This document describes available hardware modifications to tap the Delta Ray throttle signals.

Three methods are described. There may be additional possibilities that other people come up with, these are just my own ideas.

An explanation of how the stock Delta Ray driver works is provided in Appendix A (for those interested).

Appendix B contains some information about the connection to the ESC.

Appendix C contains some practical tips on setting up the Delta Ray.

Appendix D details how to modify the Delta Ray brick to use a 3S battery.

For convenience, often in this document the singular term “throttle signal” will be used. Of course there are two throttle signals, one for each motor, but for the purposes of clarity (for the most part) this document is written as if there is only one.

Please note the following:
1. In all cases the ESC requires ground (0V) on the brown connector for the ESC. It is important that this ground be tapped from the Delta Ray brick itself. It should not be tapped from the battery or from the ESCs (or their wiring) because during motor switching there can be substantial transients and a lot of noise on the wiring associated with the motor. The easiest place to tap it is on the board where the ground lead of the battery enters the brick, or from one of the terminals of the servo connectors for the elevons. The Delta Ray has a large filtering capacitor located on the brick and it helps to keep the transients on the brick to a minimum.
2. The Delta Ray brick contains a lot of static-sensitive components so it’s important to follow standard procedures for dealing with that. If you have an antistatic strap then use it, otherwise be sure to ground yourself by (for example) touching a water pipe just before you start working on the brick. The problem with static damage is that it is often insidious; it can create intermittent problems (which is a recipe for a “whole bunch of no fun” if the problem occurs at 200m altitude).

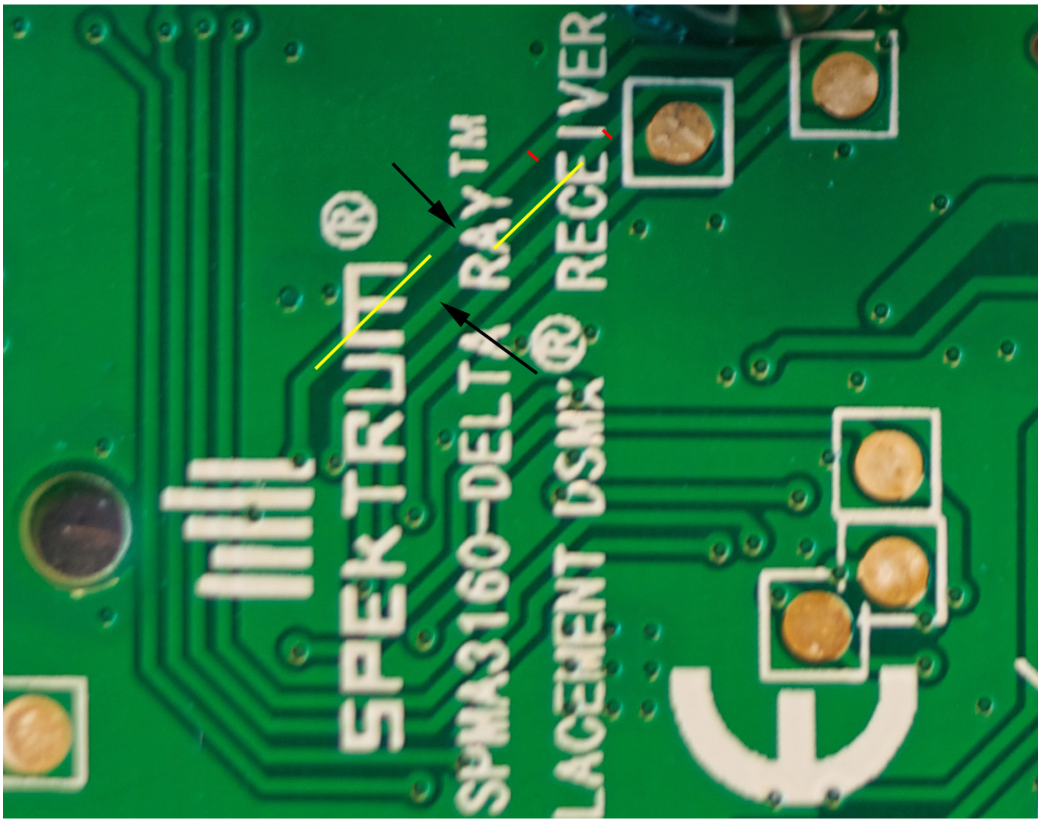
1. Tap the throttle signal from the Delta Ray brick microcontroller

As explained in the appendix, the Delta Ray brick microcontroller controls the throttle by using a 3.3V square-wave signal. The throttle signal is strong enough to drive most ESCs directly. Even ESCs with a 5V input will normally switch properly with a 3.3V signal.

