Writing Math Channels
in Race Studio Analysis

Racing Data Power

INDEX

Section 1 – Introduction

One of the very useful tools **Race Studio Analysis** offers is the ability to write Math Channels. This feature allows you to take data that has already been acquired by your data logger, and use it to calculate other measurements you wish to analyze, such as using speed to calculate acceleration, or using speed and RPM to calculate gear position. There are many others you can create depending on what information you are trying to get out of it. In this tutorial we show how to use existing default channels, as well as how to create your own from scratch, to write your own channels in **Race Studio Analysis** software.

To create a math channel, go to Modify on the toolbar in **Race Studio Analysis**, and select Math Channel from the drop down menu and a new window will open. All math channel creation and modification will take place in this window. You can also access this window by hitting Alt+F8. The following window will appear.
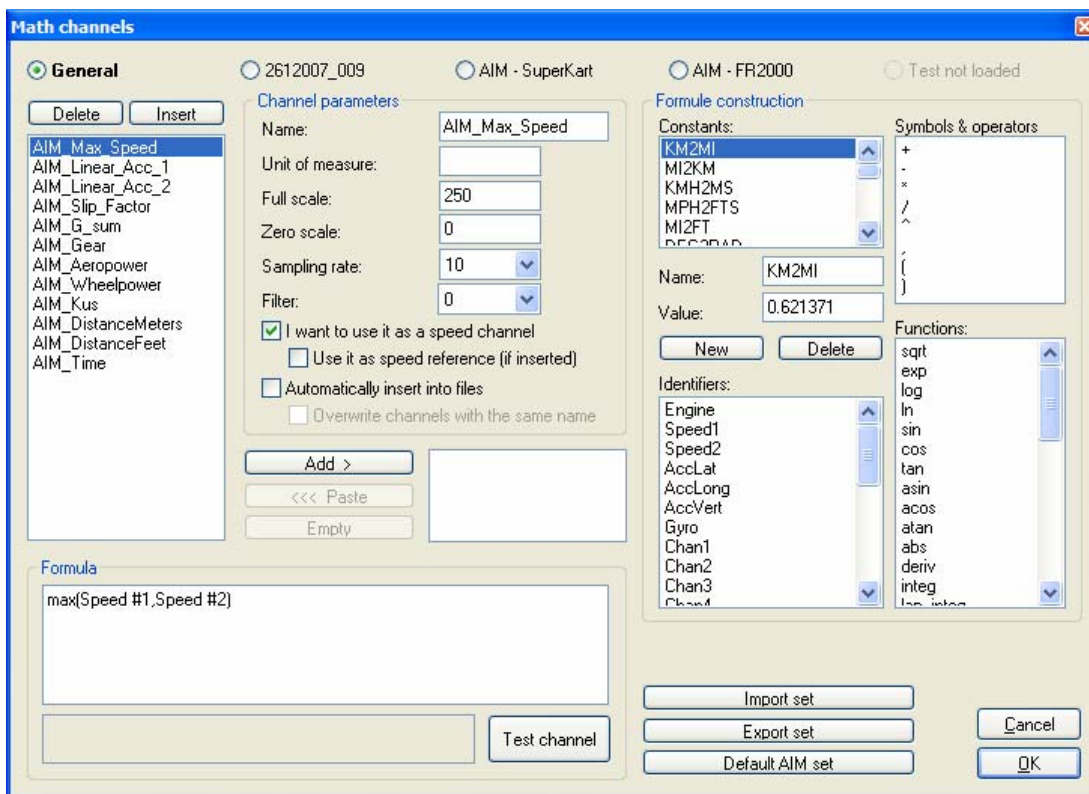

Figure 1 - Math Channels Screenshot

Before we go any further, please take a moment to review the four tables below that describe the Constants box, Symbols & Operators box, the Functions box and the Channels box.

