Operation manual for BLHeli_S
SiLabs Rev16.x

BLHeli_S firmware is the next generation code, following the base BLHeli code.

BLHeli_S is designed for superior performance in multirotors, and uses hardware generated motor pwm for smooth throttle response and silent operation.

All codes use damped light mode.
Damped light does regenerative braking, causing very fast motor retardation, and inherently also does active freewheeling.

The code supports features to prevent sync loss. There are tuneable parameters that can make the code run well even in the most demanding situations, although default settings will work excellently in normal operating environments.

The code supports regular 1-2ms pulse width input, as well as Oneshot125 (125-250us), Oneshot42 (41.7-83.3us) and Multshot (5-25us).
The input signal is automatically detected by the ESC upon power up.

The code also supports a beacon functionality, where the ESC will start beeping after a given time of zero throttle. This can be very useful for finding lost crafts.

Code naming convention:

The BLHeli_S codes are named with a letter, another letter and two numbers, in addition to the revision. For example "A_L_10_REV16_0.HEX".

The first letter denotes the pinout of the MCU.
The second letter is either L or H. L is for 24MHz MCUs, and H is for 48MHz MCUs.
The two numbers denote the FET switching deadtime. The unit is 20.4ns.

Some FET drivers have adaptive FET deadtime control, and for these 00 is used to denote FET switching deadtime.

Programming parameters:

Startup power:
Startup power can be set to relative values from 0.031 to 1.5. This is the maximum power that is allowed during startup. Actual applied power depends on throttle input, and can be lower, but the minimum level is a quarter of the maximum level.
Startup power also affects bidirectional operation, as the parameter is used to limit the power applied during direction reversal.
For low rpms, the maximum power to the motor is limited, in order to facilitate detection of low BEMF voltages. The maximum power allowed can be set via the startup power parameter. A lower startup power parameter will give lower maximum power for low rpms (this is implemented from rev16.1).

Commutation timing:
Commutation timing can be set to low/mediumlow/medium/mediumhigh/high, that correspond to $0^0/7.5^0/15^0/22.5^0/30^0$ timing advance.

Typically a medium setting will work fine, but if the motor stutters it can be beneficial to change timing. Some motors with high inductance can have a very long commutation demagnetization time. This can result in motor stop or stutter upon quick throttle increase, particularly when running at a low rpm. Setting timing to high will allow more time for demagnetization, and often helps.

Demag compensation:
Demag compensation is a feature to protect from motor stalls caused by long winding demagnetization time after commutation. The typical symptom is motor stop or stutter upon quick throttle increase, particularly when running at a low rpm. As mentioned above, setting high commutation timing normally helps, but at the cost of efficiency.

Demag compensation is an alternative way of combating the issue. First of all, it detects when a demag situation occurs.
- In this situation, there is no info on motor timing, and commutation proceeds blindly with a predicted timing.
- In addition to this, motor power is cut off some time before the next commutation.

A metric is calculated that indicates how severe the demag situation is. The more severe the situation, the more power is cut off.
When demag compensation is set to off, power is never cut.
When setting it to low or high, power is cut. For a high setting, power is cut more aggressively.

Generally, a higher value of the compensation parameter gives better protection.
If demag compensation is set too high, maximum power can be somewhat reduced.

Direction:
Rotation direction can be set to fwd/rev/bidirectional fwd/bidirectional rev.
In bidirectional mode, center throttle is zero and above is fwd rotation and below is reverse rotation. When bidirectional operation is selected, programming by TX is disabled.

Beep strength:
Sets the strength of beeps under normal operation.

Beacon strength:
Sets the strength of beeps when beeping beacon beeps. The ESC will start beeping beacon beeps if the throttle signal has been zero for a given time. Note that setting a high beacon strength can cause hot motors or ESCs!

Beacon delay:
Beacon delay sets the delay before beacon beeping starts.

Programming by TX:
If disabled, throttle calibration is disabled.

Min throttle, max throttle and center throttle:
These settings set the throttle range of the ESC. Center throttle is only used for bidirectional operation. The values given for these settings are for a normal 1000us to 2000us input signal, and for the other input signals, the values must be scaled.

Thermal protection:
Thermal protection can be enabled or disabled.

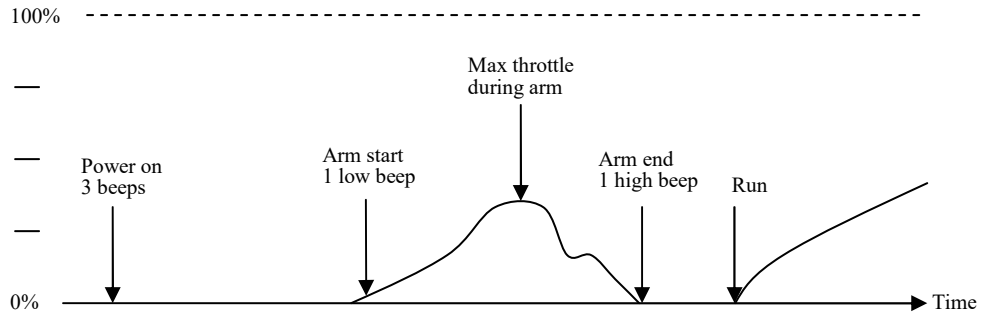
Low RPM power protect:
Power limiting for low RPMs can be enabled or disabled. Disabling it can be necessary in order to achieve full power on some low kV motors running on a low supply voltage. However, disabling it increases the risk of sync loss, with the possibility of toasting motor or ESC.

