User manual

PERFORMANCE IMPROVING DEVICES

IMU CAN

Inertial platform and vehicle dynamic management module for motorcycles

(Hardware version v.003)

1.0 INTRODUCTION

Description of inertial platform

GRIPONE IMU CAN is an inertial platform specifically designed for uses on motorcycles with traditional or electric engine, for sports or road use. A complex algorithm processes the data, comes from the MEMS sensors, to calculate the roll angle, the pitch angle, the accelerations of 3 axis and the gyro speed of three axis. All data are made available via CAN bus communication.
IMU CAN is pre-configured in factory (for its basic functions) so it is ready to be used (simply connecting the CAN bus). In addition to the basic functions, the inertial platform has two digital inputs, thanks to which it can acquire the signal of the speeds of both wheels. Thanks to this peculiarity and thanks to the include control strategies, GRIPONE IMU CAN becomes a real vehicle dynamic control module.

Basic functions of inertial platform

GRIPONE IMU CAN is set to supply the following data by CAN bus:

- Acceleration X-axis
- Acceleration Y-axis
- Acceleration Z-axis
- Gyro X-axis
- Gyro Y-axis
- Gyro Z-axis
- Roll angle
- Pitch angle

These basic values are transmitted by CAN bus, following the format described in paragraph 4.0.

Advanced functions of inertial platform

GRIPONE IMU CAN is able to detect the speed signal coming from external speed sensors (like the ABS speed sensors). Using speed signals, IMU CAN is able to activate the traction control

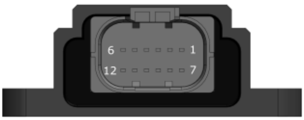
strategy, the anti-wheelie strategy and the engine brake strategy. These strategies are based on simplified mathematical models of the vehicle and the configuration parameters.
As output, these strategies provide a value that can be used by the ECU that manage the engine to implement a correction of power delivery, so as to restore the stability of the vehicle. As advanced functions, GRIPONE IMU CAN is set to supply the following data (*1):

- TC power reduction
- AW power reduction
- EB friction reduction

Note 1: the output of traction control strategy, anti-wheelie strategy and engine brake strategy can be customized upon request.

2.0 HOW TO CONNECT

Pin out



1	POWER SUPPLY
2	CAN Low
3	CAN High
4	GND
5	3.3 TTL UART TX
6	3.3 TTL UART RX
7	SPEED REAR WHEEL
8	SPEED FRONT WHEEL
9	USB GND
10	USB D+
11	USB D-
12	USB +5Volts

Base connection

The base connection of GRIPONE IMU CAN is made by four pins: +12v (pin 1), CAN Low (pin 2), CAN High (pin 3) and GND (pin 4). This connection is enough to guarantee the basic functionalities of the inertial measurement unit.

Additional connection for advantage functions

To let GRIPONE IMU CAN detect the speed signal of both wheels of the vehicle it is necessary connect the SPEED REAR WHEEL (pin7) and SPEED FRONT WHEEL (pin 8). By the signal of front wheel, the inertial platform will be able to detect the wheelie of the motorcycle (intended as the detachment of the front wheel from the ground). Connecting both speed signals (front wheel speed and rear wheel speed), the inertial platform will be able to activate the traction control strategy, the anti-wheelie strategy and the engine brake strategy.

Please note: the control strategies (traction control, anti wheelie and engine brake) can't act on the vehicle if the vehicle's engine management unit is unable to process the data provided by GRIPONE IMU CAN.

Fixing to the vehicle

GRIPONE IMU CAN must be positioned on the vehicle respecting a precise orientation. The arrow X must point in the direction of drive of the vehicle. The arrow Y must point to the right of the vehicle. The inertial platform must be positioned horizontally.

The GRIPONE IMU CAN may be sensitive to the vibration, for that reason we suggest to fix the body of IMU by soft rubber silent blocks. The best place of IMU is in the center of the front end of the vehicle. If the IMU is placed in the middle of the vehicle, it could not recognize the wheelie.
When you fabricate the wiring loom to connect the IMU CAN to the vehicle, we suggest to use thin wires (Maximum AWG 26). The thin wires will not transfer vibration from harness to inertial platform.

