Razor Gimbal
Stabilization System

INSTRUCTIONS

ver 1.0

THE PERFECT PHOTOGRAPHER'S TOOL

The Razor Gimbal controller is a complete, ready to fly 3-axis stabilization system designed to fit any 1, 2 or 3-axis camera gimbal stabilization system. Designed to be fully customizable, and utilize the cutting edge technology in MEM's sensors and a 9-state Extended Kalman Filter, this system will enable you to get complex shots with ease. With this system we are taking you to the next level of unprecedented stability, control and reliability.

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Introduction

The Razor Gimbal was designed to control 1, 2, and 3 axis camera gimbals with either Standard PWM servos or Constant Rotation PWM servos of all sizes.

This system contains the latest in MEM's technology and a microprocessor capable of advanced data filtering and processing.

The microcontroller has 4 high resolution PWM outputs, an onboard USB port, and is able to read signals from a variety of commonly available radio control receivers.

The sensor fusion algorithms combine the measurements of a 3-axis accelerometer, 3-axis gyro, and a 3-axis magnetometer. These sensors combined with our 9-state Extended Kalman Filter provide a very robust system capable of maintaining leveling accuracy below 0.1 degrees. Through our algorithms, this accuracy rivals that typically found on very expensive Inertial Measurements Units (IMU's).

Installation

For the basic user, the Razor Gimbal was designed to be plug-and-play; no special soldering or tweaking of any kind. For the advanced user, we have included a Graphical User Interface (GUI) which provides a variety of customization capabilities to meet the needs of your specific gimbal system. Below is a basic pin mapping.

RX connections (from left to right => Roll, Pitch, Yaw, Mode)

Servo connections (from left to right => Roll, Pitch, Yaw, Trigger)

Power connections (top +, bottom -)

- \+ Power may be supplied to any of the pins on the middle row
- \- Power may be supplied to any of the pins on the bottom row

It is possible to power the Razor Gimbal with 5-16 VDC, however the power supplied on any pin (input) will be supplied to all pins (output). So if you are using an RX which is only capable of 5V, only supply a maximum of 5V to the Razor Gimbal.

STEP 1 MOUNTING THE RAZOR GIMBAL

Unlike many camera stabilization systems, the Razor Gimbal is not restricted to a single mounting orientation. However, this does not mean that you can mount in any orientation. What this does mean is that you have 24 different mounting orientations which are software selectable in the GUI. The limitation is that you mount the Razor Gimbal in such a way that the outline of the case, aligns with the pitch and roll attitudes of your camera gimbal.

Start by determining the best location for mounting the Razor Gimbal. Try to find a location on the mounting plate where the camera will sit. It is okay to mount the Razor Gimbal underneath the camera mount (hence the 24 selectable orientations).
NOTE: It is highly recommended that the Razor Gimbal system is connected to Continuous Rotation servos. This will allow the algorithms to compensate for motion in either direction of the servo. Standard Rotation servos are not linear in their servo throw/commanded throw, and the result will be leveling errors at higher pitch and roll angles, as much as 20 degrees from actual level at 60 degrees.

Next, you will need to attach the Razor Gimbal. Please ensure that the module is rigidly attached to the camera mount. 3M double sided foam core tape is highly recommended for this application. The sensors used in the system are very sensitive and it is important that they are firmly attached, so that they can accurately sense all the movements of the camera mount.

STEP 2 MAKING THE CONNECTIONS

The wiring for the modules will depend on what type of receiver system you will use (PPM, PWM, S.Bus or Spektrum). PWM wiring will result in a more cluttered wiring layout; therefore, we recommend using S.Bus, PPM, or Spektrum over PWM. When using S.Bus, PPM or Spektrum, you are able to connect to the Razor Gimbal with only one cable (signal, +, -).

STEP 3 CAMERA BALANCING

Mount your camera to the gimbal in the same configuration you use for filming. If your gimbal uses belts to actuate pitch and roll, remove the belts from the gimbal so that the system will easily pivot. If your gimbal is actuated by control rods, disconnect one end of the rod on both the pitch and roll axes.

