AUTOQUAD

Analysis of the oscillation-divergence issue. SOLVED

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General

We call "*divergence-oscillation*" at the tilt oscillation of the copter after applying a hard stick pulse during some 1-2 second (stick to the ends, then release).

This normally happen in low powered motors compared with that copter size, due to a saturation of the motor control that induces a loose of control inducing big oscillations sometimes diverging to a crash.

Plot below shows a real flight showing a couple of divergences situations . In these cases the copter recuperated the horizontality (other cases ends with a crash). Rotation angles reached +50º.

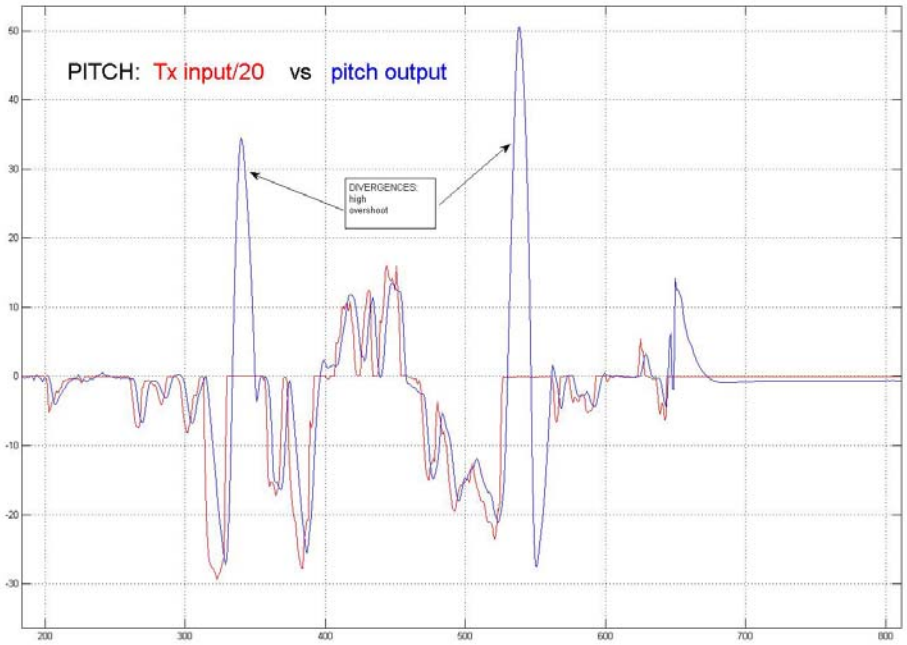


Figure 1

In figure 2 (corresponding to same flight forcing many divergences) we can see that MOT_PITCH reach the max limit (300) many times. After reaching the limit there are no more control available.

In fact the copter reach in some cases big angles (90º) that are far away of max angle permitted (37º) controlled with the CTRL_FACT_PITC = 0.5

