channels. For example, if the X channel is inactive, all following data shift up in the data frame by two bytes.

The threshold setting is also different in binary mode in that a report will still be generated even if it is below the threshold setting, but it will read '1025'. This is to ensure that the data frame is always a known length.

The Sample Number increases with every output and will roll-over at 65535. The X,Y,Z and R values are in 16 bit binary form. They are numbers directly returned from the ADC conversion.

#### 4.6 Threshold

Press '6' from the main menu to set the threshold values for the device. Setting the threshold prevents the WiTilt from displaying values that are less than the desired threshold limit. For example, by setting the threshold to 0.5g, only accelerations greater than 0.5g will be displayed for the accelerometer axis (the gyroscope threshold is set in degree/second). This is useful if your system is only looking for a certain shock threshold. The threshold for the Battery voltage behaves differently in that, if set, the battery value will only be displayed if it is below the threshold. This is useful if you want to receive a warning when the battery is going low. By returning the threshold to 0.0 g (or 0 deg/sec), all of the values will be reported.

After entering the Threshold setting menu, the user is prompted to enter the desired threshold value for the accelerometer in g's. Press 'i' to increase the threshold value, or 'd' to decrease. The accelerometer threshold has a 0.1 g resolution. The 'x' character may be entered if no change is needed for the accelerometer threshold value.

Next, the user is prompted to enter the gyroscope threshold value. The gyroscope threshold is measured in deg/second, and has a 1 deg/second resolution. Again, press 'i' to increase the threshold, or 'd' to decrease it. To exit the threshold setting mode, press 'x'.

After setting the threshold values for the accelerometer and gyroscope, the threshold value will need to be entered for the battery voltage. The battery threshold is displayed in millivolts, and may be increased or decreased in increments of 100 mV. Remember, the battery value will only be displayed if it is less than the threshold value.

Table 1: Binary Data String: Binary Output Format

Byte	Description
0	Start Character – always '#'
1	Data Output Designator – always '@'
2	Sample Number High Byte
3	Sample Number Low Byte
4	X Axis High Byte
5	X Axis Low Byte
6	Y Axis High Byte
7	Y Axis Low Byte
8	Z Axis High Byte
9	Z Axis Low Byte
10	Battery Value Low Byte
11	Battery Value High Byte
12	R Value High Byte
13	R Value Low Byte
14	End Character – always '\$'

Note: Make sure to calibrate the unit before setting a non-zero threshold.

#### 4.7 Output Frequency

Press '7' from the main menu to enter the output frequency select mode. You will then be prompted to press 'i' to increase or 'd' to decrease the output frequency in '10' Hz increments.

Each display mode has a maximum output frequency setting: 50 Hz for degree mode, 135 Hz for gravity mode, 220 Hz for Raw ADC mode and 610 Hz for binary mode. You will not be able to exceed the maximum allowed value for the given display mode from the output frequency menu, but it is possible to get an incorrect setting if you don't set the output frequency after changing the display mode.

#### 4.8 Steps for Reliable Operation

A great deal of versatility has been built into the WiTilt v3. As such, it may be possible to get it into a questionable state (though we've taken great pains to see that it won't). To keep everything running as smoothly as possible, please follow this sequence of steps:

- 1) Set the sensor range
- 2) Calibrate the device
- 3) Set the threshold (if any)
- 4) Set the display mode
- 5) Set the output frequency
- 6) Set active channels (this can be any time)
- 7) Go!

## 5 Calculations

The user may use the following equations to convert the ADC counts into g's (for the accelerometer) or degrees per second (for the gyroscope).

$$g = \frac{(ADC - \text{Midpoint})}{\text{Width}}$$

This equation will find the number of g's exerted on a single axis of the accelerometer. For example, to find the number of g's on the X axis, one would use the X Midpoint and X g-width (found in the calibration menu), and the number of ADC counts reported on the X axis (this is the number reported using the Raw Output Mode). To use binary data, simply convert the binary data into decimal data.

$$\text{Rate} = \frac{(ADC - \text{Zero})}{341}$$

The rate of the gyroscope (in degrees per second) can be found using this equation. The Zero can be found in the calibration menu, while the ADC is the number of counts reported on the R channel. The scaler 341 is an inherent figure determined by the accuracy of the Melexis gyroscope.

$$\text{angle}_y = \arctan\left(\frac{y}{\sqrt{x^2 - z^2}}\right)$$

This formula can be used to find the angle of the X axis in degrees. The X, Y and Z values should be in g's.

$$\arctan = \left(\frac{x}{\sqrt{y^2 - z^2}}\right)$$

This formula can be used to find the angle of the Y axis in degrees. The X, Y and Z values should be in g's. While the X and Y angle formulas yield accurate results, the user must take into consideration that, based on the properties of the equation the result will always be between 0 and 90 degrees. In order to derive more useful values, the orientation of the axis must be used to determine the proper quadrant. Once the quadrant has been found it can be used to offset the angle value.

## 6 Sampling Rate and Aliasing

The Freescale MMA7260Q has a bandwidth of 350 Hz on its X and Y axes and a bandwidth of 150 Hz on its Z axis. These are set by internal switched capacitor filters on the device. The Melexis 90601 E2 has a bandwidth of 36 Hz on the rotational axis.

The WiTilt v3 allows the user to set the output frequency of a full frame of data, where one frame is one measurement from each active axis. Therefore the output frequency is equivalent to the sampling rate for any given axis.

Because of bandwidth restrictions of the MMA7260Q, some aliasing may be seen at output frequencies lower than about 225 Hz. Best results can be realized while operating in binary output.

