Conversion of a Turnigy 9X to Hall effect sensors

Because English is not my mother language I kindly ask to be gracious.

Unfortunately I had several times some problems with the low quality potentiometers on my Turnigy 9X transmitter. I decided to equip my transmitter with wear-free Hall effect sensors because it's nearly impossible to get well fitting high quality replacement potentiometers.

used hardware

- Hall sensors type Allegro A1302KUA-T

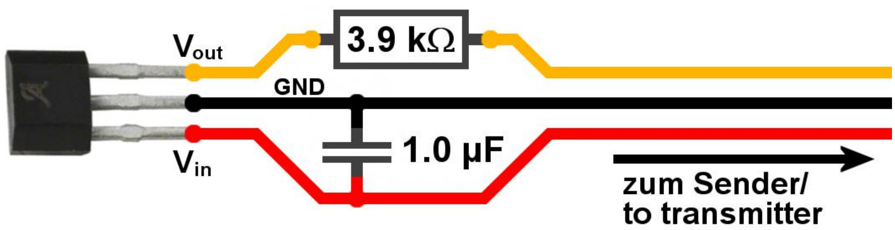
- Neodymium ring magnets, Ø 10/5 mm, height 5 mm, N45, **diametrically magnetized**

Because of the low angel of rotation of approx. +/- 30° of the potentiometer shaft the magnetic field strength needs to be quite high to achieve sufficient effects in the Hall sensors.
I got the magnets at http://www.supermagnete.de.

electronics

First I thought about the circuitry of the Hall sensors. The Hall sensor type Allegro A1303KUA-T has three pins for ground (GND), supply voltage input (V_{in}) and signal output (V_{out}).
According to the data sheet the circuitry is pleasingly simple. Only a capacitor between ground and supply voltage input is required. Other external components are not required. A friend gave me the advice to use a current protection resistor in series with the signal output line to protect the transmitter's main CPU from high current.
Because João (user name jhsa) selected 3.9 kΩ for his conversion I decided to use the same value. But I think with any value between 2.2 and 4.7 kΩ you'll be in a reasonable range.

This is the circuitry of my sensors:



I've been told it's recommended to place the capacitor as near as possible to the Hall sensor. The capacitance is not a critical value and a capacitor in a range of 100 nF to 2 µF should be alright. I decided to use ceramic capacitors of 1.0 µF capacitance.

VERY IMPOTANT:
Please don't rely on the colors of the cables inside the transmitter! It's absolutely essential to check all wires with a multimeter to find out which one is ground, supply voltage input and signal output.
Unfortunately inside the transmitter this is done completely random and hence you may find ground on a white wire...

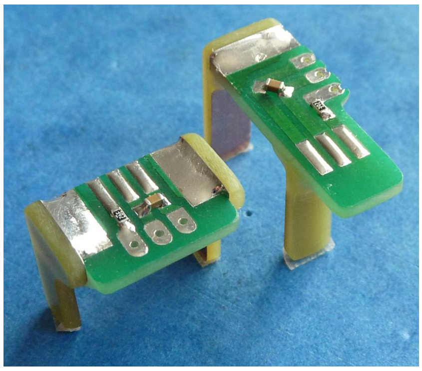
power consumption

According to the data sheet an Allegro A1302KUA-T hall sensor has a maximum current consumption of 11 mA. With my sensors I've measured 7 mA current during operation so that I get additional 28 mA for all four sensors. The voltage regulator on the Turnigy 9X motherboard is designed for 100 mA maximum. With the additional consumption by the Hall sensors that could possibly be too much. Under unfavorable circumstances it may be necessary to replace the original regulator with a more powerful device.

mechanics

After I got the electronics questions clarified I thought about the mounting possibilities of the sensors. My goal was to finally achieve a complete unit of potentiometer housing with shaft, Hall sensor element and magnet.