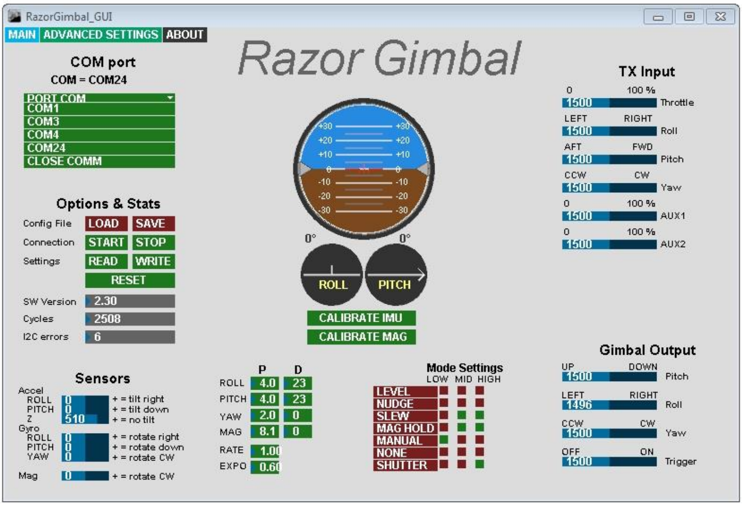
The goal is to balance the camera on the gimbal such that you can position the camera at any roll, tilt and pan angle and it will remain stationary. This is also important for stability of your helicopter (or any other vehicle system) as any motion of the gimbal will feedback inertial motion to the host system. Therefore our goal here is to minimize this as much as possible.

The normal workflow is to balance the pitch axis first, then the roll axis, and then the pan axis. To balance the pan axis, it is easiest to hang the helicopter from a boom end and adjust the gimbal forward and backward to achieve a good pan balance. Careful balancing will enhance stabilization performance and also allow higher gain settings so that they can accurately sense all the movements of the camera mount.

STEP 5 USING THE GUI

This Graphical User Interface (GUI) will give you a real time display of all the channels. This can be helpful in deciphering the channel assignment used in your particular transmitter / receiver.

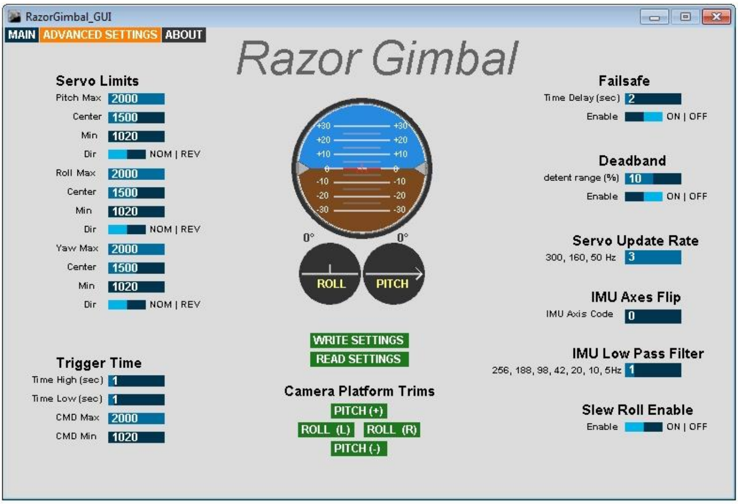
Main Tab



This tab is the location where you will:

- Select the COM port.
- Read/ write/ save your settings.
- View the sensor outputs.
- Change the PID gains.
- Select your modes.
- View the TX input and Gimbal output.
- Calibrate the IMU & Magnetometer.