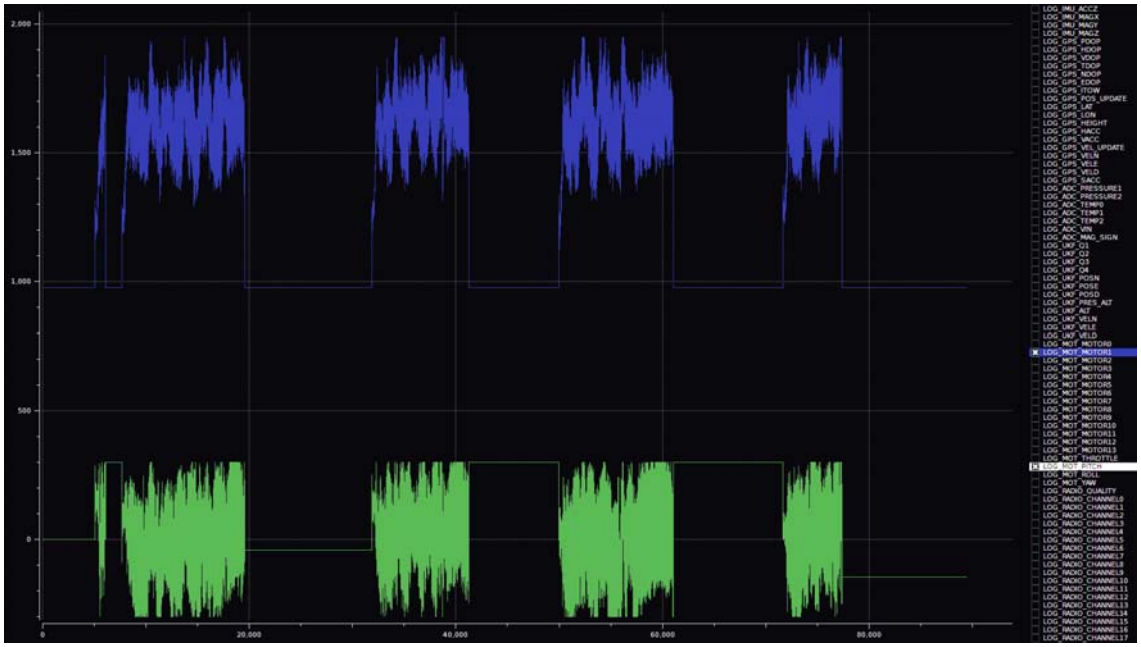


Figure 2

In any case motor control are always limited to +-300pwm ("control.c", line 209)

```
pitchCommand = constrainFloat(pitchCommand, -p[CTRL_MAX],p[CTRL_MAX]);
p[CTRL_MAX] = DEFAULT_CTRL_MAX;
#define DEFAULT_CTRL_MAX  300.0f     //maximum control applied to motors +- throttle
```

I guess CTRL_MAX (DEF=300) is in any case in addition to CTRL_TLT_ANG_OM (def=250)

Effect of mixing table.

This has a dramatic effect in this problem. It's very different the use of a "50" mixing table than based on "100%". It's much more "effective" the tilt control by using "100" since tilt output control is factorised by this number.

It's very easy to "feel" that with a hand test. Try using 20%, then 50% and then 100%. The necessary force to rotate the copter is very different.

In fact for the same reaction force (tilt control) the necessary MOT_ROLL/PITCH values are inversely proportional to the mix percentage (20-50-100) and this is a key factor since using lower % we quicky reach the limits, and so we loose the control capability.

Tilt based on mix table "50"

M#	T	P	R	Y
M2	100	50	0	-100 front
M5	100	0	50	100 left
M9	100	0	-50	100 right
M13	100	-50	0	-100 rear

Tilt based on mix table "100"

M#	T	P	R	Y
M2	100	100	0	-100 front
M5	100	0	100	100 left
M9	100	0	-100	100 right
M13	100	-100	0	-100 rear

Comparing previous plot in figure 2 (uses a mix table "50" based) with the one below (figure 3 "100" based) we see that we need less tilt control levels (about the half) than with previous, and the more important, rarely we reach the "300" pwd limitation, so the copter it´s able to control the oscillation.