Table 1. Constants and Conversions Chart

Constant/Conversion	Conversion Factor/ Default Value(D)	Description
KM2MI	1 km = 0.621371 mile	Convert Kilometres to Miles
MI2KM	1 Mile = 1.60934 km	Convert Miles to Kilometres
KMH2MS	1 km/hr = 0.277778 m/s	Convert Kilometres per hour to Meters per second
MPH2FTS	1 MPH = 1.46667 ft/sec	Convert Miles per hour to Feet per second
MI2FT	1 Mile = 5280 ft	Convert Miles to Feet
DEG2RAD	π/180° = 0.017453 rad	Degrees to Radians
KW2CV	1 kW = 1.35962 CV	Horse Power
KW2HP	1 kW = 1.34102 HP	Kilowatts to Horse Power
BAR2KPA	1 bar = 100kPa	Convert Bar to Kilopascals
ZEROKELVIN	-273.16°Kelvin	Absolute Zero
ACCGRAV	9.806 m/s2	Acceleration due to Gravity (Metric Units)
PI	3.14159 rad	Pi (π)
DOUBLEPI	6.28318 rad	2 * Pi (2π)
MASS	480 lb (D)	Vehicle Mass
WHEELBASE	2.81 m (D)	Vehicle Wheelbase
GEARFACTOR	5 (D)	Number of Gears
Cx	0.5 (D)	Drag Coefficient
FRONTSURF	0.9 ft2 (D)	Frontal Surface Area
FTPERSEC	32.2 ft/sec2	Acceleration due to Gravity (English Units)

Table 2. Operators Chart

Operation	Description
+	Addition
-	Subtraction
*	Multiplication
/	Division
^	Power
,	Comma
(	Open Parenthesis
)	Close Parenthesis

Table 3. Functions Chart

Function	Description
sqrt	Square Root
exp	Exponent (e=2.71828) -- Ex: exp(5) = e5
log	Log base 10 – log = log10
ln	Natural Log (Log base e) – ln = loge
sin	Sine
cos	Cosine
tan	Tangent
asin	Arcsine = inverse sine function
acos	Arccosine = inverse cosine function
atan	Arctangent = inverse tangent function
abs	Absolute Value
derive	Derivative
integ	Integral
lap_integ	Integral over course of one lap
min	Minimum
med	Medium
max	Maximum
high_pass	Function for high pass filter
low_pass	Function for low pass filter
band_pass	Function for band pass filter
bit_and	Function for bitwise AND of two given integers
bit_or	Function for bitwise OR of two given integers
bit_xor	Function for bitwise XOR (exclusive "or") of two given integers
time	Time
bike_angle	Function for calculating lean angle of bike
gear	Gear calculator function
slip	Clutch slip calculator function
bike_acclat	Lateral Acceleration calculator function for bike
bike_cornrad	Corner radius calculator function for bike
GT	Greater Than operation
GE	Greater Than/Equal To operation
LT	Less Than operation
LE	Less Than/Equal To operation
EQ	Equal To
NE	Not Equal To
IF	If statement to code If loop
atan2	Arctangent function if given sin & cos

Table 4. Default AIM Channels Chart

Default AIM Channel	Formula	Description
AIM_Max_Speed	max(Speed #1,Speed #2)	Calculates the maximum of the two wheel speeds at any point
AIM_Linear_Acc_1	deriv(Speed #1 * KMH2MS) / 9.806	Longitudinal acceleration calculation in Metric units (m/s2) by taking the derivative of speed
Aim_Linear_Acc_2	deriv(Speed #1 * MI2KM * KMH2MS) / 9.806	Longitudinal acceleration calculation in English units (ft/sec2) by taking the derivative of speed
AIM_Slip_Factor	slip(Engine, Speed #1)	Clutch slip as a function of engine RPM and wheel speed
AIM_G_sum	sqrt((AccLat^2)+(AccLong^2))	Sum of the acceleration forces to calculate total acceleration
AIM_Gear	gear(Engine, Speed #1, 1, 6)	Gear calculation as a function of engine RPM and speed
AIM_Aeropower	(0.5 * 1.23 * FRONTSURF * Cx * (Speed #1 * KMH2MS)^3)/1000	Power required to overcome drag as a function of Frontal surface area, drag coefficient, and speed
AIM_Wheelpower	AIM_Aeropower + (MASS * (Speed #1 * KMH2MS) * (Linear Acc. * ACCGRAV)) / 1000	Power required to accelerate the vehicle at a certain acceleration as a function of drag, vehicle mass, speed and longitudinal acceleration
AIM_Kus	ACCGRAV*(((Steer*DEG2RAD)/(Lateral acc.*ACCGRAV))-(WHEELBASE/((Speed #1*KMH2MS)^2)))	Understeer/Oversteer calculation using the relationship between steering angle and lateral acceleration, and wheelbase and speed
AIM_DistanceMeters	lap_integ(Speed #1 * KMH2MS)	Distance of a lap in meters calculated by finding the integral of speed over lap time
AIM_DistanceFeet	lap_integ(Speed #1 * MPH2FTS)	Distance of a lap in feet calculated by finding the integral of speed over lap time
AIM_Time	time()	Time

The first step to creating a math channel is to determine which test you wish to create this math channel for. Any test you currently have open will show up as a bullet across the top of the screen for you to choose from, as shown in the screenshot above in **Figure 1**. Now there are two ways to create the channel. You can either use one of the "General" formulas that are already in the software, or you can create one from scratch. Later we will show how to create one from scratch, but let us review how to use the already existing formulas to meet your needs.