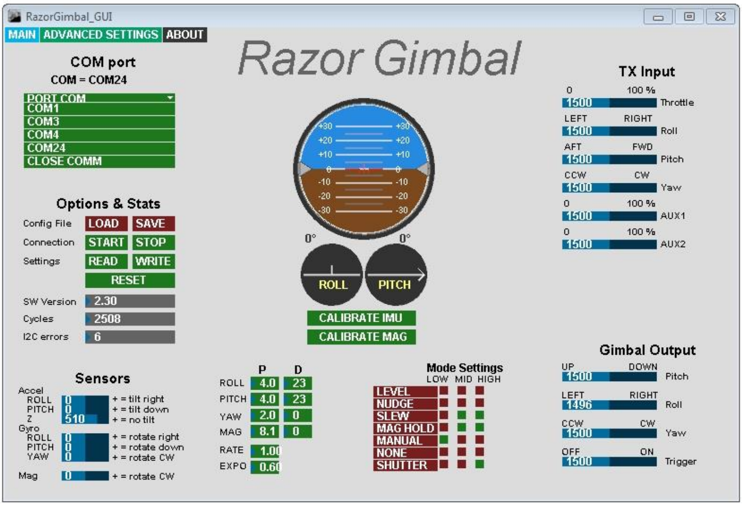
Advanced Tab



This tab is the location where you will:

- Select the servo limits and direction.
- Select the trigger time.
- Select the failsafe settings.
- Select the Deadband settings.
- Select servo update rates.
- Select the Mounting Axis.
- Select the IMU Filters.
- Trim the Camera Platform angles.

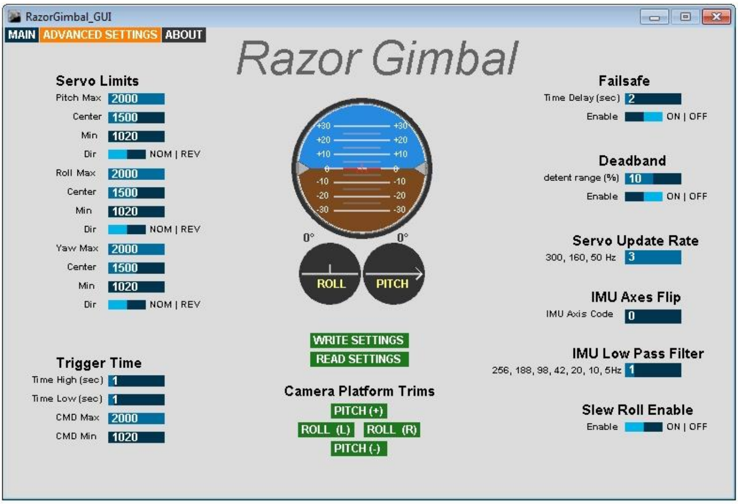
EXAMPLE 1:



This example you can see that we have:

- Connected and pressed “Start” & “Read” to get the current information from the Gimbal.
- We have obtained the PD Gains.
- We have obtained the Rate and Expo.
- We have set the AUX Switch:
    - Low to “Manual Mode”.
    - Mid to “Slew” & “Mag Hold”.
    - High to “Slew” & “Mag Hold” and in this case also “Camera Shutter” to maintain the commanded camera attitude and trigger the camera shutter with the AUX switch HIGH.

EXAMPLE 2:



This example you can see that we have:

- Set the limits of our servos, and the proper direction.
- Set the camera trigger time, 1 sec. low, 1 sec. high, this translates to holding and releasing the camera shutter button for 1 sec. each.
- We have disabled our Failsafe.
- We have disabled our Deadband.
- We have set the servo refresh rate to 50 Hz.
- We have set the IMU Axis to 0, (sitting flat on a table).
- We have set the 256 Hz Low Pass Filter (minimal delay).
- We have enabled the Roll Slew for operator override.

DEFAULTS
Each module is shipped with the basic software necessary to stabilize a camera gimbal right out of the box. It is recommended however to go through this exercise of programming your module at least once.

Whenever you connect to the modules, you MUST click “Read” first to populate the configuration window with the current module settings.

Once the modules are in the proper mounting orientation, click “Read” and then click the appropriate default option.

Next, enter your preferred configurations (see discussion below) and click “Write” to write the data to the module. To confirm that your mounting / chosen default is correct, rotate the mount in the corresponding direction for the module you are working on and ensure the Artificial Horizon window is changing as expected.