Brake on stop:
Brake on stop can be enabled or disabled. When enabled, brake will be applied when throttle is zero. For nonzero throttle, this setting has no effect.

LED control:
LEDs can be controlled on ESCs that support it. Up to 4 LEDs can be turned on or off.

Arming sequence:

The figure below shows an example of throttle value versus time.



At power on, the ESC beeps 3 beeps.

When throttle signal is detected, it beeps one low tone beep. This signals the start of the arming sequence.
Then, when or if throttle is zero, it beeps one high tone beep. This signals the end of the arming sequence.

Also, if 100% throttle is detected during the arming sequence, the ESC starts throttle calibration.

If the esc is armed and sees zero throttle for a given time, it beeps beacon beeps, which are about a beep per three seconds.

Input signal:

Available throttle calibration range is from 1000us to 2000us, and the difference between minimum and maximum throttle must be more than 140us (70us in bidirectional mode). If a calibration is done where the difference is less than 140us (70us), the maximum will be shifted so that the difference is 140us (70us).

Oneshot125 mode works just the same as regular 1-2ms mode, the only difference is that all timing is divided by 8. And the same for Oneshot42, where all timing is further divided by 3. Multishot also works similarly, except the input signal range is 5-25us.

The input signal is always sampled with the MCU clock, at 24MHz or 48MHz.

For MCUs running at 24MHz, input signal pulse rates above 8kHz are not recommended.
For MCUs running at 48MHz, input signal pulse rates up to 32kHz are supported.
But please remember that signal rates faster than the gyro or PID loop of the FC does not make sense, it only results in unnecessary loading of the MCU.

Thermal protection:

The ESC measures temperature within the MCU and limits motor power if the temperature is too high. Motor power is limited in four steps:
- If the temperature is above 140^0C, motor power is limited to 75%.
- If the temperature is above 145^0C, motor power is limited to 50%.
- If the temperature is above 150^0C, motor power is limited to 25%.
- If the temperature is above 155^0C, motor power is limited to 0%.

Stall protection:

If the motor has attempted to start but not succeeded for a few seconds, it will stop attempting and wait for throttle to be zeroed before attempting again.

Regenerative braking / active freewheeling:

Damped light mode is implemented by doing regenerative braking, and inherently active freewheeling is also implemented.
Then losses due to braking are counteracted by the reduced losses of active freewheeling.

Motor PWM:

The motor PWM frequency is always 24kHz. The resolution is 2048 steps for MCUs running at 48MHz on ESCs that have automatic deadtime control. On ESCs that have fixed deadtime, the PWM resolution is 1024 steps. For MCUs running at 24MHz, the PWM resolutions are half.

Maximum speeds:

For ESCs with a 24MHz MCU, maximum speed is limited to 350k eRPM, at which point power to the motor is limited. For ESCs with an MCU running at 48MHz, this number is 500k eRPM.

Beeps - Normal operation:

Power up:

Once

Throttle signal detected (arming sequence start):

Once

Zero throttle detected (arming sequence end):

Once

After this, the motor will run.

Beeps - Throttle calibration:

Power up:

Once

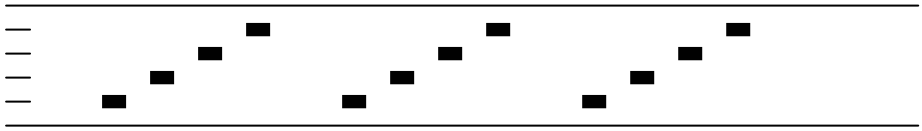
Throttle signal detected (arming sequence start):

Once

When throttle is above midstick (measuring max throttle):

While measuring

If throttle is above midstick for 3 seconds:



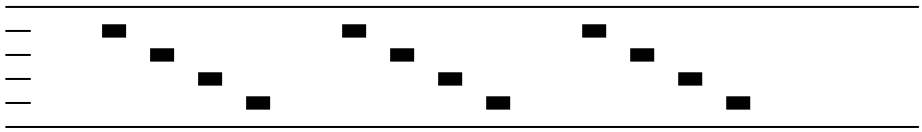
Once

This beep sequence indicates that max throttle has been stored

When throttle is below midstick (measuring min throttle):

While measuring

If throttle is below midstick for 3 seconds:



Once

This beep sequence indicates that min throttle has been stored

At this point throttle calibration values are stored. You may remove power from the ESC, or just continue running your ESC.

Revision history:

- Rev16.0 Started. Built upon rev 14.5 of base code
  - Using hardware pwm for very smooth throttle response, silent running and support of very high rpms
  - Implemented reverse bidirectional mode
  - Implemented separate throttle gains fwd and rev in bidirectional mode
  - Implemented support for Oneshot42 and Multishot
- Rev16.1 Made low rpm power limiting programmable through the startup power parameter
- Rev16.2 Fixed bug that prevented temperature protection
  - Improved robustness to very high input signal rates
  - Beeps can be turned off by programming beep strength to 1
  - Throttle cal difference is checked to be above required minimum before storing. Throttle cal max is not stored until successful min throttle cal