Section 2 – Modifying Existing Math Channels

To use an existing math channel, select the one you wish to use, and click the "Add>" button underneath the Channel Parameters section. The channel you have selected will show up in the box to the right, as shown in the screenshot below (**Figure 2**).
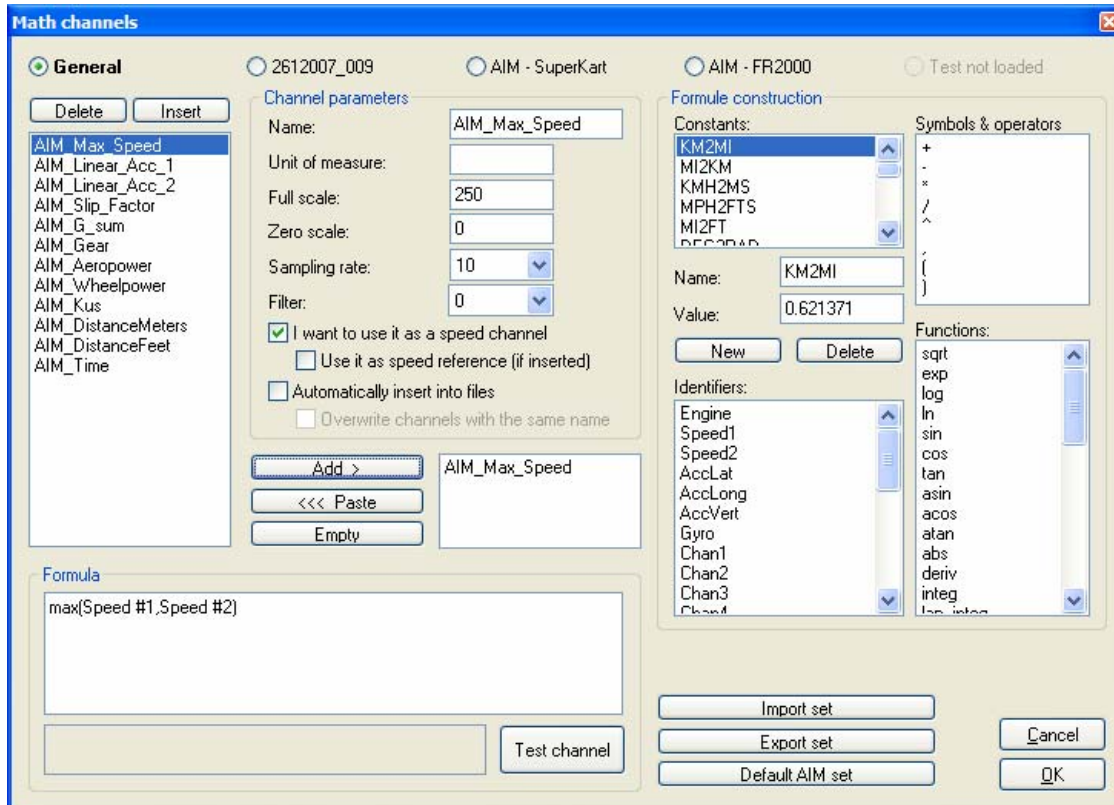