For instance, after installing the module, try rotating the mount. Given proper installation and chosen parameters, the Artificial Horizon window will change as you rotate.

DEADBAND
The deadband setting adjusts how much stick travel is required before the stick demand creates a slew command. This setting can be useful if the transmitter stick does not center in a repeatable fashion. Its function is to prevent unwanted axis drift. The default setting is 5%, but feel free to adjust as needed to suit your needs.

SERVO PULSE RATE
This setting adjusts the pulse rate output frequency for the mount stabilization. For analogue servos, it is recommended to keep the setting at 50Hz, doing otherwise will potentially burn out the

servo. Digital servos have a higher data rate and it is recommended to set the value at 300 Hz for best performance. For other mounts / servos, you may need to adjust the pulse rate.

- 1 = 300Hz (Digital Servos ONLY!)
- 2 = 150 Hz (Digital Servos ONLY!)
- 3 = 50 Hz

PD GAINS

This is the primary adjustment setting for the module. The Gain adjusts the force with which the stabilization module reacts to disturbances. Higher gain settings will cause a greater reactive force, but can also lead to instability in the system. The goal is to run the highest gain setting possible that is stable and has no oscillations. Start with a low gain setting and work your way up. A good way to test a particular gain setting is to gently 'tap' the axis you are tuning and see if it causes the mount to oscillate. If so, the gain is too high and needs to be lowered.

NOTE: It is necessary to tune the module in the way that they will be used in the air. For the 2-axis gimbal, this means you can tune the system with the helicopter sitting on the table since the gimbal is suspended by the vibration isolation system. On the 3-axis gimbal, however, the landing gear is potentially built onto the gimbal, so it is necessary to hang the helicopter or suspend it, so that the gimbal will be suspended by the vibration isolation system while tuning. This will make a large difference in the tuning of the system, so please do not attempt to tune the 3-axis gimbal while it is sitting on the table, as the tuning will likely require much different gain parameters in flight.

Remember to start with a low gain and work your way up. A nice way to tune the system is to have the transmitter next to your test stand and raise the gain little by little. If you get a setting that is too high and causes oscillations, you can simply switch the mode switch on the transmitter to “off” and lower the gain.

IMU Low Pass Filter

This can be used to reduce the affect of helicopter vibration on the Gimbal IMU. Higher numbers are better (less lag), but severe vibration may require longer filter time. It is recommended to remove all vibration as much as possible and use this as a last resort.

- 1 = 256 Hz
- 2 = 188 Hz
- 3 = 98 Hz
- 4 = 42 Hz
- 5 = 20 Hz
- 6 = 10 Hz
- 7 = 5 Hz

RATE & EXPO

This setting allows you to set the max slew rate for each axis and the command sensitivity around stick center. This will allow you to fine tune the feel of the system to your camera operator’s preferences. If you prefer to tune the slew rate remotely via the transmitter, this is possible using the ATV / AFR / Endpoints of your radio for the given slew channel. A slew rate setting of 60°/second is typically what we use (the actual number will change based on your servos). A high rate number will result in faster rotation. A high expo number will result in near zero output around stick center and lots of output at stick endpoints.

ANGLE TRIM

Angle trim allows for the fine tuning of the module to account for slight errors and offsets in the mounting. Angle trim is usually used on the roll axis to allow for slight trimming of the system to enable the user to set the system for a level horizon. However angle trim can also be used for tilt axis as well.

VERY IMPORTANT:
Read / Write – Remember to use the "Read" / "Write" functions for each module. When you initially connect the programmer to the module, ensure you click "Read" to populate the configuration window with the current module settings. After making any changes to the configuration, click "Write" to write the new settings into the module.

MODES
The mode switch is intended to be setup on a 3 position switch on the camera operator's transmitter. Though there are several selectable modes, the system is designed to be programmed to 3.

Stable mode
Pitch-Roll stabilization with YAW lock (no RC required).

Level mode
Pitch-Roll stabilization with YAW lock and RC manual override. In this mode the RC stick position = camera position, let go of the sticks and the camera returns to level.

