LED Strip

Cleanflight supports the use of addressable LED strips. Addressable LED strips allow each LED in the strip to
be programmed with a unique and independant color. This is far more advanced than the normal RGB strips which
require that all the LEDs in the strip show the same color.

Addressable LED strips can be used to show information from the flight controller system, the current implementation
supports the following:

- Up to 32 LEDs.
- Indicators showing pitch/roll stick positions.
- Heading/Orientation lights.
- Flight mode specific color schemes.
- Low battery warning.
- AUX operated on/off switch.
- GPS state.
- RSSI level.
- Battery level.

Support for more than 32 LEDs is possible, it just requires additional development.

Supported hardware

Only strips of 32 WS2811/WS2812 LEDs are supported currently. If the strip is longer than 32 LEDs it does not matter,
but only the first 32 are used.

WS2812 LEDs require an 800khz signal and precise timings and thus requires the use of a dedicated hardware timer.

Note: Not all WS2812 ICs use the same timings, some batches use different timings.

It could be possible to be able to specify the timings required via CLI if users request it.

Tested Hardware

- Adafruit NeoPixel Jewel 7 (https://www.adafruit.com/products/2226) (preliminary testing)
    - Measured current consumption in all white mode ~ 350 mA.
    - Fits well under motors on mini 250 quads.
- Adafruit NeoPixel Stick (https://www.adafruit.com/products/1426) (works well)
    - Measured current consumption in all white mode ~ 350 mA.

WS2811 vs WS2812

The WS2811 (https://cdn-shop.adafruit.com/datasheets/WS2811.pdf) is a LED driver IC which is connected to an RGB LED. It accepts data in the form of 8 bits each of Red-Green-Blue.

The WS2812 (https://cdn-shop.adafruit.com/datasheets/WS2812.pdf) is integrated into the package of a 50:50 LED rather than as a separate device. It accepts data in the form of 8 bits each of Green-Red-Blue.

It is thus possible, depending on the LED board/strip being used that either Red-Green-Blue or Green-Red-Blue encoding may be required. This may be controlled by setting the following.

```
set ledstrip_grb_rgb = RGB
```

or

```
set ledstrip_grb_rgb = GRB
```

Then confirm the required setting by simply setting an LED to be green. If it lights up red, you have the wrong setting.

Connections

WS2812 LED strips generally require a single data line, 5V and GND.

WS2812 LEDs on full brightness can consume quite a bit of current. It is recommended to verify the current draw and ensure your
supply can cope with the load. On a multirotor that uses multiple BEC ESC's you can try use a different BEC to the one the FC
uses. e.g. ESC1/BEC1 -> FC, ESC2/BEC2 -> LED strip. It's also possible to power one half of the strip from one BEC and the other half
from another BEC. Just ensure that the GROUND is the same for all BEC outputs and LEDs.

Target	Pin	LED Strip Signal
Naze	RC5	Data In PA6
CC3D	RCO5	Data In PB4
ChebuzzF3/F3Discovery	PB8	Data In PB8
Sparky	PWM5	Data In PA6

Since RC5 is also used for SoftSerial on the Naze it means that you cannot use SoftSerial and led strips at the same time.
Additionally, since RC5 is also used for Parallel PWM RC input on both the Naze, Chebuzz and STM32F3Discovery targets, led strips
can not be used at the same time at Parallel PWM.

If you have LEDs that are intermittent, flicker or show the wrong colors then drop the VIN to less than 4.7v, e.g. by using an inline
diode on the VIN to the LED strip. The problem occurs because of the difference in voltage between the data signal and the power
signal. The WS2811 LED's require the data signal (Din) to be between 0.3 * Vin (Max) and 0.7 * VIN (Min) to register valid logic
low/high signals. The LED pin on the CPU will always be between 0v to ~3.3v, so the Vin should be 4.7v (3.3v / 0.7 = 4.71v).
Some LEDs are more tolerant of this than others.

The datasheet can be found here: http://www.adafruit.com/datasheets/WS2812.pdf

Configuration

The led strip feature can be configured via the GUI.

GUI:
Enable the Led Strip feature via the GUI under setup.

Configure the leds from the Led Strip tab in the cleanflight GUI.
First setup how the led's are laid out so that you can visualize it later as you configure and so the flight controller knows how many led's there are available.

There is a step by step guide on how to use the GUI to configure the Led Strip feature using the GUI http://blog.oscarliang.net/setup-rgb-led-cleanflight/ which was published early 2015 by Oscar Liang which may or may not be up-to-date by the time you read this.

CLI:
Enable the `LED_STRIP` feature via the cli:

```
feature LED_STRIP
```

If you enable LED_STRIP feature and the feature is turned off again after a reboot then check your config does not conflict with other features, as above.