Figure 2 - Math Channel Screenshot

Once you have selected which channel(s) you wish to use (you may select more than one at a time), click on the bullet corresponding to the test you wish to apply this channel to. For this example we have selected the AIM_Max_Speed channel, which shows the maximum speed value for a given point in time between the Speed_1 channel and the Speed_2 channel that are being measured using the data logger. After you choose which test you would like to use it for, the channels box will show the channels already inserted in the test or will be empty if no math channel has been inserted, and you will be able to add your desired channels to it as shown in the screenshot directly below (**Figure 3**).
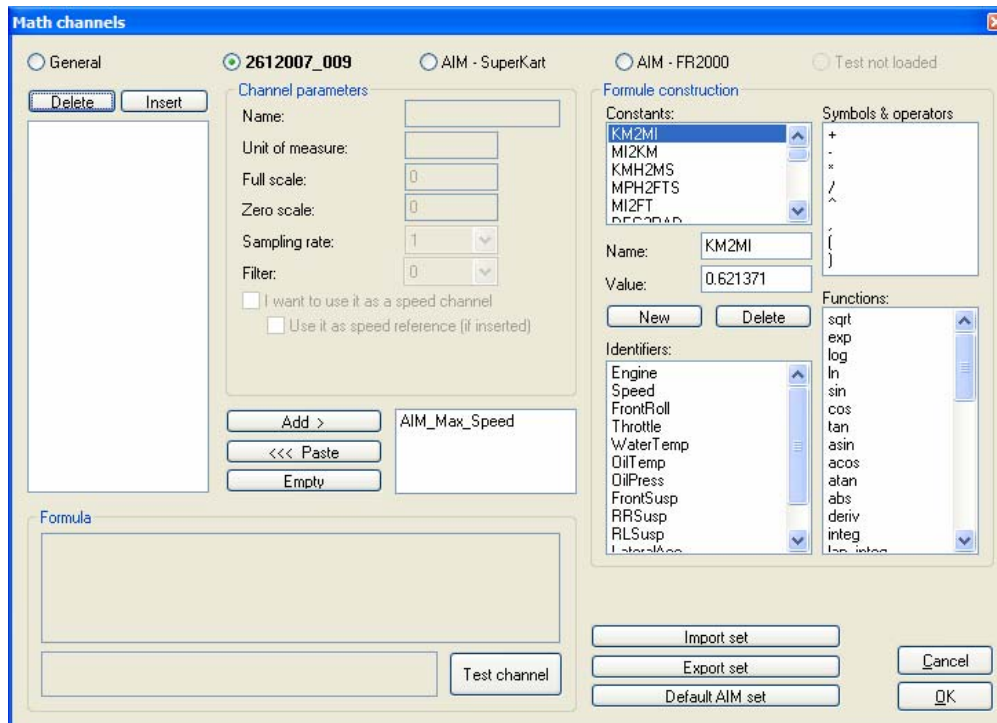
Figure 3 - Opened Math Channels for test named 2612007_009

Now that we have selected which test to apply this to, our next step is to apply it. Click on the "<<< Paste" button to add any desired channels to the channels box for that test. Once they are over there, you can do one of two things. You can leave them as they are and use them how our software has already defined them, or you can make adjustments to the channel. For instance, you can change the units of the measurement or something of that nature. You may have to adjust the identifiers like we do for this test. The Speed#1 and Speed#2 channel names do not exist for this test, so we must change them to which speeds we wish to use. For this test we wish to know the max between the two rear wheel speeds. We'll erase the Speed#1 and Speed#2 inputs, and select from the Identifiers list the SPEEDRL and SPEEDRR channels. Double click on each one to send them into the formula box, remembering they need to be separated by a comma.

Note: For speed channels such as this one you need to make sure the checkbox labelled "I want to use it as a speed channel" is checked. Also, if you wish to use this as your reference speed, click on the checkbox marked "Use it as speed reference (if inserted)."

Also, be sure to change the scale values and sampling rate if needed. In this case, the Full Scale setting needs to be changed from 250 to 350. This value is determined by the graphing scale for the SPEEDRL and SPEEDRR channels. For sampling rate, it is best to simply set this at the lowest sampling rate of any channels used in the calculation. The settings for math channels range from 1 Hz to 1000 Hz. After you have completed writing your channel, you can then click on the "Test channel" button to make sure you channel has been input correctly. If it has you will see the message "Ok, the formule has been correctly interpreted" to the right of the "Test Channel" button as shown in **Figure 4** below.
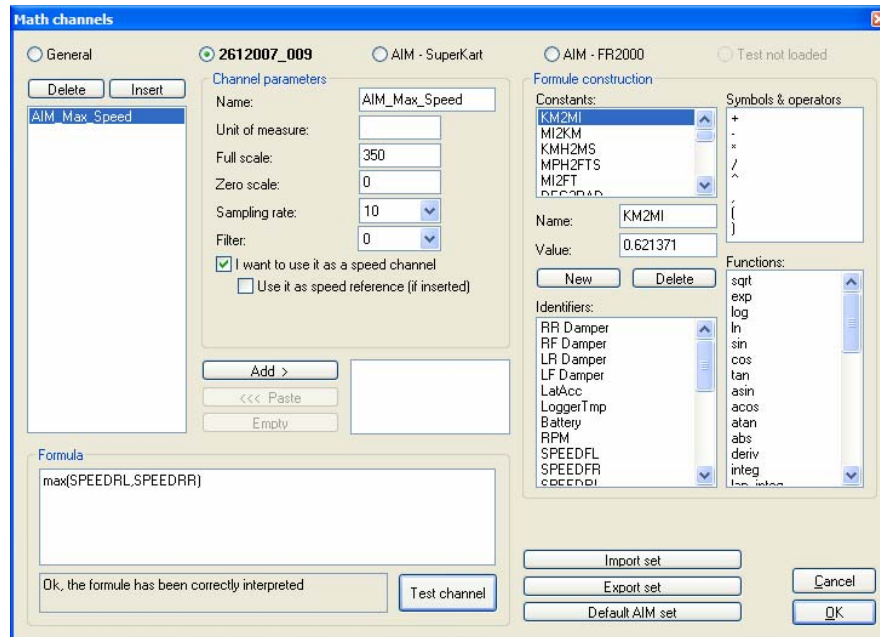