However, in order to get the best quality signal, it is important to cut the trace leading to the MOSFET drivers for the motor. Otherwise the signal will have a long rise/fall time as explained in Appendix A.

The throttle signal can most easily be tapped at the board as shown in the photo below
This photo shows a section of the top of the board (where the wires come out). This part of the board is easy to find because of the Spektrum symbol. The two black arrows point to the throttle signal traces. The red lines indicate recommended locations to cut the throttle traces to disconnect the MOSFET drivers. The yellow lines represent recommended places to connect wires to the traces to tap off the throttle signals.

A couple of notes of caution:
1. The PCB traces are extremely fine and unless you’re a neurosurgeon you probably need a “third hand tool” with a magnifier on it to be safely able to carry out this procedure. These are cheap and readily available in many hardware and hobby stores.



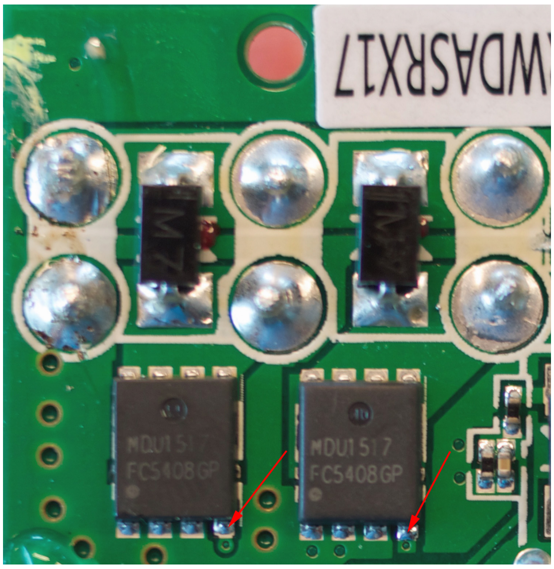
2. Use a scalpel to cut the trace until you expose the fibreglass board material beneath the trace. Be careful to ensure you do not short the cut area to any other traces around. Use denatured alcohol to clean the area afterwards and ensure the cuts goes right through the traces.
3. To connect a wire to the trace, begin by first removing the green insulator on top of the trace. Either use a scalpel (very carefully so as not to cut the traces!) or a very small screwdriver to scrape the insulator away until the bright copper trace is exposed. Work slowly and carefully, it can take some time to work through the insulator: if you're too aggressive it is quite easy to peel off the trace underneath the insulator (the traces are very thin). Once the copper is exposed clean the trace with denatured alcohol.
4. The next step is to mask over the board area around the trace (I recommend insulation tape) to keep things clean and ensure you don't solder anywhere you shouldn't.
5. Using a low-power soldering iron (maximum 20W!) "tin" the exposed copper with some solder.
6. Finally, take the wire (I recommend wire-wrap wire, it is very thin and single-stranded) and lay the exposed end of it over the trace (I recommend taping it down to hold it in place). Then gently solder the wire on top of the trace. Let it cool and ensure it is attached properly.
7. After removing the masking tape, clean the board to get any solder flux off (denatured alcohol or acetone - but keep acetone away from the foam of the Delta Ray). Then glue the insulating part of the wire to the PCB to act as a strain relief to prevent the wire breaking at the solder joint if it gets pulled.
8. The signal traces now need to be connected to the signal input of the ESC, along with the ground signal that you can tap off the battery. See Appendix B for details.

Using the throttle calibration function of BLHeli FW - Delta Ray Edition you can check that the throttle signal is functioning correctly.