3.0 ADVANCED STRATEGIES

All control strategies work thanks to the user entering the configuration parameters. The configuration parameters can be edited using the inertial platform management software (available at web address download.gripone.com/gripone_imu_can_hid/). The management software communicates with the inertial platform via the USB cable. When the USB cable is connected to the GRIPONE UIMU CAN, the software recognize the device (without install any USB driver).

Traction control strategy

The traction control strategy independently generates a "slip target" which varies according to various factors such as the roll angle, the wheel load and user handled parameters (like TRACTION CONTROL LEVEL). The "slip target" is the so-called safe slip percentage over which the vehicle become unstable.
The "slip target" value is then compared to the slipping level of rear wheel, calculated by the wheels speed signals. The error between these two values, is handled by a PID controller. The

PID controller works on the basis of configuration parameters such as, ENGINE POWER, VEHICLE WEIGHT and WHEEL BASE. The PID controller send (via CAN bus) the final output as percentage of power reduction needed to restore the stability.

Parameters handled by the user

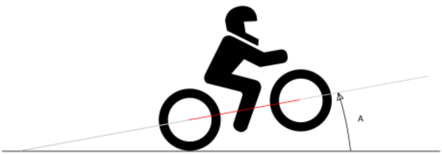
Name	Min	Max	Description
TRACTION CONTROL LEVEL	1	10	TCL represents an index of the level of support that you want to receive from the traction control. TCL = 1 indicates to the strategy that rider wants to be able to slide a lot with the rear tire. TCL = 10 indicates to the strategy that rider wants the maximum possible support from the traction control.

Output: TC_POWER_REDUCTION [%]

Anti-wheelie control strategy

The anti-wheelie strategy detects the moment when the front wheel lifts off the ground. From that moment (and until the front wheel does not come back into contact with the ground) the relative pitch angle is calculated. The relative pitch angle is close to zero when the front wheel is on the ground and it increase when the front wheel lifts off the ground. The pitch angle will increase if the distance between the front wheel and the ground increase.

$A \approx 0°$
When both wheels are on the ground, the pitch angle is zero



$A > 0°$
When the front wheel is not on the ground, the pitch angle is greater than zero.

The anti-wheelie strategy defines a “pitch angle target” which varies according to various factors such as the roll angle and user handled parameters (like ANTI WHEELIE CONTROL LEVEL).
The "pitch angle target" is then compared to the pitch angle. The error, calculated between these two values, is handled by a PID controller. The PID controller works on the basis of configuration parameters such as, ENGINE POWER, VEHICLE WEIGHT and WHEEL BASE. The PID controller send (via CAN bus) the final output as percentage of power reduction needed to restore the normal pitch angle.

Parameters handled by the user

Name	Min	Max	Description
ANTI WHEELIE CONTROL LEVEL	1	10	AWCL represents an index of the level of support that rider want to receive from the anti-wheelie control strategy. AWCL = 1 indicates to the strategy that rider wants to be able to lift the front tire a lot. AWCL = 10 indicates to the strategy that rider wants the maximum possible support from the anti-wheelie control.

Output: AW_POWER_REDUCTION [%]

Engine brake control strategy

The engine brake control strategy independently generates a "locking target" which varies according to various factors such as the roll angle, the wheel load and user handled parameters (like ENGINE BRAKE CONTROL LEVEL). The "locking target" is the so-called safe negative slip percentage, over which the vehicle become unstable. The " locking target" is then compared to the locking level of rear wheel, calculated by the speed signals. The error, calculated between these two values, is handled by a PID controller. The PID controller works on the basis of configuration parameters such as, VEHICLE WEIGHT and WHEEL BASE. The PID controller send (via CAN bus) the final output as percentage of friction reduction needed to restore the normal grip level.

Parameters handled by the user

Name	Min	Max	Description
ENGINE BRAKE CONTROL LEVEL	1	10	EBCL represents an index of the level of support that you want to receive from the engine brake control. EBCL = 1 indicates to the system that you want to be able to lock the rear tire a lot. EBCL = 10 indicates to the system that you want the maximum possible control from the engine brake control.