Figure 4 - Screenshot of the correctly interpreted formula

If the channel has not been correctly interpreted, you will see the message "Error: an identifier, a constant or a symbol is unknown" and the problem will be highlighted as shown in the screenshot below in **Figure 5**.
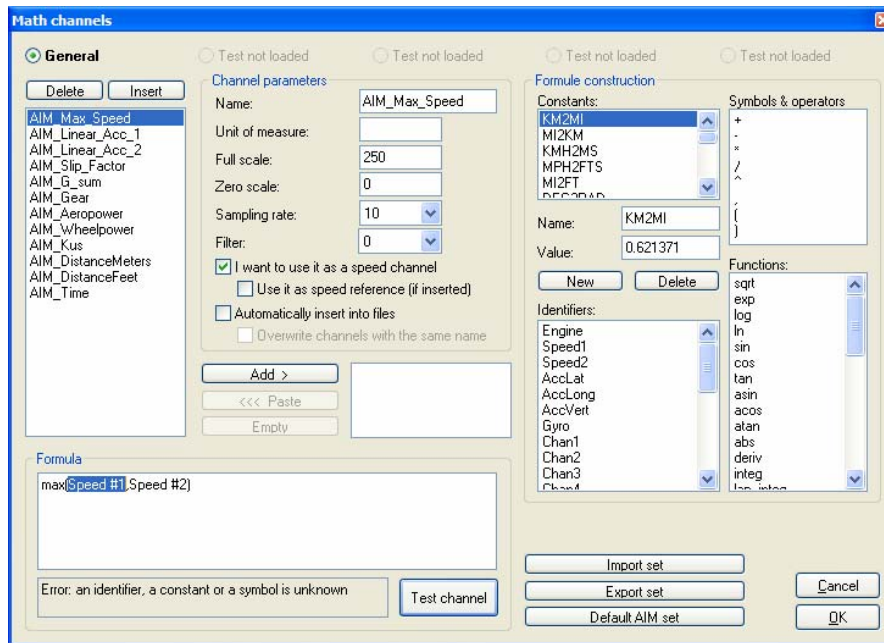
Figure 5 - Screenshot of incorrectly written formula

If this happens, you can double click on the correct identifier, constant, or symbol and the highlighted problem will automatically be replaced. In the example above it is the Speed#1 identifier that is not correct. In this case you would go to the Identifiers box and double click on the Speed1 identifier to replace Speed#1.