Note: good practice calls for the MOSFET input signal (which has been disconnected by cutting the trace) should be tied to ground to prevent any potential oscillation from the floating gate. Probably nothing bad will happen if you don't do it - so long as there are no motors attached to the Delta Ray brick.

2. Tap the throttle signal from the Delta Ray brick MOSFET input

An alternative approach is to tap the throttle signal from the MDU1517 MOSFET (again there are two of them, one for each throttle). The pins to solder the wires two are marked with red arrows in the photo below



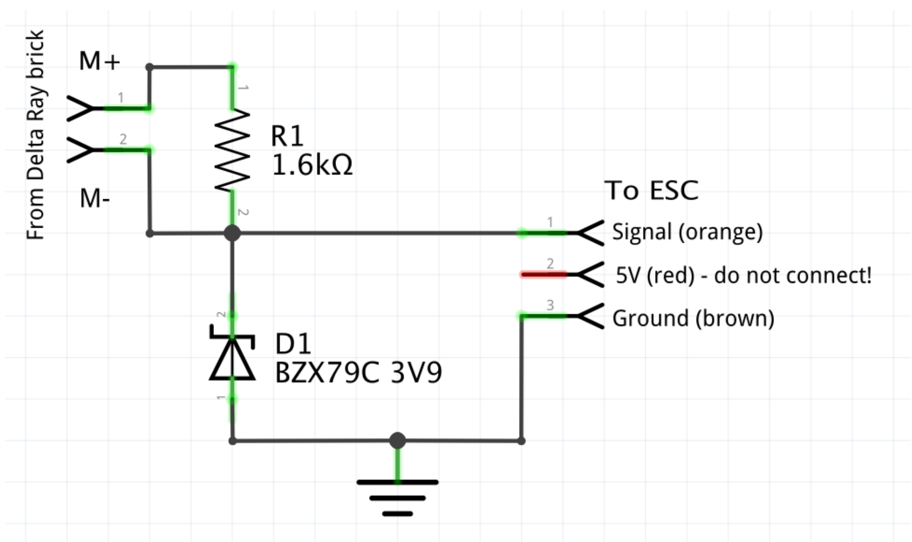
The advantage of this method is that you don't have to cut PCB traces or solder wires onto them. The disadvantage is that the throttle signal rises quite slowly, which will have the following negative impact:

1. Throttle sensitivity will be reduced somewhat because at high and low throttle levels the slowly-rising/falling gate signal will not reach a level low/high enough for the ESC input to recognise it and switch.
2. The slow signal will also probably introduce more jitter into the throttle value read by the ESC.

I haven't actually tested this approach, so I am not sure just how much these disadvantages will impact real-world performance.

3. Tap the throttle signal from the MOSFET output

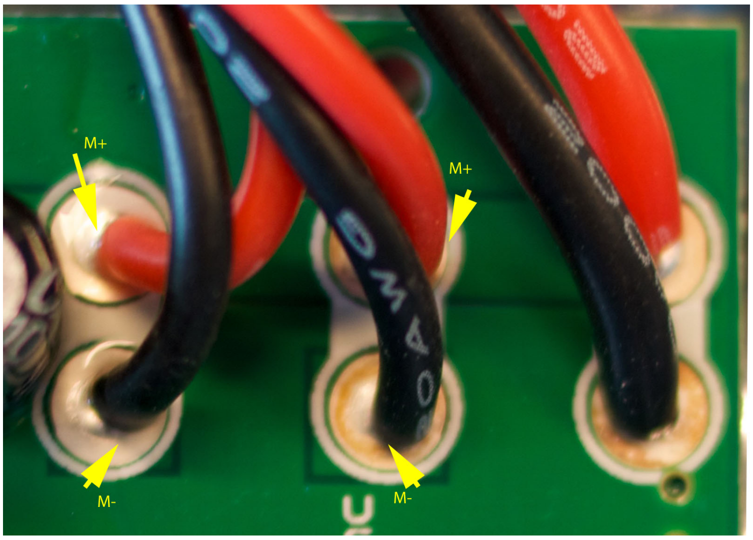
As a final alternative, the output of the MOSFET (again, there are two) can be used to drive the ESC. This is done using a Zener diode and a resistor as shown below.