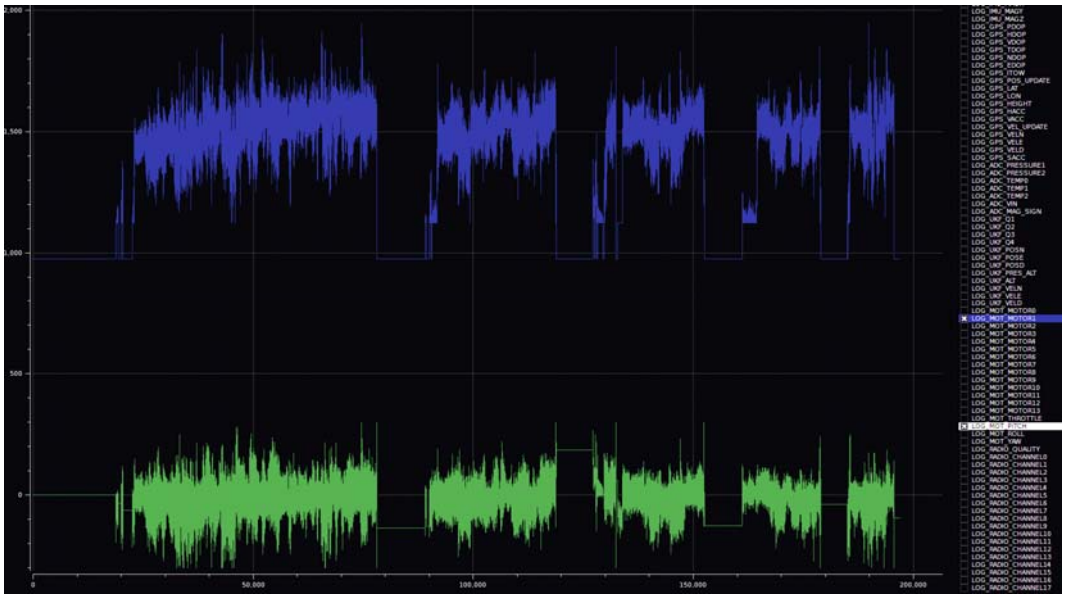


Figure 3

The reason for divergence problem

Figure 4 shows a pitch angle of a flight using a mix table of 100% in a X quad and showed none divergences. We see that max angle reached Is 37º (corresponding to a mot factor = 0.05)

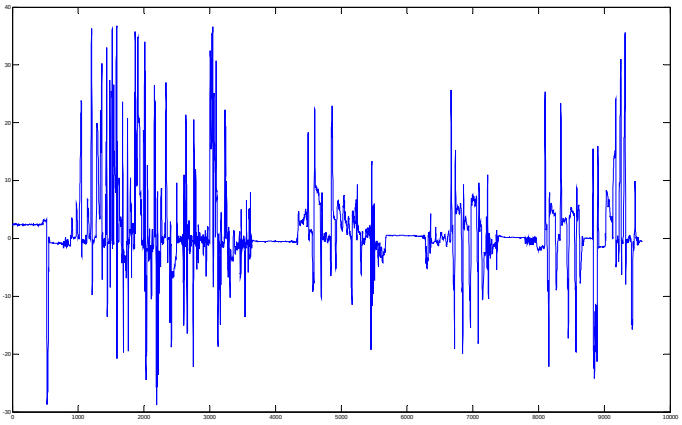


Figure 4

By the contrary, in a flight having divergences (figure 5, pitch angle) we largely overpass the 37º reaching values up to 90º .This should never happen if there is enough control power, so then, it's happening because there is a lack of tilt control.

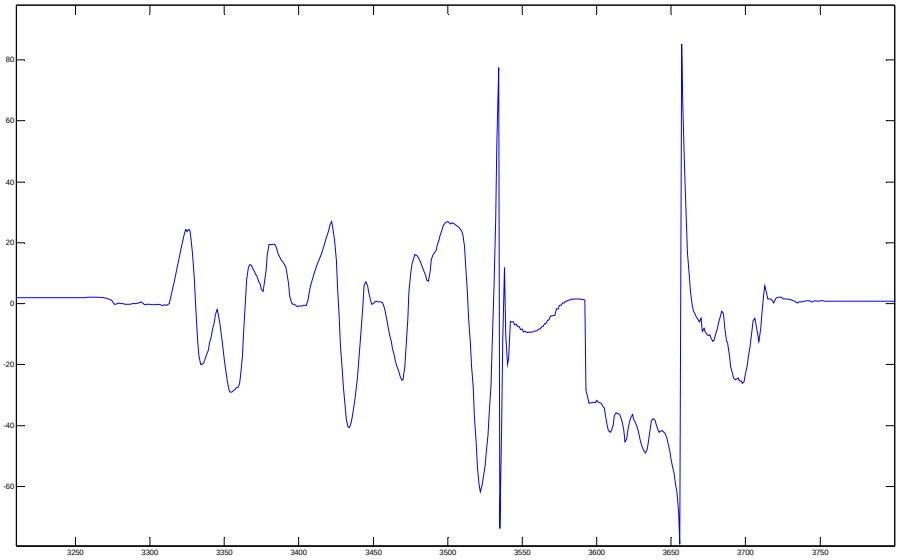


Figure 5

In this cases MOT_PITCH/ROLL reach many times the "300pwm" limit. This is because the control is factorised by the "mix-table-50 based" so it needs to grow up to get the required control reaching quickly the 300pwm limit. The solution is to change to mix-table- higher based to increase the tilt control "effectiveness".
In addition we canincrease also the ctr_max = 300 to a higher value.