Slew mode
Hold desired pitch/roll attitude with Pitch-Roll-Yaw stabilization. In this mode the RC stick position increments camera attitude, let go of the sticks and the camera maintains last commanded attitude. It is important to not attempt to takeoff / land with a 3-axis gimbal in "Slew" mode, as the pan stabilization will cause the helicopter to spin around and could confuse the pilot. Only takeoff / land in "Level" and "Stable" modes.

Heading Hold mode
In this mode the yaw stick will slew the pan axis of the gimbal, let go and it locks the camera magnetic heading so that the vehicle can rotate 360 degrees independent of the camera.

Manual mode

In this mode the stabilization system remains active in the background, but performs no stabilization output, but rather a direct manual output. **Warning: This mode is dangerous when constant rotation servos are used on the gimbal.**

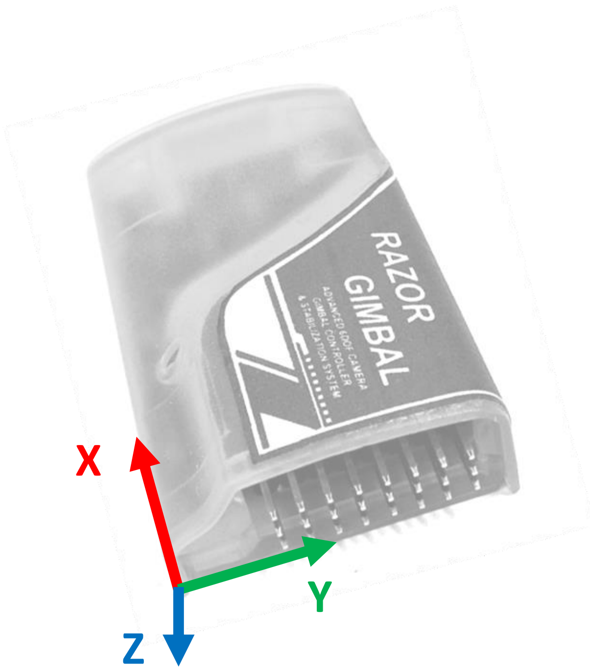
PROGRAMMING RECOMMENDATIONS

We recommend initially programming the stabilization module with the servos unplugged, so that you can establish baseline settings without the camera gimbal moving. Connect to the Razor Gimbal using the supplied USB cable.
It is also recommended to set the roll slew channel “OFF”, so that the camera operator will not accidentally move the roll setting inadvertently when a level horizon is desired. If the camera operator needs to ‘fly’ the roll axis for a certain type of shot, then it can be assigned to a channel for slew control.

The “Trigger” setting can be used to drive any type of accessory from the module. An example would be a PWM controlled remote shutter, or a video start/stop. You can also trigger a remote strobe (with a “Y” harness) for better illumination at the time of the camera trigger.

IMU AXIS DEFINITIONS

The Razor Gimbal is capable of being mounted in 24 different orientations, i.e. on its side, upside down, on end, etc. Please use the figure and table below to determine which axis code to enter into the GUI.



The IMU Axes Definitions use standard Aviation NED convention:

- North = Out the vehicle nose
- East = Out the vehicle right side
- Down = Out the bottom of the vehicle

IMU AXIS CODE TABLE:

Use the following table to align the module with your flight vehicle. For example, if your vehicle X,Y,Z axis match the X,Y,Z of the previous image for the Razor Gimbal, then you would select Code #0. If any of the axes are flipped, then you need to select a different code.