A Zener voltage of 3.9 V is probably a good choice, for example the Fairchild BZX79C 3V9 (which costs about 5 cents). The zener breakdown will occur at about 1mA current through the diode. With a discharged 2S battery the absolute minimum voltage will be 6.6V. This means a resistor value of (6.6 - 3.9)/0.001 = 1692 Ω (i.e., 1600 Ω standard value) would be good. As a check: with a full 2S battery and 8.4 V, the diode current will be (8.4 - 3.9)/1600 = 2.8 mA and with a full 3S battery it will be (12.6 - 3.9)/1600 = 5.4 mA which mean the diode voltage will be about 3.9 + 90*4.4mA = 4.3 V, which is low enough not to damage the ESC input.

Note: Zener diodes do not have great high-frequency performance but a standard Zener diode will work fine in an application running at "only" 15kHz.

The connection to the Delta Ray brick has to be made as shown in the photo below. The terminals marked M+ and M- are the motor connection points.



Zener diodes look like this:

The black line marks the cathode and the wire coming out of the cathode needs to be connected to the resistor and the M- terminal. The other terminal needs to be connected to ground.

The advantage of this approach are that no modification at all is required to the Delta Ray brick. The zener diode and resistor can be wired into the servo cable for the ESC.

The disadvantages of this approach are the same as tapping the MOSFET input.

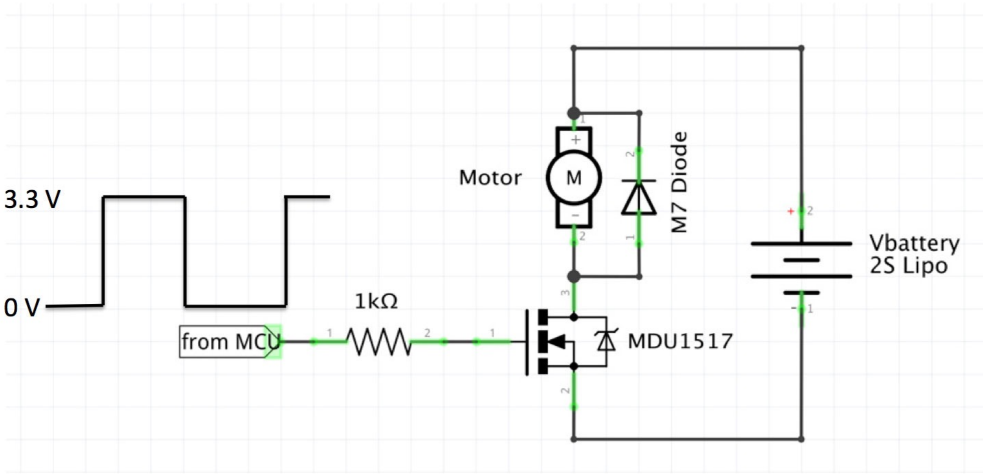
Note: the ESC signal in this case will be "inverted" (since when the MCU output is high, the MOSFET output is low and vice-versa). So in BLHeliSuite PC software, a "negative" PWM signal must be selected.

Again, I have not built and tested this, but it's pretty much a "no brainer" of a circuit. The only thing I would recommend is that before connecting the ESC, measure the voltage of the signal (orange wire) coming from the Delta Ray brick at both 0% throttle and 100% throttle with a full battery (2S and 3S if you plan to modify the board to accept 3S power). It should be below 5V in all cases - otherwise there is the risk it could damage the ESC input.

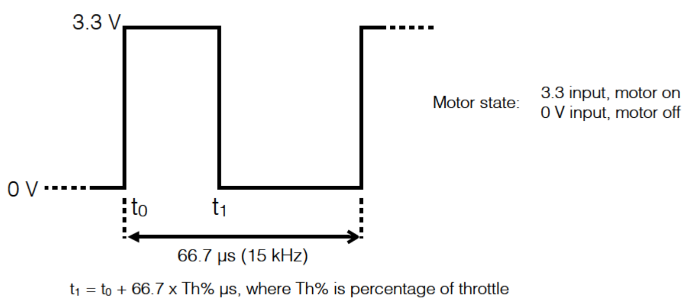
It may be that there are ESCs that accept only 3.3V logic inputs. In that case, the Zener voltage will have to be changed (e.g., a 2.4V zener like the Vishay BZX55). Hopefully the ESC documentation will indicate if a 3.3V signal only is accepted.