Configure the LEDs using the `led` command.

The `led` command takes either zero or two arguments - an zero-based led number and a sequence which indicates pair of coordinates, direction flags and mode flags and a color.

If used with zero arguments it prints out the led configuration which can be copied for future reference.

Each led is configured using the following template: `x,y:ddd:mmm:cc`

`x` and `y` are grid coordinates of a 0 based 16x16 grid, north west is 0,0, south east is 15,15
`ddd` specifies the directions, since an led can face in any direction it can have multiple directions. Directions are:

`N` - North
`E` - East
`S` - South
`W` - West
`U` - Up
`D` - Down

For instance, an LED that faces South-east at a 45 degree downwards angle could be configured as `SED`.

Note: It is perfectly possible to configure an LED to have all directions `NESWUD` but probably doesn't make sense.

`mmm` specifies the modes that should be applied an LED.

Each LED has one base function:

- C - Color.
- F - Flight mode & Orientation
- A - Armed state.
- R - Ring thrust state.
- G - GPS state.
- S - RSSSI level.
- L - Battery Level.

And each LED has overlays:

- W - Wwarnings.
- I - Indicator.
- T - Thrust state.
- B - Blink (flash twice) mode.
- O - Lars0n Scanner (Cylon Effect).
- N - Blink on laNding (throttle < 50%).

cc specifies the color number (0 based index).

Example:

```
led 0 0,15:SD:AWI:0
led 1 15,0:ND:AWI:0
led 2 0,0:ND:AWI:0
led 3 0,15:SD:AWI:0
led 4 7,7::C:1
led 5 8,8::C:2
led 6 8,9::B:1
```

To erase an led, and to mark the end of the chain, use `0,0::` as the second argument, like this:

```
led 4 0,0:::
```

It is best to erase all LEDs that you do not have connected.

Modes

Warning

This mode simply uses the LEDs to flash when warnings occur.

Warning	LED Pattern	Notes
Arm-lock enabled	flash between green and off	occurs calibration or when unarmed and the aircraft is tilted too much
Low Battery	flash red and off	battery monitoring must be enabled. May trigger temporarily under high-throttle due to voltage drop
Failsafe	flash between light blue and yellow	Failsafe must be enabled

Flash patterns appear in order, so that it's clear which warnings are enabled.

GPS state

This mode shows the GPS state and satellite count.

No fix = red LED
3D fix = green LED

The LEDs will blink as many times as the satellite count, then pause and start again.

RSSI level

This mode binds the LED color to RSSI level.

Color	RSSI
Green	100%
Lime green	80%
Yellow	60%
Orange	40%
Red	20%
Deep pink	0%

When RSSI is below 50% is reached, LEDs will blink slowly, and they will blink fast when under 20%.

Battery level

This mode binds the LED color to remaining battery capacity.

Color	Capacity
Green	100%
Lime green	80%
Yellow	60%
Orange	40%
Red	20%
Deep pink	0%

When Warning or Critial voltage is reached, LEDs will blink slowly or fast.
Note: this mode requires a current sensor. If you don't have the actual device you can set up a virtual current sensor (see Battery (Battery.md)).

Blink

This mode blinks the current LED, alternatively from black to the current active color.

Blink on landing

This mode blinks the current LED, alternatively from black to the current active color, when throttle is below 50% and the craft is armed.

Larson Scanner (Cylon Effect)

The Larson Scanner replicates the scanning "eye" effect seen on the mechanical Cylons and on Kitt from Knight Rider.

This overlay merely varies the brightness of each LED's current color.

Flight Mode & Orientation

This mode shows the flight mode and orientation.

When flight modes are active then the LEDs are updated to show different colors depending on the mode, placement on the grid and direction.

LEDs are set in a specific order:

- LEDs that marked as facing up or down.
- LEDs that marked as facing west or east AND are on the west or east side of the grid.
- LEDs that marked as facing north or south AND are on the north or south side of the grid.

That is, south facing LEDs have priority.

The mapping between modes led placement and colors is currently fixed and cannot be changed.

Indicator

This mode flashes LEDs that correspond to roll and pitch stick positions. i.e. they indicate the direction the craft is going to turn.