Once the channel is set up how you wish, click the "OK" button, and the channel will show up at the bottom of the Measures tab in your **Race Studio Analysis** as shown in **Figure 6** below.
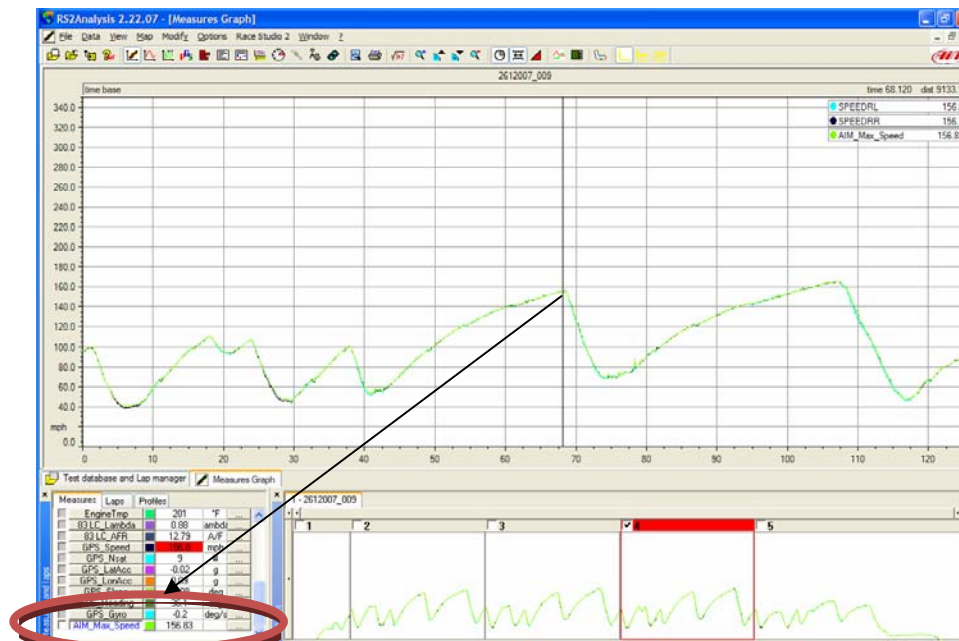

Figure 6 - Measures Tab after Math Channel has been added to test analysis

Section 3 – Writing Your Own Math Channel from Scratch

If you do not wish to modify one of the existing math channels, or need something that is not offered by those, you can create your own. We will start by doing a sample calculation. In this section you will learn how to create a math channel to calculate Longitudinal Acceleration using the speed channel provided by the GPS module.

First thing you need to do to create a channel from scratch is click the "Insert" button above the Channels box and a "New Channel" will appear. Change the channel name in the Channel Parameters to whatever you would like it to be. Choose a name that describes the channel it is calculating. I have named this one Long_Acc. Next remember to change the scale and unit of measure. We have based ours on the scale already in place for the GPS_LonAcc channel, which is the longitudinal acceleration that the GPS module has already calculated.

Reminder: If you are creating a speed channel, you need to check the box labeled "I want to use it as a speed channel."

Now you can move down to the Formula box to start writing the formula. Select the "deriv" function from the function list. Now open your parenthesis, and type in the speed channel you wish for this to be calculated from. In this case, you will type in GPS_Speed. You can also input it by selecting GPS_Speed from the Identifiers list and double clicking on it. The units of the GPS_Speed value are in MPH. G-forces, however, are calculated based on acceleration in units of either ft/sec2 or m/s2, so we have to convert the MPH to either ft/sec or m/s (feet per second or meters per second). For this example we will do our calculations in metric units, so we will convert MPH to m/s. To do this, simply multiply the GPS_Speed value you have already input first by the MI2KM factor to put it in km/hr (kilometers per hour), and then multiply by the KMH2MS factor to convert from km/hr to m/s (meters per second). Finally, close your parenthesis and divide by the ACCGRAV constant, which is the acceleration due to gravity (9.806 m/s2). What this does is convert from the acceleration value with units of m/s2 to a g (G-force) value. What we have essentially done is taken the derivative of speed over time to calculate acceleration. Your final formula for this channel should look like the one below and its corresponding screenshot (**Figure 7**).

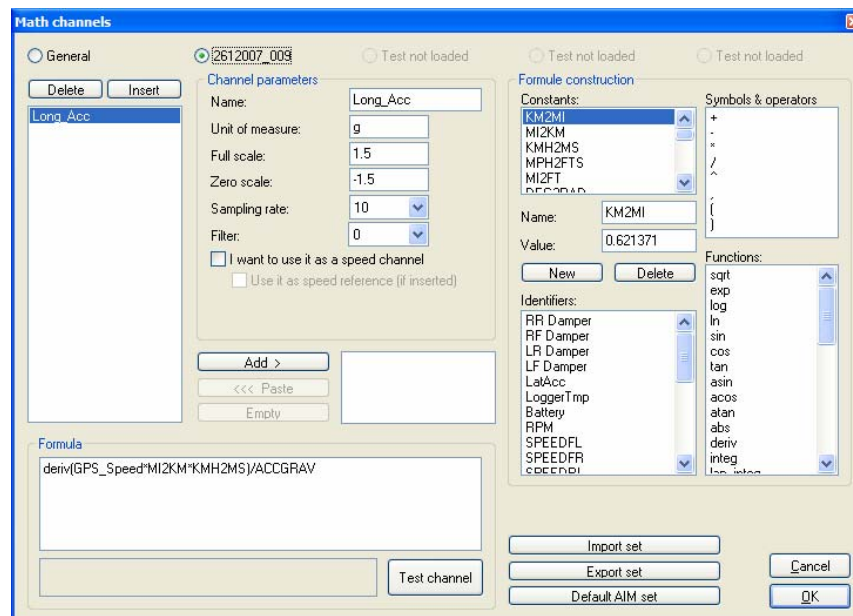**Long_Acc** = deriv(GPS_Speed*MI2KM*KMH2MS)/ACCGRAV