Appendix A: Explanation of the Delta Ray motor driver circuit

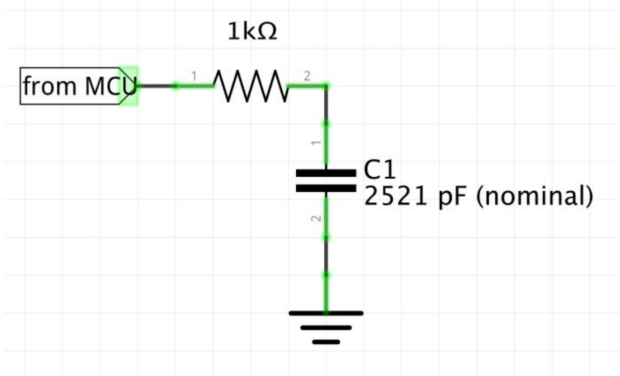
The Delta Ray motor driver schematic is shown below. The microcontroller (MCU) outputs a square wave signal between 0 - 3.3V. The signal drives the MDU1517 MOSFET and switches the power on across the motor. The M7 flyback diode is required to eliminate voltage spikes when the MOSFET switches off.



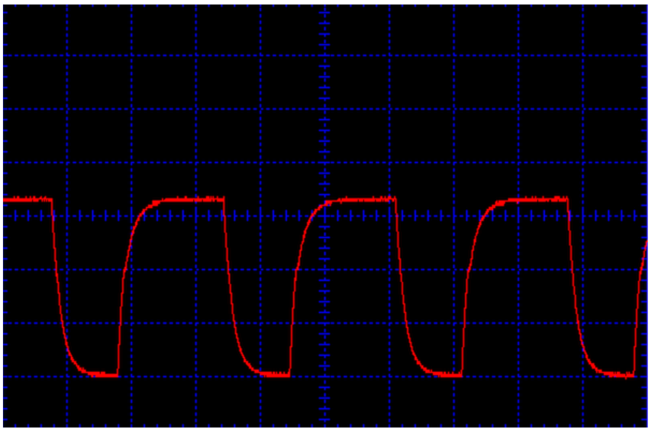
The throttle signal waveform varies with throttle position as shown in the following sketch



Electrically, the input of the circuit looks like this:



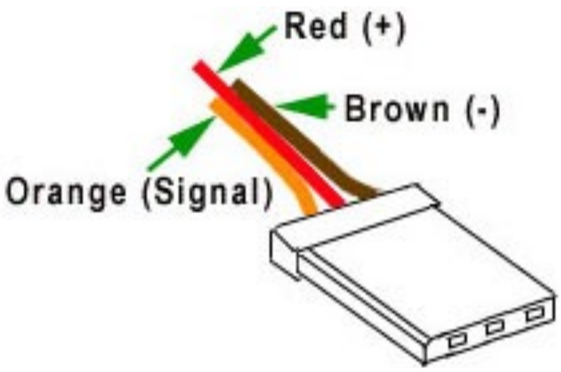
The 2521 pF capacitor is the input capacitance of the MDU1517. This is a classical “RC” circuit that takes times to charge up. It takes about 6 μs to charge the input of the MDU1517 to 3V - which is about the point at which the MDU1517 switches on (barely!). So the input signal into the MDU1517 looks like this:



As a result, the motor switching is fairly sluggish (which is why improved driver circuits can make a big difference to brushed Delta Ray motor performance).

Appendix B: ESC connectors

All ESCs I am familiar with use the standard JR connectors, shown in the schematic below



The orange wire is the signal wire and that’s where the Delta Ray throttle signal should be connected. The red wire is for the BEC and should NOT be connected. The brown wire is ground (0V) and should be connected to the ground terminal of the Delta Ray brick.