Output: EB_FRICTION_REDUCTION [%]

Vehicle parameters

All the strategies use the user handled parameters (like TRACTION CONTROL LEVEL, ANTI WHEELIE CONTROL LEVELE and ENGINE BRAKE CONTROL LEVEL) and the configuration parameters related to characteristics of the motorcycle. To obtain a proper result, it is necessary insert the correct values in the following configuration parameters:

Name	Min	Max	Description
COG HEIGHT	500	1500	It is the distance between the center of gravity position and ground (in mm)
WHEEL BASE	1000	2500	It is the distance between the center of the front wheel to the center of the rear wheel (in mm).
VEHICLE WEIGHT	50	400	It is the weight of the vehicle (in kg).
ENGINE POWER	35	300	The power of the engine in HP.

4.0 CAN BUS COMMUNICATION

Transmission via CAN

GRIPONE IMU CAN transmits data via CAN bus on three different IDs and receive over one ID. All IDs are 11bit deep and are programmable by the user through the inertial platform management software. The CAN bus is set as follow:

Baud rate: 1Mbs
Format: Intel LSB CAN 2.0B 11-bit
Output rate: 100 Hz

The ID are set to their default value as follow:

1° ID (output)	default value is 0x500 (HEX)
2° ID (output)	default value is 0x510 (HEX)
3° ID (output)	default value is 0x520 (HEX)
4° ID (input)	default value is 0x480 (HEX)

All IDs can be modified by the management software.

Transmission protocol on 1° ID (default value is 0x500)

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 0	Bit 0
BYTE 0	Acceleration X (low byte)							
BYTE 1	Acceleration X (high byte)							
BYTE 2	Acceleration Y (low byte)							
BYTE 3	Acceleration Y (high byte)							
BYTE 4	Acceleration Z (low byte)							
BYTE 5	Acceleration Z (high byte)							
BYTE 6	Roll angle (low byte)							
BYTE 7	Roll angle (high byte)							

Parameter	Byte	Type	Scale	U.M.
Acceleration X	0-1	unsigned word	Acceleration = (WORD – 32000) / 1000	g
Acceleration Y	2-3	unsigned word	Acceleration = (WORD – 32000) / 1000	g
Acceleration Z	4-5	unsigned word	Acceleration = (WORD – 32000) / 1000	g
Roll angle	6-7	unsigned word	Roll angle = (WORD – 18000) / 200	deg

Transmission protocol on 2° ID (default value is 0x510)

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 0	Bit 0
BYTE 0	Gyro X (low byte)							
BYTE 1	Gyro X (high byte)							
BYTE 2	Gyro Y (low byte)							
BYTE 3	Gyro Y (high byte)							
BYTE 4	Gyro Z (low byte)							
BYTE 5	Gyro Z (high byte)							
BYTE 6	Pitch angle (low byte)							
BYTE 7	Pitch angle (high byte)							

Parameter	Byte	Type	Scale	U.M.
Gyro X	0-1	unsigned word	Gyro = (WORD – 30000) / 10	deg/sec
Gyro Y	2-3	unsigned word	Gyro = (WORD – 30000) / 10	deg/sec
Gyro Z	4-5	unsigned word	Gyro = (WORD – 30000) / 10	deg/sec
Pitch angle	6-7	unsigned word	Ritch angle = (WORD – 18000) / 200	deg

Transmission protocol on 3° ID (default value is 0x520)

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 0	Bit 0
BYTE 0	TC_POWER_REDUCTION (low byte)							
BYTE 1	TC_POWER_REDUCTION (high byte)							
BYTE 2	AW_POWER_REDUCTION (low byte)							
BYTE 3	AW_POWER_REDUCTION (high byte)							
BYTE 4	EB_FRICTION_REDUCTION (low byte)							
BYTE 5	EB_FRICTION_REDUCTION (high byte)							
BYTE 6	DIAGNOSTIC (low byte)							
BYTE 7	DIAGNOSTIC (high byte)							

Parameter	Byte	Type	Scale	U.M.
TC_POWER_REDUCTION	0-1	unsigned word	Reduction = WORD / 100	%
TC_POWER_REDUCTION	2-3	unsigned word	Reduction = WORD / 100	%
EB_FRICTION_REDUCTION	4-5	unsigned word	Reduction = WORD / 100	%
DIAGNOSTIC	6-7	unsigned word	See “diagnostic bit flag” table	***