Code	Unit Axis	Vehicle Axis	Unit Axis	Vehicle Axis	Unit Axis	Vehicle Axis
0	X	X	Y	Y	Z	Z
1	X	-X	Y	Y	Z	-Z
2	X	-X	Y	-Z	Z	-Y
3	X	-X	Y	-Y	Z	Z
4	X	Y	Y	Z	Z	X
5	X	Z	Y	-Y	Z	X
6	X	-Y	Y	-Z	Z	X
7	X	-Z	Y	-Y	Z	X
8	X	Z	Y	X	Z	Y
9	X	Y	Y	X	Z	-Z
10	X	-Z	Y	X	Z	-Y
11	X	-Y	Y	X	Z	Z
12	X	X	Y	Z	Z	-Y
13	X	-X	Y	Z	Z	Y
14	X	X	Y	-Z	Z	Y
15	X	X	Y	-Y	Z	-Z
16	X	-Y	Y	Z	Z	-X
17	X	Z	Y	Y	Z	-X
18	X	Y	Y	-Z	Z	-X
19	X	-Z	Y	-Y	Z	-X
20	X	-Z	Y	-X	Z	Y
21	X	-Y	Y	-X	Z	-Z
22	X	Z	Y	-X	Z	-Y
23	X	Y	Y	-X	Z	Z

STEP 6 FLIGHT TUNING

Now that the programming and setup is complete, it is time for in-flight tuning. After setting the gain on the bench, it is important to do some test flights to observe the operation of the stabilization system in the air. It can be helpful to tune one axis at a time.

PAN AXIS:

For in-flight tuning, start with the pan axis. To test the pan, yaw the helicopter and observe the 3-axis gimbal. The gimbal should smoothly stabilize and stay on its original heading regardless of what is done with the helicopter above it. Please be careful at first when using pan stabilization, as it can be very confusing for the pilot to observe the helicopter spinning above a stationary camera gimbal. It is a good idea to learn to only look at the helicopter for visual flight cues and not the gimbal. Once you turn on the stabilization / slewing on the 3-axis gimbal, the pilot and camera operator will be de-coupled and the camera operator and pilot can operate completely independently.

ROLL AXIS:

With the pan axis tuned properly, we can move on to the roll axis. For roll axis, ensure that the camera is perfectly balanced. We want to be able to move the camera to any roll angle setting and have it stay at that setting without the tendency to swing back to neutral. Once the roll axis gain has been roughly tuned, we can do a test flight and observe the roll axis behavior. Over gain will often show as small twitches. If you see any of these symptoms, please lower the gain and test again. The proper gain setting will allow for fast and smooth stabilization with minimal twitches.

TILT AXIS:

Tuning the tilt axis will largely depend on the length and inertia of the camera you are using. After setting an initial gain on the bench, do a test flight to ensure you do not have any over gain symptoms such as oscillations. After finding the setting that allows for smooth and fast stabilization, your 3-axis gimbal will be setup and ready for use. Please note that while the control algorithm on the stabilization system is quite robust, drastic changes to camera mass and balance (lens changes, etc.) may require further fine tuning of the system.

Normal Operation

INITIALIZATION:

NOTE: The stabilization module needs to sit perfectly still for 5 seconds when initially powered up. The best way for this to happen reliably is to power the mount with the camera mount transmitter set to the “OFF” position on the mode switch. This will prevent any of the axes from moving on power up and allow for accurate calibration.

LEDs:

The LEDs give a visual indication of the module’s status as follows:

Green LED fast blink = Initializing stabilization algorithms
Green LED slow blink: = IMU self-test & initializing (keep still)
Green LED solid = Stabilization System is ARMED
Red LED solid = Stabilization System is Powered

ANGLE LIMITS:

The stabilization system has programmed software limits of -85° to +40° on the tilt axis and -60° to +60° on the roll axis. Keep in mind these angles are relative to the ground reference, not the aircraft.

Technical Details

Prozessor:
Atmel ATmega32u4 MU
- 16Mhz
- 32 kB Flash
- 2.5 kB SRAM
- 1kB EEPROM
Datasheet:
http://www.atmel.com/Images/doc7766.pdf

Gyro & Accelerometer:
InvenSense MPU-6050
Datasheet:
http://www.invensense.com/mems/gyro/documents/PS-MPU-6000A.pdf

Magnetometer:
Honeywell HMC-5883L
Datasheet:
http://www51.honeywell.com/aero/common/documents/myaerospacecatalog-documents/Defense_Brochures-documents/HMC5883L_3-Axis_Digital_Compass_IC.pdf

USB Interface:
- Mini USB

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