Mode	Direction	LED Color
Orientation	North	WHITE
Orientation	East	DARK VIOLET
Orientation	South	RED
Orientation	West	DEEP PINK
Orientation	Up	BLUE
Orientation	Down	ORANGE
Head Free	North	LIME GREEN
Head Free	East	DARK VIOLET
Head Free	South	ORANGE
Head Free	West	DEEP PINK
Head Free	Up	BLUE
Head Free	Down	ORANGE
Horizon	North	BLUE
Horizon	East	DARK VIOLET
Horizon	South	YELLOW
Horizon	West	DEEP PINK
Horizon	Up	BLUE
Horizon	Down	ORANGE
Angle	North	CYAN
Angle	East	DARK VIOLET
Angle	South	YELLOW
Angle	West	DEEP PINK
Angle	Up	BLUE
Angle	Down	ORANGE

Mag	North	MINT GREEN
Mag	East	DARK VIOLET
Mag	South	ORANGE
Mag	West	DEEP PINK
Mag	Up	BLUE
Mag	Down	ORANGE
Baro	North	LIGHT BLUE
Baro	East	DARK VIOLET
Baro	South	RED
Baro	West	DEEP PINK
Baro	Up	BLUE
Baro	Down	ORANGE

Armed state

This mode toggles LEDs between green and blue when disarmed and armed, respectively.

Note: Armed State cannot be used with Flight Mode.

Thrust state

This mode fades the LED current LED color to the previous/next color in the HSB color space depending on throttle stick position. When the
throttle is in the middle position the color is unaffected, thus it can be mixed with orientation colors to indicate orientation and throttle at
the same time. Thrust should normally be combined with Color or Mode/Orientation.

Thrust ring state

This mode is allows you to use one or multiple led rings (e.g. NeoPixel ring) for an afterburner effect. The light pattern rotates clockwise as throttle increases.

A better effect is acheived when LEDs configured for thrust ring have no other functions.

LED direction and X/Y positions are irrelevant for thrust ring LED state. The order of the LEDs that have the state determines how the LED behaves.

Each LED of the ring can be a different color. The color can be selected between the 16 colors availables.

For example, led 0 is set as a Ring thrust state led in color 13 as follow.

```
led 0 2,2::R:13
```

LED strips and rings can be combined.

Solid Color

The mode allows you to set an LED to be permanently on and set to a specific color.

x,y position and directions are ignored when using this mode.

Other modes will override or combine with the color mode.

For example, to set led 0 to always use color 10 you would issue this command.

```
led 0 0,0::C:10
```

Colors

Colors can be configured using the cli `color` command.

The `color` command takes either zero or two arguments - an zero-based color number and a sequence which indicates pair of hue, saturation and value (HSV).

See http://en.wikipedia.org/wiki/HSL_and_HSV

If used with zero arguments it prints out the color configuration which can be copied for future reference.

The default color configuration is as follows:

Index	Color
0	black
1	white
2	red
3	orange
4	yellow
5	lime green
6	green
7	mint green
8	cyan
9	light blue
10	blue
11	dark violet
12	magenta
13	deep pink
14	black
15	black

```
color 0 0,0,0
color 1 0,255,255
color 2 0,0,255
color 3 30,0,255
color 4 60,0,255
color 5 90,0,255
color 6 120,0,255
color 7 150,0,255
color 8 180,0,255
color 9 210,0,255
color 10 240,0,255
color 11 270,0,255
color 12 300,0,255
color 13 330,0,255
color 14 0,0,0
color 15 0,0,0
```

Mode Colors Assignement

Mode Colors can be configured using the cli `mode_color` command.

- No arguments: lists all mode colors
- arguments: mode, function, color

First 6 groups of ModeIndexes are :

mode	name
0	orientation
1	headfree
2	horizon
3	angle
4	mag
5	baro
6	special

Modes 0 to 5 functions:

function	name
0	north
1	east
2	south
3	west
4	up
5	down

Mode 6 use these functions:

function	name
0	disarmed
1	armed
2	animation

3	background
4	blink background
5	gps: no satellites
6	gps: no fix
7	gps: 3D fix

The ColorIndex is picked from the colors array ("palette").

Examples (using the default colors):

- set armed color to red: `mode_color 6 1 2`
- set disarmed color to yellow: `mode_color 6 0 4`
- set Headfree mode 'south' to Cyan: `mode_color 1 2 8`

Positioning

Cut the strip into sections as per diagrams below. When the strips are cut ensure you reconnect each output to each input with cable where the break is made.
e.g. connect 5V out to 5V in, GND to GND and Data Out to Data In.

Orientation is when viewed with the front of the aircraft facing away from you and viewed from above.