Diagnostic bit flag table

Value	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	***	Temperature is under 50°C	Gyro Z works in the right range	Gyro Y works in the right range	Gyro X works in the right range	Accelerometer Z works in the right range	Accelerometer Y works in the right range	Accelerometer X works in the right range
1	***	Temperature is over 50°C	Gyro Z does not work in the right range	Gyro Y does not work in the right range	Gyro X does not work in the right range	Accelerometer Z does not work in the right range	Accelerometer Y does not work in the right range	Accelerometer X does not work in the right range
Value	**Bit 15**	**Bit 14**	**Bit 13**	**Bit 12**	**Bit 11**	**Bit 10**	**Bit 9**	**Bit 8**
0	***	EB strategy off	AW strategy off	TC strategy off	Rear wheel speed is in the range (*1)	Front wheel speed is in the range (*1)	No spikes detected in the rear wheel speed	No spikes detected in the front wheel speed
1	***	EB strategy on	AW strategy on	TC strategy on	Rear wheel speed is not in the range (*1)	Front wheel speed is not in the range (*1)	Spikes detected in the rear wheel speed	Spikes detected in the front wheel speed

Note 1: If the inertial platform detects the front wheel speed, it supposes to detect also the rear wheel speed. If the front wheel speed is greater than zero and the rear wheel speed is zero, the bit flag 10 is set to 1. If the rear wheel speed is greater than zero and the front wheel speed is zero, the bit flag 11 is set to 1. This bit flag alert the external devices about failures of speed signals. The external devices can use this bit flag as diagnostic and in case disable the strategy.

Reception via CAN

GRIPONE IMU CAN is able to receive information via CAN bus and modify (in real time) the user handled parameters. By this ability, the inertial platform can modify the output of traction control, anti-wheelie control and engine brake control (during the riding).
Please note: if onboard the vehicle there is another device able to detect the speeds and transmit the values by CAN bus, GRIPONE IMU CAN is able to receive the speed value of both wheels.

Reception on 4° ID (default value is 0x480)

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 0	Bit 0
BYTE 0	TRACTION CONTROL LEVEL (**TCL**)							
BYTE 1	ANTI-WHEELIE CONTROL LEVEL (**AWCL**)							
BYTE 2	ENGINE BRAKE CONTROL LEVEL (**EBCL**)							
BYTE 3	FRONT WHEEL SPEED (low byte)							
BYTE 4	FRONT WHEEL SPEED (high byte)							
BYTE 5	REAR WHEEL SPEED (low byte)							
BYTE 6	REAR WHEEL SPEED (high byte)							
BYTE 7	***							

Parameters received on 4th ID must fall within a specific range. If the transmitted values do not fall within the correct range, they will be saturated to the maximum allowed value.

Parameter	Byte	Type	Scale	U.M.	Range
TCL	0	unsigned byte	TRACTION CONTROL LEVEL	***	1 – 10
AWCL	1	unsigned byte	ANTI_WHEELIE CONTROL LEVEL	***	1 - 10
EBCL	2	unsigned byte	ENGINE BRAKE CONTROL LEVEL	***	1 - 10
FRONT SPEED	3-4	unsigned word	Value = WORD / 100	Km/h	0 - 60000
REAR SPEED	5-6	unsigned word	Value = WORD / 100	Km/h	0 - 60000

GRIPONE IMU CAN saves the values of TCL, AWCL and EBCL in its internal flash memory. Each time GRIPONE IMU CAN receives these values (via the CAN bus), it will check if any changes have occurred (with respect to the previous values) and will save the new value in the flash memory (in case of change). A few moments later, GRIPONE IMU CAN will begin to use the new values in the calculations of strategies.

If the user wants to send the speed signals to GRIPONE IMU CAN via CAN bus, the user must set the parameter "**INPUT TYPE"** to "VIA CAN BUS", into the SPEED SIGNAL tab of the software (see paragraph 5 for more details). If the user wants to send the speed signals to GRIPONE IMU CAN, using the digital inputs, the user must set the parameter "**INPUT TYPE"** to "DIGITAL INPUT", into the SPEED SIGNAL tab of the software.