Appendix C: Practical Tips

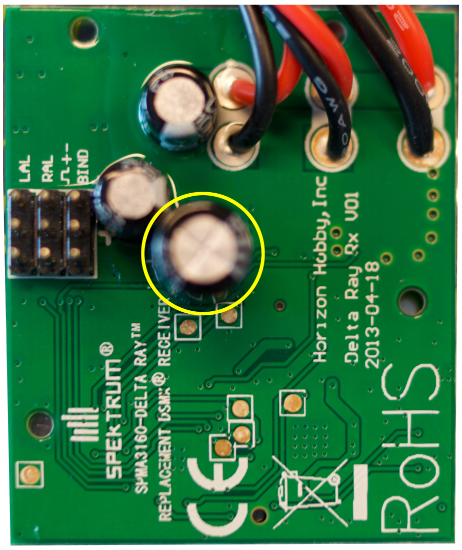
This is not an exhaustive list, just some suggestions that might help to make the build easier

1. The Delta Ray forum on RCGroups has quite a number of write-ups about selecting brushless motors and propellers and mounting them on the Delta Ray. For example, this write up from MartinT: http://www.rcgroups.com/forums/showthread.php?t=2007692&page=2#post29628639
2. Because the Delta Ray brick uses SAFE, I strongly recommend using counter-rotating propellers on the two motors. Otherwise there is some danger of the torque resulting from the motors rotating in the same direction will interact with the SAFE stabilisation.
3. Although BLHeliSuite allows you to reverse the rotation direction of the motor, I recommend setting up the motors so that they both rotate in the correct direction (i.e., with the tip of the prop above the motor rotates down towards the fuselage) with the rotation direction set to

"Normal." That way both motors can be flashed with identical settings and you don't have to worry about the direction again. If when you initially wire up a motor it rotates in the wrong direction, just swap two of the three motor wire connections and it will rotate in the opposite direction.

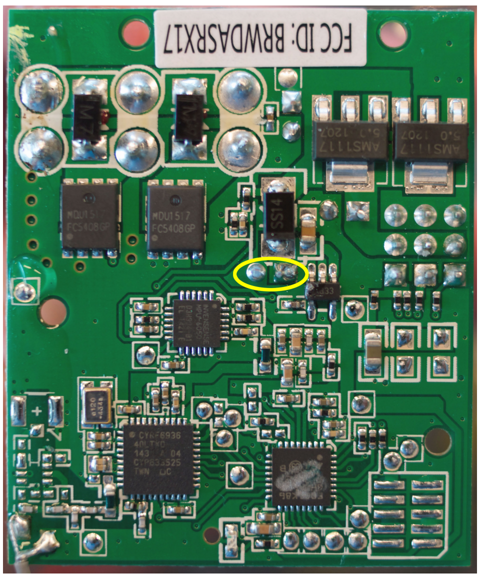
Appendix D: Modifying the Delta Ray brick to take a 3S battery

The Delta Ray brick is capable of handling a 3S battery provided a single capacitor is changed. The capacitor is circled in the photo below.



The capacitor is a 10V 1000 μF electrolytic and it needs to be replaced with a 1000 μF electrolytic capacitor of a higher voltage rating. 16V or above is fine. It will probably have a large diameter than the existing capacitor so the terminals for the capacitor might have to be bent inwards to fit into the holes on the brick.

The capacitor has two terminals, marked in the photo below



To remove the old capacitor you have to desolder it. Use a low-power soldering iron and use a solder sucker (not desoldering wick). If you've never done this before, this document provides a very good guide to desoldering: http://www.hardwaresecrets.com/how-to-desolder-components/

The Delta Ray brick cannot directly handle 4S or above batteries. However, should you wish to do so it is possible as follows:

1. First of all, put your mental health analyst on danger money, baby. You're seriously whacko for trying to see how a 500g plastic and foam glider will perform with 500W or more of motor power. You might want to strength the plastic motor mounts with titanium because I doubt they'll hold otherwise. I see a shower of foam and debris raining down upon you in your near future. But hey, whatever floats your boat.
2. Use a voltage regulator across the battery to regulate the voltage down to 12V (e.g., the Linear Technologies LT1083) to provide power to the board. You need a regulator that can deliver a significant current since the elevon servo motors demand large current spikes when they move. Throw in a decoupling capacitor or two for good measure. Then you'll be good to go. For as long as it lasts, anyway. I wouldn't pay extra for long-lifetime components, it's not worth it.