In the fig.6 it´s shown a case “100%” based, X mode) the control works great without any divergence.

Stick input in red, (value/20). The resulting pitch reaction of the quad is in blue and the motor_pitch/10 in green. In any case the maximum limit for control (300pwm) is overpassed (values around 100).

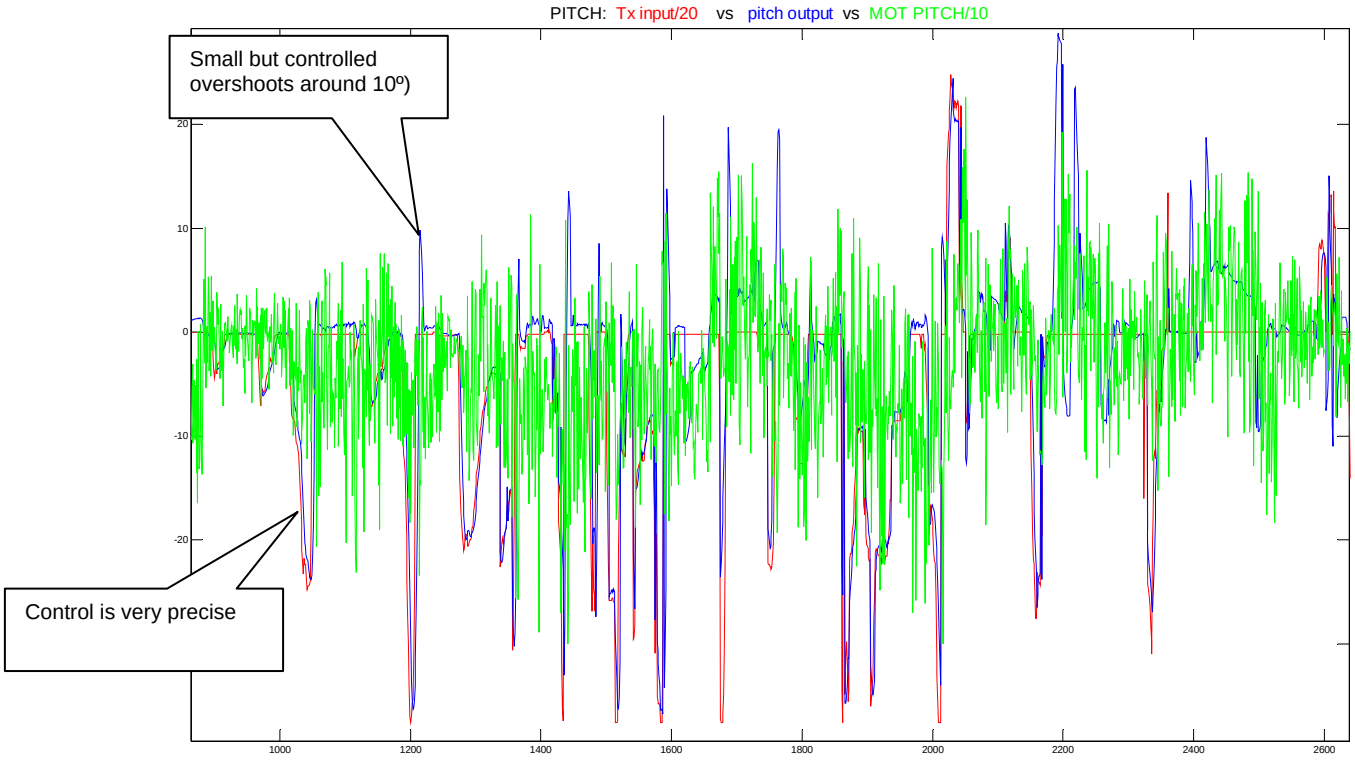


Figure 6

Optimizing a light copter

I´m going to optimize the copter of the image below (800gr) that has hard divergence problems in “X” mode when using default parameters.

