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Freestyle Tuning Principles

This is a work in progress and not a final document.

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Motivation

Provide easy and simple guidelines to set-up Betaflight for freestyle.

While Betaflight benefits from a large and vivid developers community with frequent updates and new features releases, it has often been criticized by freestyle pilots for being too complicated to use and hard to keep up with.

This guide aims to provide simple guiding principles and tune suggestions to make the best out of Betaflight for freestyle purposes.

Note: before editing this guide consider discussing changes on the original document.

Principles and Attributes

Freestyle is mainly about the footage of a smooth and precise acrobatic flight.

To achieve such goals a freestyle quad should be tuned with the following principles in mind:

1. Optimized for smoothness over low latency and sharp control.
   > Freestyle pilots tend to prefer a smoother and "looser" quad over an extremely reactive (brain reading feeling) one. Mainly because it helps to smooth out micro correction and makes the footage look more organic and fluid.
2. Optimized to behave predictively and with consistency.
   > Consistency helps pilots to build muscle memory and get a feel of the quad, hence gain confidence and precision. One among the best pilots, Mr. Steel is known for running the same setup for several years and he very rarely makes changes to it.

With the above principles in mind we can distill three attributes we should optimize for:

Consistency	Consistency is the ability of the craft to behave based in a consistent and predictable manner given the provided stick inputs. The more predictable is the quad behaving the more **precision and confidence the pilot will gain**.
Attitude Hold	Attitude hold is the ability of the craft to keep it's trajectory and behave as expected. A quadcopter with good attitude resists changes in orientation from outside forces, and responds only to user stick inputs. These outside forces can include wind, propwash, vibrations, and other forces. Attitude provides **smoothness**.
Responsiveness	Responsiveness is the ability of the craft to track setpoint (stick inputs) as close as possible. A responsive quad has very **low latency and feels connected**.

In theory all three attributes are equally important in practice an increase of responsiveness might affect the pilot ability to fly smoothly and consistently.

Therefore it is advised to compromise on responsiveness to keep the quad behaving in a predictive and consistent manner

Betaflight Tune

Important note: the suggested tuning values are intended for a typical 5" setup either 6S with [1600 to 1800] KV motors or 4S with [2400-2600] KV motors.

VBat Sag Compensation

This feature aims to provide motor response consistency across the entire flight (BF doc ref. By enabling VBat Sag Compensation the craft will fly more consistently and predictively.

If you plan to use this feature it's crucial to enable it before performing the PID tuning.

Suggested setting: values for a 5"

	Value
VBat Sag Period (vbat_sag_lpf_period)	200 (20 second)
VBat compensation	40–70

💡 **Advanced Considerations**

> ▸ Click to expand!

PID

PID are at the core of a quad tuning, with PID tuning we can achieve a good quadcopter attitude.

D is the most important PID term to achieve smooth flying, D helps to minimize propwash as well as dampening any quads movement. Freestyle quads tend to use higher D gains.

To counterbalance a higher than usual D gain P needs to be increased as well.

A simple approach to tune P and D is to set a desired D gain (e.g. 45) and slowly increase P as high as possible without producing any bounce back on flips and rolls (see UAV Tech video).

The I term is generally good enough on default, however if the quad feels sloppy increasing the gain could improve the overall attitude.

Suggested settings: values for a 5"

	P	I	D
Roll	60–70	90–100	40–50
Pitch	60–70	90–100	40–50
Yaw	30–40	90–100	0

💡 **Advanced Considerations**

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Feed Forward

Feed Forward is used to help the quad copter tracking the setpoint (stick inputs) closer. In other words it reduces the latency between stick movement and quadcopter movement.

Feed Forward is intended to increase responsiveness by more directly applying stick inputs into the mixer ahead of other PID inputs, reducing the need for the PID controller to respond to setpoint error in order to respond to inputs Feed Forward is great to increase responsiveness by anticipating a soon expected PID error based on stick movement.

Suggested setting: values for a 5"

Feed Forward Transition	0.9-1

	Feed Forward
Roll	90-100
Pitch	90-100
Yaw	90-100

D Min

D Min allows to run higher D gain on not so clean builds by dynamically increasing D on sharp moves.It has been introduced to run cooler motors, and have faster stick responsiveness.

D Min can negatively affect consistency as D is no longer constant but varies depending on how quick the move is. Also, running a lower D during shallow flight will reduce smoothness.