5.0 USB COMMUNICATION

GRIPONE IMU CAN (hardware version 003 or higher) provides basic functions without the need to be configured. However, to correctly set the device and obtain the correct result from its advanced functions, it is necessary to send (via USB connection) the configuration parameters.
The management software communicates with the inertial platform via the USB cable. The USB cable is a simple cable that use the following signals:

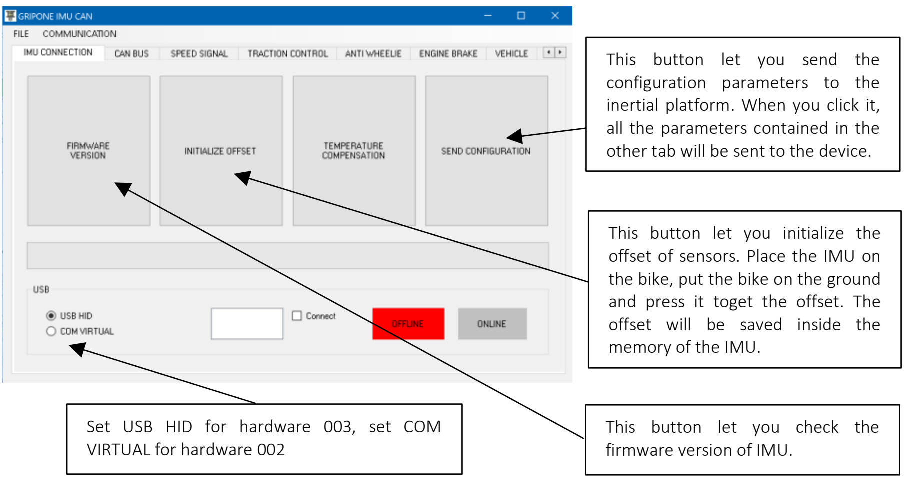
USB cable	Corresponding pin of GRIPONE IMU CAN	Note
USB power	12	Red wire
USB D-	11	White wire
USB D+	10	Green wire
GND	9	Black wire

GRIPONE IMU CAN management software

The management software is available to be downloaded from our web site at *download.gripone.com/gripone_imu_can_hid/*. Click on "**Installa**" and run *setup.exe* to install it. At the end of procedure, you can find the link in Start menu.
When you run the software, you can see several tabs. Each tab contains several configuration parameters.

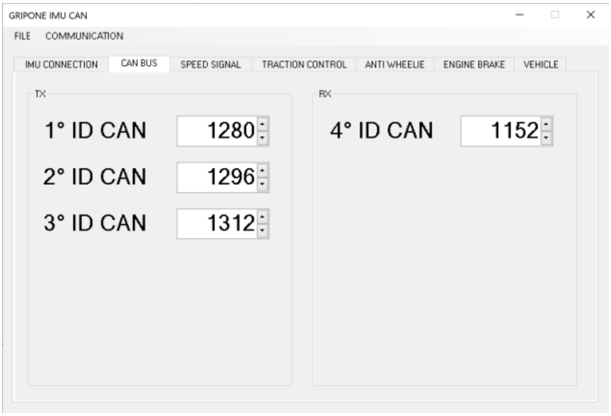
IMU CONNECTION tab

In this tab you can find 4 buttons that allow you to communicate with the inertial platform. As soon you connect the USB cable to GRIPONE IMU CAN, the green light "ONLINE" will switch on. From this moment you can communicate with the device.



CAN BUS tab

In this tab you can set the ID where receive the data from IMU and the ID where send information to IMU.



SPEED SIGNAL tab

In this tab you can set the development of both wheels, the pulses detected by the speed sensors and the type of used speed sensor.