Figure 7 - Screenshot of a properly created Longitudinal Acceleration channel in metric units

Now if you wish to calculate this longitudinal acceleration using English units instead of Metric, simply follow the formula below.

Long_Acc = deriv(GPS_Speed*MPH2FTS)/FTPERSEC

Where MPH2FTS is the conversion from Miles per hour to feet per second, and FTPERSEC is the acceleration due to gravity in English units (32.2ft/sec2). Below is a screenshot of the channel using this method (**Figure 8**).
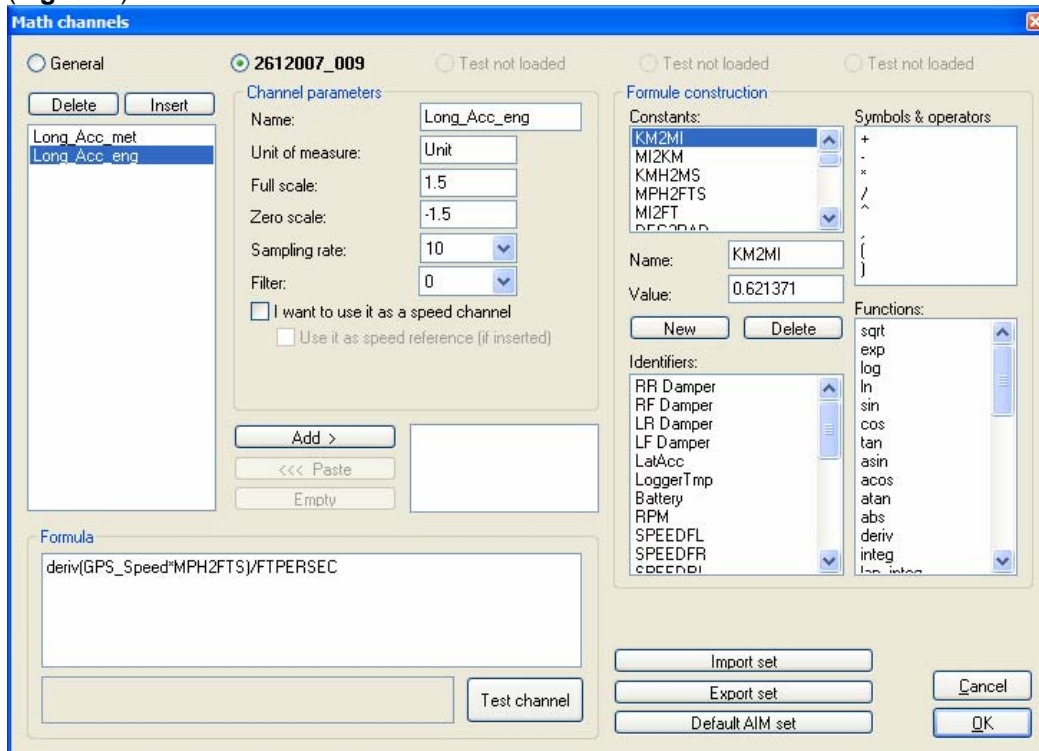

Figure 8 - Screenshot of a properly created Longitudinal Acceleration channel in English units

Section 4 – Importing and Exporting Channels Sets

Some other very useful things you can do using math channels is save channel sets to import them later into another test, along with the ability to import the entire set of default AIM math channels. We will begin with saving a channel set. If you refer to the screenshot above (**Figure 8**) you will see that we have two channels defined. If we want to use those channels in another test we can save them in one of our folders and access them later when we write math channels for another test.

Once you have a set of channels you wish to save, click the "Export set" button down in the bottom right hand corner. This will open up the FORMULE (C:\Program Files \ AIM \ DATA \ SAMPLES \ FORMULE) folder where you will save the channels set. Give it any name you wish, and it will be saved there for you to import later. When you do want to import that set, or any other set you have saved, you do not need to go find it in that folder. Simply open up the math channels tool, select the test for which you wish to import the channels set, and click on the "Import set" button. This will open up the import window and you can browse it to choose which set you would like to import. The channel set you have imported will show up in the Channels box below the "Delete" and "Insert" buttons. Remember to change the channel names, scale values and identifiers as appropriate for the test you wish to use these channels for.