Suggested setting: off

If your quad allows it (clean build with low noise) disabling D Min increases the quad flight consistency by keeping D constant and at a generally higher value.

TPA

TPA lowers the D and P gain after a certain throttle threshold. It has been introduced to address fast oscillations induced by high throttle motor noises on quads running high PID gains.

Similar to D Min this settings could negatively affect consistency leading to an increase of rotation rate when more throttle applied BF doc ref

Increasing the default breakpoint value allows to keep D constant also around mid throttle .

Suggested setting: values for a 5"

	Rate	Breakpoint
TPA	0.40-0.50	1600- 1750

Lower rate and higher breakpoint will increase consistency but eventually introduce oscillations, carefully tune the settings to minimize the impact of TPA while avoiding oscillations.

Thrust Linear

If a unusually large TPA is required to avoid high-throttle oscillations whilst good performance is observed at low and mid throttle then consider reducing TPA and employing thrust_linear. Thrust linearization is designed to account for situations where a linear throttle input produces an exponential throttle output. This can happen on builds which fall outside of the normal power/weight ratio. In these cases thrust_linear can be used to PID boost response at low throttle and reduce PID response at high throttle.

thrust_linear defaults to 0. If you experience oscillations which TPA cannot sufficiently correct then thrust_linear is a good next step.

Because thrust_linear will boost PID response at low throttle the master PID values should be reduced one or two notches on the slider before introducing thrust_linear. Set thrust_linear initially at a value around 25 and then increase in increments of 5 whilst observing the effect on high-throttle oscillations.

I term relax and iterm_windup

I term relax aims to inhibit I during fast manoeuvres by preventing it from further accumulating avoiding I term induced bounce back on flips and rolls (BF doc ref).

Suggested setting: values for a 5"

	Axes	Type	Cutoff
Iterm Relax	RP (Increment only)	Setpoint	7-12

Anti gravity

Anti Gravity boosts the I term when fast throttle changes are detected. It has been introduced to mitigate the craft nose tilt on throttle changes (BF doc ref).

Anti gravity helps to increase smoothness and hold the attitude on maneuvers with fast throttle changes like boosts, powerloops, etc.

Suggested setting: values for a 5"

	Gain
Anti gravity	3.5 - 5

Motor Idle Throttle Value, Dynamic Idle Value & Thrust Linear

Lower than default Motor Idle Throttle Value allows for greater hang time and cleaner dives. However it comes at the cost of a weaker attitude hold at zero throttle and increased risk of de-sync.

Dynamic Idle Value and Thrust Linear will help to mitigate those collateral effects.

Dynamic Idle Value allows to define minimum motor RPM, if set at a reasonable amount it avoids de-sync due to too low motor RPM.

Thrust Linear helps to boost the PID gains low throttle helping to offset reduced motor responsiveness in low RPM operation compared to higher RPM responsiveness of motors. This can have some interactions with D gains at higher throttle values, which may require use of higher TPA_rate to offset.

Suggested setting: values for a 5"

	Value
Motor Idle Throttle Value	3% - 4%
Dynamic Idle	Needs to be computed according to doc.
Thrust Linear	20-25

RC smoothing

Higher than default RC smoothing helps reducing stick input glitches caused by noise in the RC link.

Suggested setting:

	Value
RC smoothing	20

Betaflight Filtering

Generally speaking the less the better as filtering introduces latency, for freestyling a more conservative approach with enough amount of filtering is advised. Not enough filtering can negatively affect smoothness and in some cases even burn motors.

Via incremental tuning effort try minimizing Gyro LPF filtering (biggest drain on phase delay that makes propwash response poor) followed by minimizing how much delay is coming from dynamic notch filtering (ideally single notch with smaller DFT bins - W=0, Q=250, MinHz 105, MaxHz 465).

Lastly, try reducing the D-term filtering, slider values up to 1.4 range, still attenuates most D_term noise very well but reduces phase latency.

ESC Settings

PWM Frequency

Increasing PWM frequency helps to run smoother motors, and provide greater control at the cost of losing some thrust.

> **Warning:** Increasing PWM frequency can introduce wobbles at zero or low throttle. Such undesired effect can be mitigated by increasing Thrust Linear or Dynamic Idle values.

Suggested setting: values for a 5"

	Value
PWM Frequency	48kHz - 96kHz or use Variable PWM Frequency

💡 Advanced Considerations

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