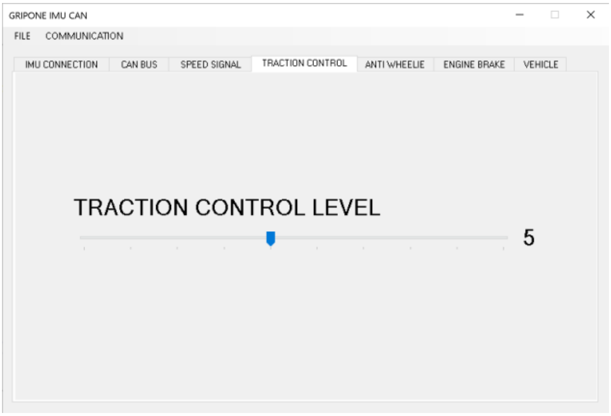
The development of the wheel is measured in mm. For each wheel there are seven fields where insert the development by the roll angle. The roll angle is zero when the vehicle is straight (perpendicular to the ground). The roll angle is 60° when the vehicle is leaned to the left or to the right side.

The wheel speed signal can be detected by ABS sensor, by other type of sensor (like Hall effect or any kind of sensor with output state NPN/PNP). If you get the signal from the OEM ABS sensors, set INPUT TYPE to ABS SENSOR. If you get the signal from sensor that give a square wave signal, set INPUT TYPE to DIGITAL TYPE. If you want to send the speed signal via CAN bus, set INPUT TYPE to VIA CAN BUS.

Please note: if you choose ABS SENSOR or DIGITAL TYPE, any speed value sent by CAN bus will be ignored. As well, if you choose VIA CAN BUS, any signal from digital inputs will be ignored.

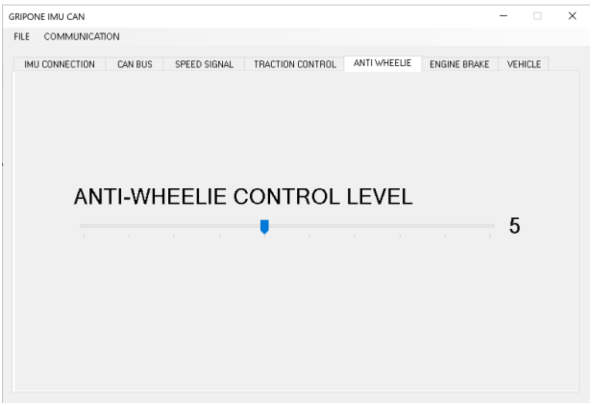
TRACTION CONTROL tab

In this tab you can set TRACTION CONTROL LEVEL. Set it to 1 to obtain the minimum level of traction control. Set it to 10 to obtain the maximum level of traction control.



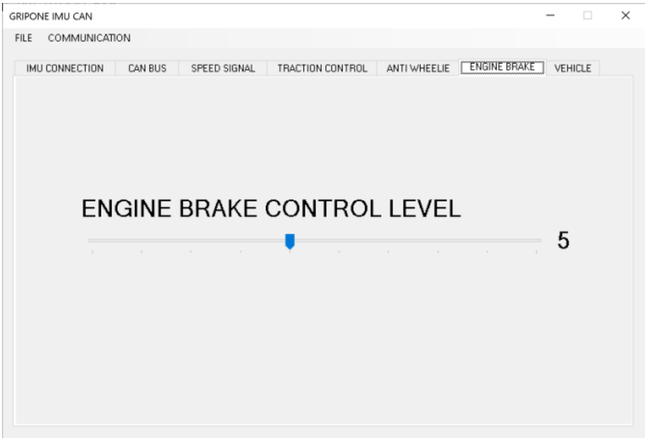
ANTI WHEELIE tab

In this tab you can set ANTI-WHEELIE CONTROL LEVEL. Set it to 1 to obtain the minimum level of anti-wheelie control. Set it to 10 to obtain the maximum level of anti-wheelie control.



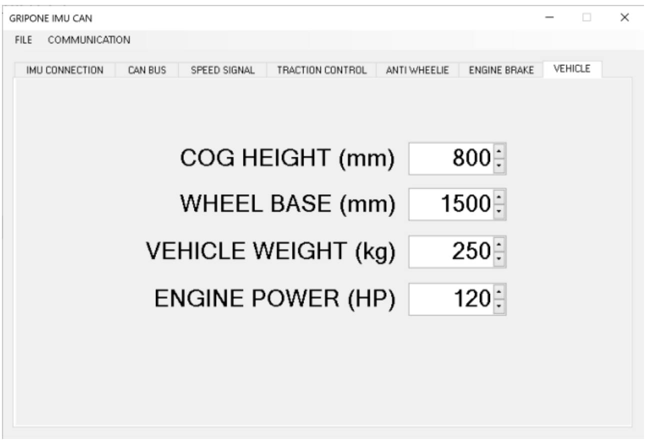
ENGINE BRAKE tab

In this you tab can set ENIGNE BRAKE CONTROL LEVEL. Set it to 1 to obtain the minimum level of engine brake control. Set it to 10 to obtain the maximum level of engine brake control.