You also have the option of using the default set of math channels that are already written in the software. This set is the one that is shown in the Channels box on the screenshot in **Figure 1** at the beginning of this tutorial. To import those back into the channels box, simply click on the "Default AIM set" button, and all of the default AIM channels will appear for you to use.

Section 5 – General Math Channels Options

For any channels you write as General channels (with the General bullet selected as opposed to a specific test), you are given the option to use them in all of your tests.
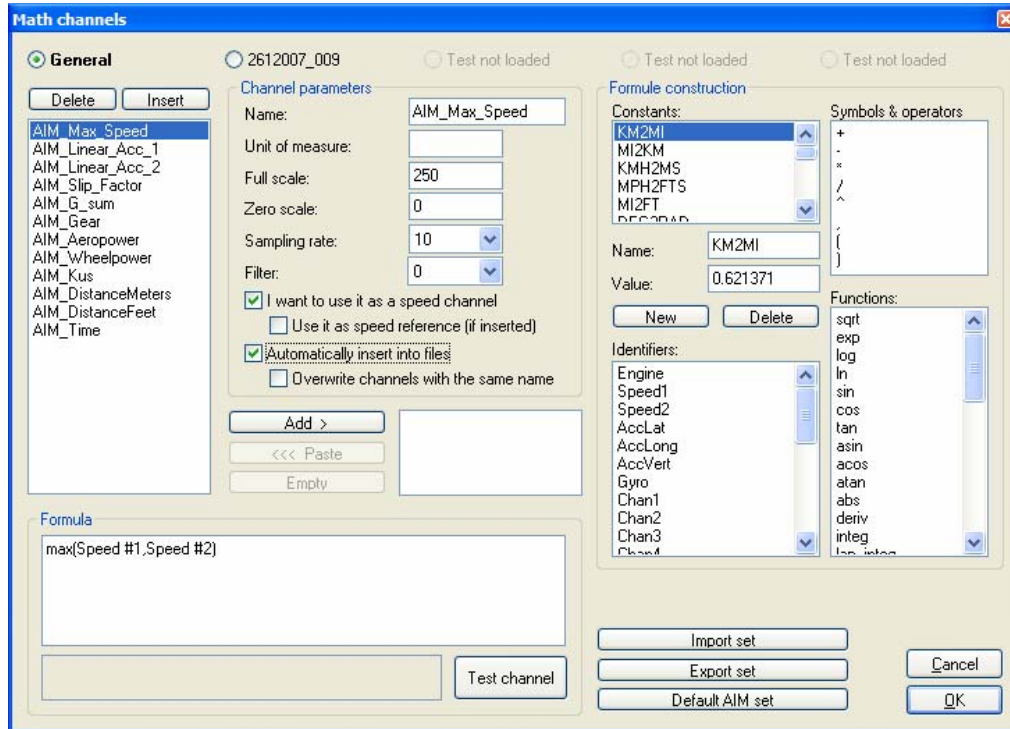

Figure 9 - Screenshot of a General Channel to be used in all tests in the database

If you wish to use the current math channel in all of your tests, select the checkbox labeled "Automatically insert into all files" as shown in the screenshot above (**Figure 9**). Remember, to do this the channel must be created as a General Channel. If you choose to automatically insert it into all files, you also have the option to overwrite any channels with the same name. For instance, if you want to write your own channel for longitudinal acceleration using speed, you can use that channel to overwrite any longitudinal acceleration channels gathered by an accelerometer in the gauge. This option is not very commonly used, but is still nice to have available.

Section 6 – Final Reminders

Always pay attention to what units you are working in. Most default math channels are defined in metric units, so if your channels are gathering data in English units, don't forget to convert them.

Make sure you have scaled your math channel properly. Sometimes the default values are not the ones you want to use, which could cause your new channel to be off the graph you are trying to view it on.
If your new math channel is a speed channel, remember to check the box next to "I want to use it as a speed channel."

When using default channels, remember to change any identifiers to the identifiers used in the test to which you are applying that math channel.

Remember to always test new channels before adding them to your measures tool bar.

If you wish for your math channel to sample at a rate higher than 10 Hz, remember to change that setting.