This is how my hall sensor holders finally look:

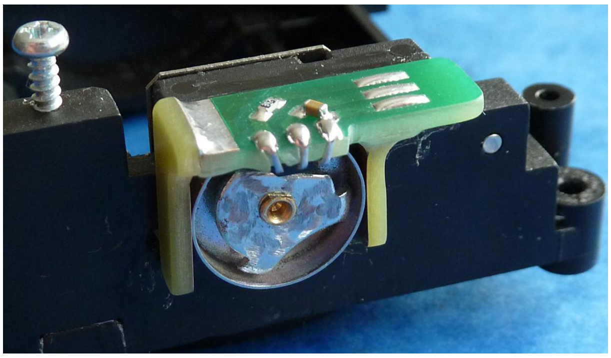


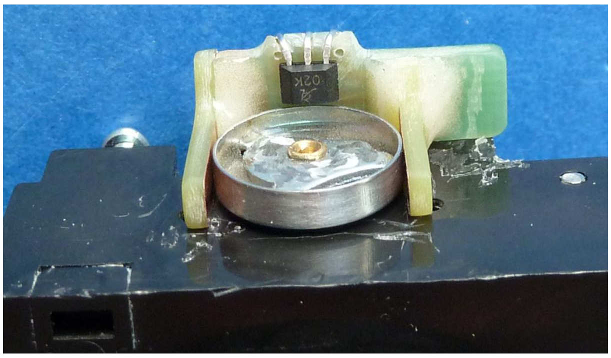
I started using small parts of glass-fiber reinforced plastic (thickness 1.5 mm) to handicraft some models until I finally found a solution that fits my ideas best.
Then I asked a good friend to make the small PCBs (the green parts on the photo). He decided to solder the capacitor and resistor directly onto the PCB as SMD components.

The holder at the left is intended for the inner core part of the gimbal and the holder at the right is intended for side mounted alignment at the gimbal unit.

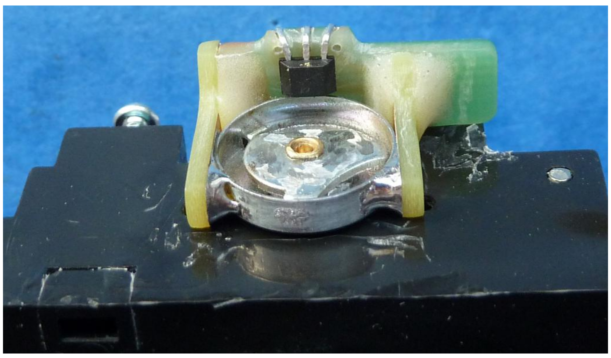
As material single side copper plated FR4 laminate of 1.5 mm thickness with 35 microns copper layer is used.
On the photo at the top you can see the solder joints at the side. Additionally the side frames were reinforced with epoxy glue at the bottom of the PCB:

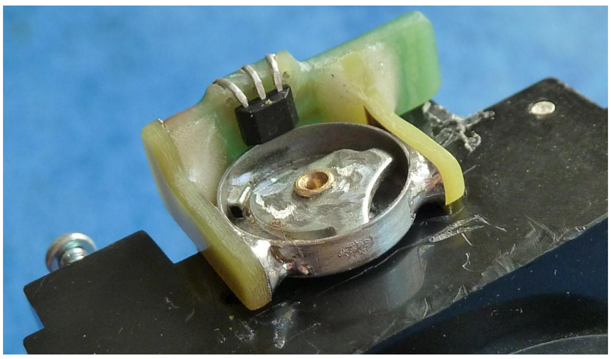
The original potentiometer housings have a diameter of quite exactly 13 mm. I made the Hall sensor holders a little bit smaller (inside dimension) to make them fit quite tight on the original potentiometer housing.
On these photos it's quite clearly visible how one of the side sensor holders is clamped onto an empty potentiometer housing:



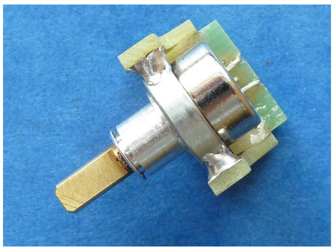
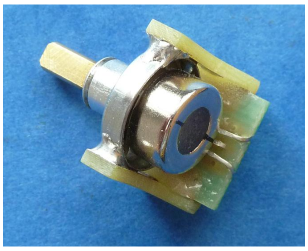


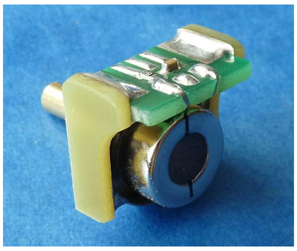
After the sensor holder is aligned correctly on the potentiometer housing I've soldered the side frame with the potentiometer housing.
Of course it could be glued as well but soldering went much quicker and lasts very well.