VEHICLE tab

In this tab you can set the parameters that the inertial platform uses to manage the calculation of TC_POWER_REDUCTION, AW_POWER_REDUCTION and EB_FRICTION_REDUCTION. COG HEIGHT is the distance from the ground to the center of gravity of the vehicle (without rider). WHEEL BASE is the distance (in mm) between the center of wheels. VEHICLE WEIGHT is the weight (in kg) of the motorcycle (rider non included). ENGINE POWER is the maximum power of the engine (in HP).



Configuration file

Once you set all the parameters, you can save the configuration in a text file. The configuration includes all the parameters that you can manage by the tabs. The values of MEMS offset (done by pressing the button INITIALIZE OFFSET) is not included into the configuration. Every time the IMU is moved from its original position, it is necessary repeat the procedure of initialization of offset. Every time the IMU crashes, it is necessary repeat the procedure of initialization of offset.
Please note: if you change value of parameters into the tabs, the IMU will be not updated until you press the button SEND CONFIGURATION in the IMU CONNECTION tab. So, it means that to set properly the IMU, you must check (and eventually edit the parameters), connect the USB cable and press SEND CONFIGURATION button.

6.0 ELECTRICAL CHARACTERISTICS

Operating range: -20°C / +80°C

Parameters	Unit	Min	Typ.	Max
Power supply	V	7	12	18
Current absorption	mA	65	80	95
I/O pin minimum Voltage	V	– 0.3		
I/O pin maximum Voltage	V			Power + 0.3
(*1) Speed low-level input voltage V_{IL}	V			<0.6
(*1) Speed high-level input voltage V_{IH}	V	>2.2		
Voltage at any bus terminal (CAN HIGH or CAN LOW)	V	-4		16
CAN bus load	Ohm		120	

(*1) valid for DIGITAL INPUT TYPE

7.0 SPECIFICATIONS

Accelerometer N.1
3-axis +/- 64g

Accelerometer N.2
3-axis +/- 32g

Gyro N.1
3-axis +/- 2000dps

CAN BUS
Baud rate: 1Mbs
Format: Intel LSB CAN 2.0B 11-bit 1Mbs
ID: programmable

Speed inputs
Max frequency: 2000Hz

Main connector
JAE ELECTRONIC - MX23A12NF1

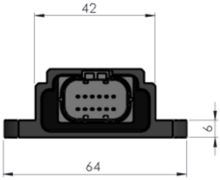
Output rate (of CAN bus)
100 Hz
Input rate (of CAN bus)
≤ 100 Hz

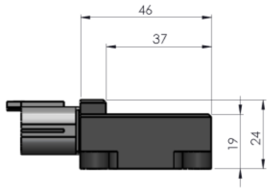
Basic Output
Acceleration X (g)
Acceleration Y (g)
Acceleration Z (g)
Gyro X (dps)
Gyro Y (dps)
Gyro Z (dps)
Roll angle (deg)
Pitch angle (deg)

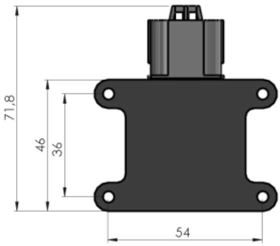
Advanced Output
TC_POWER REDUCTION (%)
AW_POWER REDUCTION (%)
EB_FRICTION_REDUCTION (%)

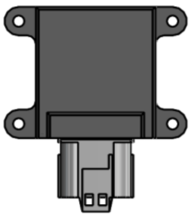
Resolution output
Accelerations: +/- 0.001g
Gyro: +/- 0.01dps
Roll: +/- 0.005 deg
Pitch: +/- 0.005 deg

8.0 DIMENSIONS









GRIPONE

is designed, owned and made by

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