Example 12 LED config

The default configuration is as follows

```
led 0 15,15:ES:IA:0
led 1 15,8:E:WF:0
led 2 15,7:E:WF:0
led 3 15,0:NE:IA:0
led 4 8,0:N:F:0
led 5 7,0:N:F:0
led 6 0,0:NW:IA:0
led 7 0,7:W:WF:0
led 8 0,8:W:WF:0
led 9 0,15:SW:IA:0
led 10 7,15:S:WF:0
led 11 8,15:S:WF:0
led 12 7,7:U:WF:0
led 13 8,7:U:WF:0
led 14 7,8:D:WF:0
led 15 8,8:D:WF:0
led 16 8,9::R:3
led 17 9,10::R:3
led 18 10,11::R:3
led 19 10,12::R:3
led 20 9,13::R:3
led 21 8,14::R:3
led 22 7,14::R:3
led 23 6,13::R:3
led 24 5,12::R:3
led 25 5,11::R:3
led 26 6,10::R:3
led 27 7,9::R:3
led 28 0,0:::0
led 29 0,0:::0
led 30 0,0:::0
led 31 0,0:::0
```

Which translates into the following positions:

```
    6             3
     \           /
      \   5-4   /
       \ FRONT /
   7,8 | 12-15 | 1,2
       /  BACK \
      /  10,11  \
     /           \
    9             0
      RING 16-27
```

LEDs 0,3,6 and 9 should be placed underneath the quad, facing downwards.
LEDs 1-2, 4-5, 7-8 and 10-11 should be positioned so the face east/north/west/south, respectively.
LEDs 12-13 should be placed facing down, in the middle
LEDs 14-15 should be placed facing up, in the middle
LEDs 16-17 should be placed in a ring and positioned at the rear facing south.

This is the default so that if you don't want to place LEDs top and bottom in the middle just connect the first 12 LEDs.

Example 16 LED config

```
led 0 15,15:SD:IA:0
led 1 8,8:E:FW:0
led 2 8,7:E:FW:0
led 3 15,0:ND:IA:0
led 4 7,7:N:FW:0
led 5 8,7:N:FW:0
led 6 0,0:ND:IA:0
led 7 7,7:W:FW:0
led 8 7,8:W:FW:0
led 9 0,15:SD:IA:0
led 10 7,8:S:FW:0
led 11 8,8:S:FW:0
led 12 7,7:D:FW:0
led 13 8,7:D:FW:0
led 14 7,7:U:FW:0
led 15 8,7:U:FW:0
```

Which translates into the following positions:

```
    6             3
     \           /
      \   5-4   /
     7 \ FRONT / 2
       | 12-15 |
     8 /  BACK \ 1
      /  10-11  \
     /           \
    9             0
```

LEDs 0,3,6 and 9 should be placed underneath the quad, facing downwards.
LEDs 1-2, 4-5, 7-8 and 10-11 should be positioned so the face east/north/west/south, respectively.
LEDs 12-13 should be placed facing down, in the middle
LEDs 14-15 should be placed facing up, in the middle

Exmple 28 LED config

```
#right rear cluster
led 0 9,9:S:FWT:0
led 1 10,10:S:FWT:0
led 2 11,11:S:IA:0
led 3 11,11:E:IA:0
led 4 10,10:E:AT:0
led 5 9,9:E:AT:0
# right front cluster
led 6 10,5:S:F:0
led 7 11,4:S:F:0
led 8 12,3:S:IA:0
led 9 12,2:N:IA:0
led 10 11,1:N:F:0
led 11 10,0:N:F:0
# center front cluster
led 12 7,0:N:FW:0
led 13 6,0:N:FW:0
led 14 5,0:N:FW:0
led 15 4,0:N:FW:0
# left front cluster
led 16 2,0:N:F:0
led 17 1,1:N:F:0
led 18 0,2:N:IA:0
led 19 0,3:W:IA:0
led 20 1,4:S:F:0
led 21 2,5:S:F:0
# left rear cluster
led 22 2,9:W:AT:0
led 23 1,10:W:AT:0
led 24 0,11:W:IA:0
led 25 0,11:S:IA:0
led 26 1,10:S:FWT:0
led 27 2,9:S:FWT:0
```

```
       16-18  9-11
19-21 \           / 6-8
       \  12-15  /
        \ FRONT /
        /  BACK \
       /         \
22-24 /           \ 3-5
       25-27   0-2
```

All LEDs should face outwards from the chassis in this configuration.

Note:
This configuration is specifically designed for the [Alien Spider AQ50D PRO 250mm frame (http://www.goodluckbuy.com/alien-spider-aq50d-pro-250mm-mini-quadcopter-carbon-fiber-micro-multicopter-frame.html)](http://www.goodluckbuy.com/alien-spider-aq50d-pro-250mm-mini-quadcopter-carbon-fiber-micro-multicopter-frame.html).

Troubleshooting

On initial power up the LEDs on the strip will be set to WHITE. This means you can attach a current meter to verify
the current draw if your measurement equipment is fast enough. Most 5050 LEDs will draw 0.3 Watts a piece.
This also means that you can make sure that each R,G and B LED in each LED module on the strip is also functioning.

After a short delay the LEDs will show the unarmed color sequence and or low-battery warning sequence.

Also check that the feature `LED_STRIP` was correctly enabled and that it does not conflict with other features, as above.