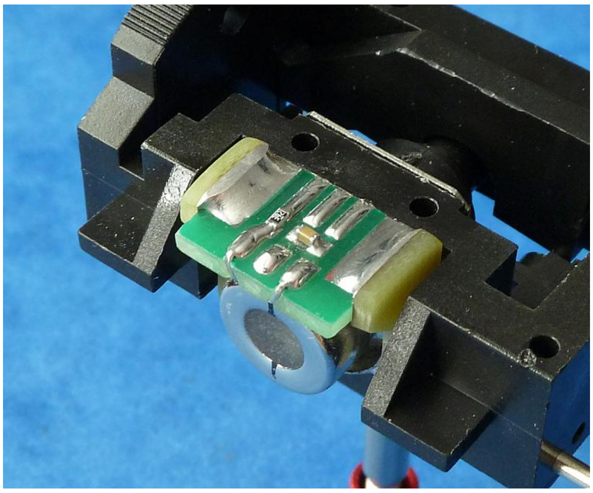
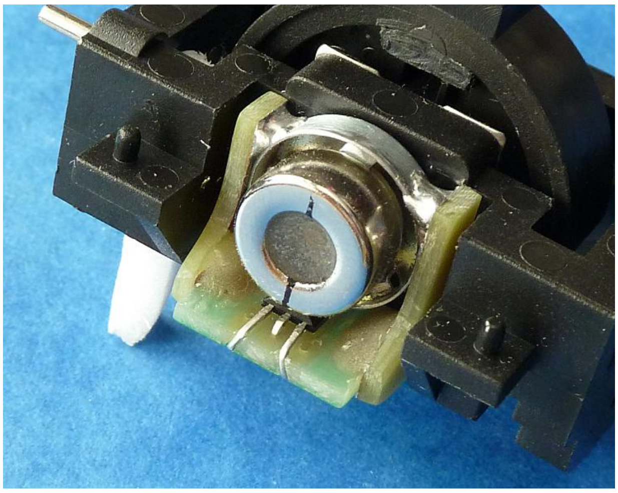


The entire hall sensor unit can be easily removed and is not attached permanently to the plastic frame of the gimbal unit.
You can see this on these photos of a hall sensor unit for the inner core part of a gimbal unit:

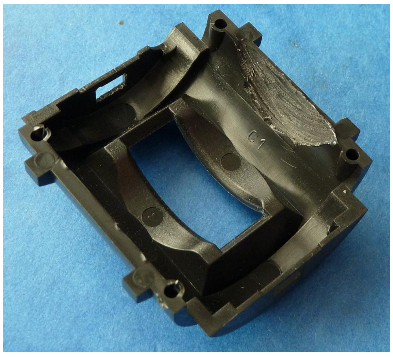
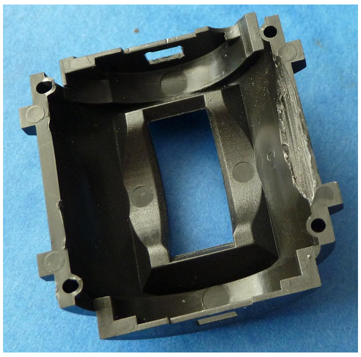