The idea is to use a higher value for the mix table tilt values (default is 50%). In previous cases I´ve used 100% that solved the issue, but I can heard too much noise in the motors due to an excessive (& unnecessary) control action.

Feel the “mix table effect”

> Doing a “***hand test”*** we feel an enormous compensation force when trying to rotate (using 100% is in fact the double respect default value of 50%). But we´ve seen that we need more tilt control efficiency because we reach the CTR_MAX limits easily.

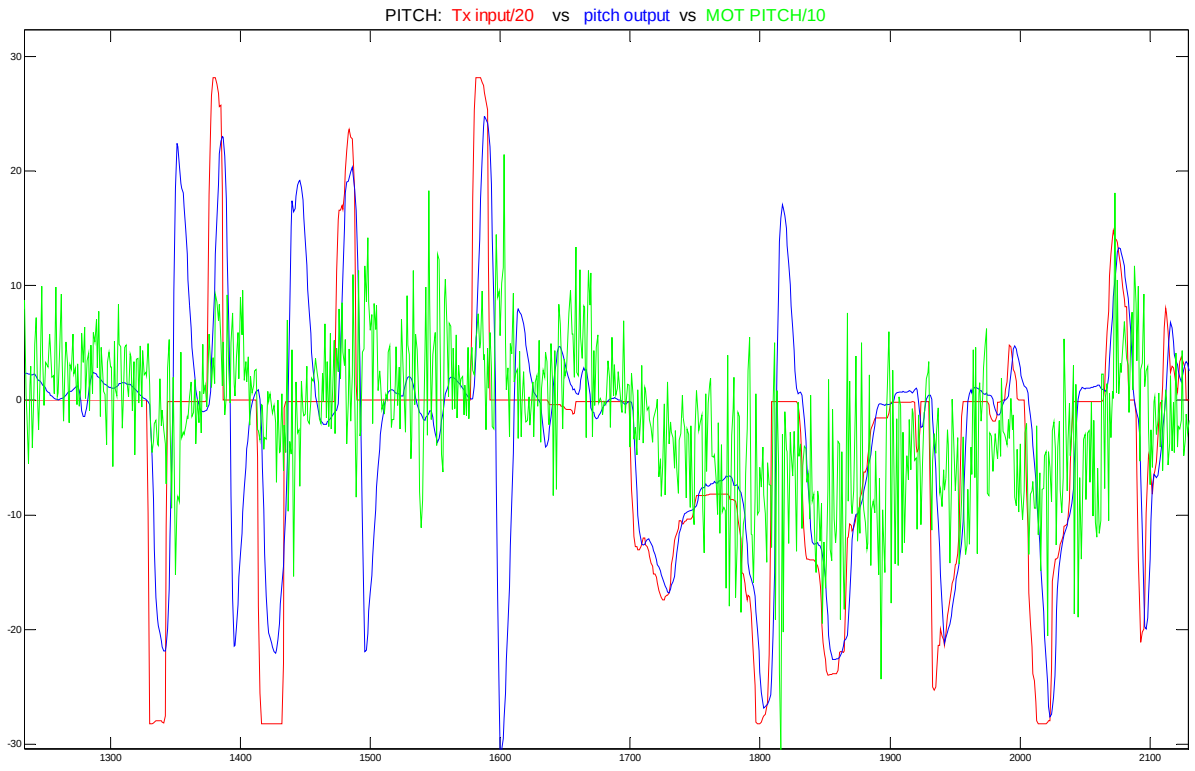
So, the proposed parameters are the following:

mixtable 80% based: to improve tilt control efficiency (to avoid saturation of control by going lower than 300pwm limit)

and **crt_max = 400** to increase the limit for tilt control in extreme cases (CTR_MAX = 400)

The result is ***very good***: a <u>perfect flight without any divergence</u>. Figure below compares pitch hard stick push-releases with the pitch reaction. Also it's shown the level of control applied.

- Never shown divergences. Max angles inside limits (<20º)
- The correction of pitch overshoots a bit (<20º) after each stick pulse but always in a controlled way and only one wave (none oscillation)
- MOT_PITCH is well below max limits (400) average of 150pwm , so still marging to improve.



So, we consider these parameters good for this copter.

End-of-task