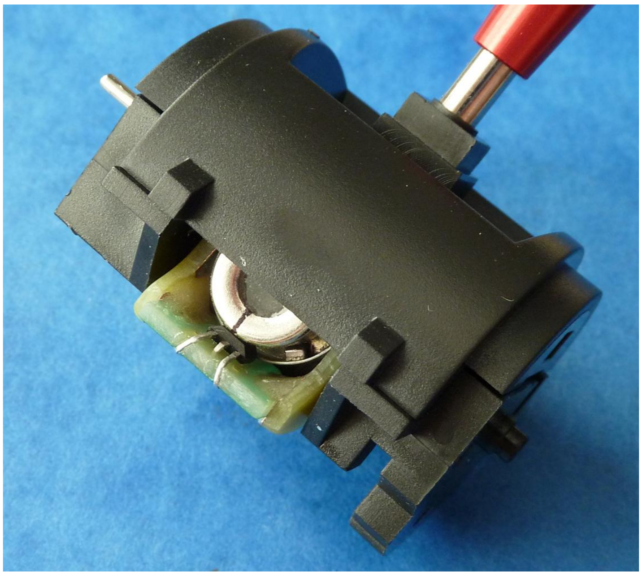
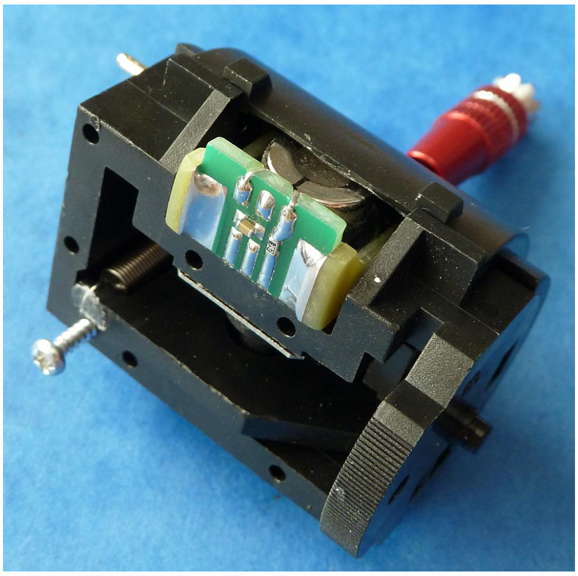
The ready-to-install Hall sensor unit only needs to be plugged into the plastic frame of the gimbal and clamped with the original spring steel plate:

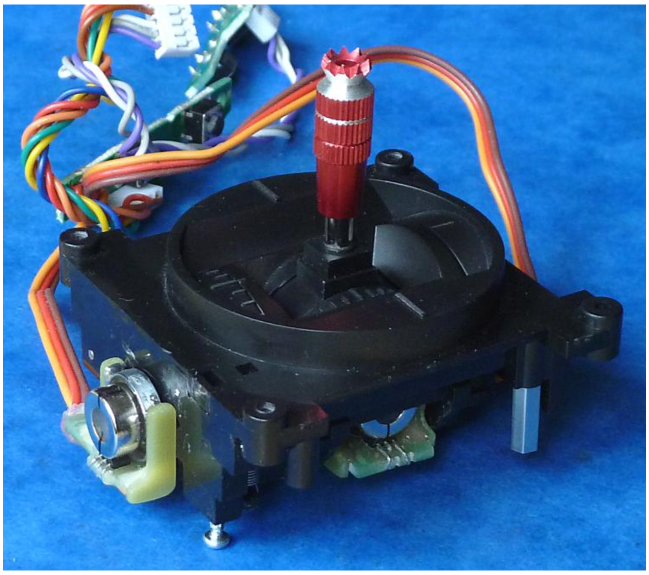
To prevent the outer plastic housing from rubbing at the magnet or jamming of the entire gimbal unit a bit of the plastic housing needs to be removed.
You've to be careful here because relatively much of the plastic housing has to be removed. The remaining wall thickness will be quite thin.

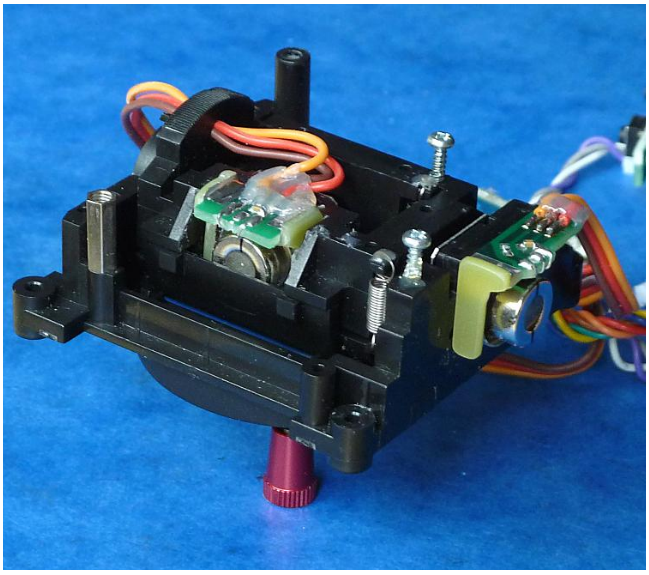



Finally assembled the inner core part of the gimbal unit looks like this:

And here you can see how the fully assembled gimbal unit with both Hall sensors looks:

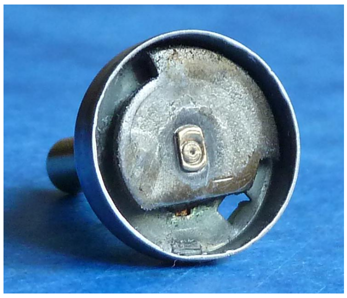




some hints on how to align the magnets:

I recommend to install and align the Hall sensor unit first and to do the positioning and alignment of the ring magnet afterward.

To remove the potentiometer slip ring from the potentiometer base plate I've used my Dremel with a small diameter cutting wheel.
And I've grinded the potentiometer base plate as smooth as possible. This is necessary to prevent the magnet from wobbling.
Furthermore I've cut away the three tiny clips of the housing and grinded the whole housing to be completely glossy.



The surface of the magnets is very smooth and they slip on the potentiometer shaft very easily. Therefore I applied a small amount of rosin to make them a little bit sticky. This makes the positioning much easier!

The correct alignment of the magnet should be done outside of the transmitter. I used a simple little “test circuit” of a 5.05 V DC power supply at GND and V_{in} and a voltmeter at GND and V_{out}.
As long as there is no magnetic field applied the sensor outputs approximately half of the supply voltage, typically 2.525 V, assuming the supply voltage is 5.05 V as in this example:

Now the magnet is placed onto the potentiometer shaft and rotated as long until the voltmeter displays the “neutral voltage” again.
It is not necessary to turn the magnet until it reaches the “neutral voltage” perfectly. Smaller deviations could be balanced in the stick calibration menu of the transmitter. But the more accurate you work here, the better is the default setting of your transmitter.

As a spacer I have inserted a small piece of thick writing paper (120 g/m²) between the Hall sensor and the magnet.
If you now move the stick fully up and down the voltage should change accordingly. It takes some time and patience until the magnet is perfectly centered and the distance magnet – Hall sensor always remains the same during stick movement.

This is an extremely important step to make the stick movement as linear as possible!
Enough time should be spent to center the magnet really well on the potentiometer shaft. Failing to do this could result on a non linear movement of the servo.
But the distance shown in the photo on the right has been relatively easy to achieve.

IMPORTANT:
The achievable maximum voltage at V_{out} is ALWAYS a little bit lower as the supply voltage and the achievable minimum voltage at V_{out} is ALWAYS a little bit higher as 0.0 V.
These values can not be exceeded, no matter how strong the magnetic field is!

Hence during the positioning of the magnet the distance between magnet and Hall sensor should be adjusted so that at full deflection of the stick the minimum and maximum values are nearly being achieved.
During my attempts I could relatively easily adjust it to 0.12 V minimum and 4.93 V maximum.
However, there seems to be quite large tolerances in both the magnets and the Hall sensors. Hence the values given above are only rough guidelines. The greater the achievable bandwidth from minimum to maximum voltage, the greater the achievable electronic resolution. However, if you can only reach a range e. g. from 1.0 to 4.0 V, then that's fine too.

Finally I glued the magnet with quickly hardening epoxy glue onto the potentiometer shaft.

Depending on how the magnet was placed, it can happen that the stick movement in the transmitter is inverted. Then maximum throttle e. g. is not at stick full up but at full down.
As long as either er9x or OpenTx is used this can be inverted again in the transmitter setup, separately for each stick channel.
With other transmitter firmware this setup option is possibly not available. In that case the magnets needs to be positioned with “right” polarity.
Even though it's not necessary to take that aspect into account when positioning the magnets of course it does not harm.

That's it!
I hope my little report will help other users with the modification of their transmitters to Hall effect sensors.

Good luck!