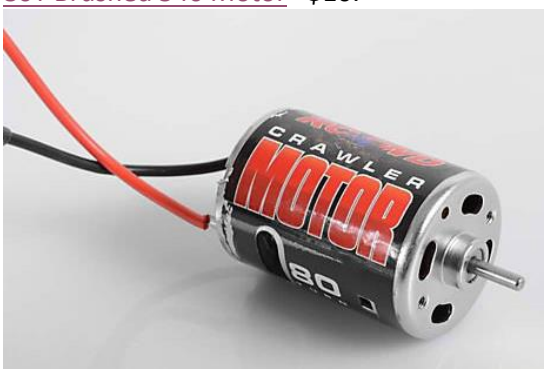
Introduction:

The Hitachi Magic Wand massager has been around for over 40 years.

This post will guide you through upgrading your Hitachi Magic Wand Original with a more powerful motor and an integrated power adjustment knob for fine tuning the vibrations. It has the added benefit of being powered from a universal power supply, which means it will work in all countries. Total cost was about $40 (+wand), and it took about 3 hours to do, though I could probably do it all again in about 1 hour.

Buy:

Servo tester. ~$4. 	Turnigy 20A Brushed ESC. ~$14 
80T Brushed 540 Motor ~$10. 	DC power supply,12V 3A. ~$10. Any 12V, 3A universal power supply will work. There are tons on Amazon. This one was convenient because it came with the female socket. Equivalent one 

Tools/materials:

Phillips screw driver

Rotary tool, e.g. Dremel, with grinding and sanding bits

Safety glasses (for use with rotary tool)

Soldering iron and solder

Super glue or 5-minute epoxy

Double sided tape

Design:

First, a bit about the Hitachi Magic Wand. It has a 120V 540-sized DC motor powered by rectified US mains voltage. The motor is connected to the counterweight in the head by a spring axle and plastic adapter, which is also a cooling fan. The motor is screwed to a metal plate with 2x 3mm screws that are 25mm apart. This metal plate holds it in place. The motor spins at about 6000 RPM on the high switch setting. In order to control speed finely, you need an external in-line motor control "dimmer" (not a good idea to hook inductive loads to an actual light dimmer). These are sometimes sold with the Magic Wand. They are bulky and have a short cord, which makes them cumbersome. It also won't work in other countries without a power converter.

I wanted to integrate the functionality of the speed controller into the magic wand. I decided to use common radio control (RC) electronics for simplicity. The basic idea was to have a motor, electronic speed controller (ESC) with a battery elimination circuit (BEC), a servo tester to control speed, which provides the pulse width modulation (PWM) signal to the ESC and is powered by the BEC, and a DC universal power supply.

The first step was to find a motor. I targeted a bit above 6000 rpm, which at 12V, meant a kV (motor voltage constant) of about 500 rpm/V. Originally, I wanted to get a brushless motor because they don't have brushes that wear out and are generally more efficient. I focused on inrunner type brushless motors because the shaft is supported at both ends by bearings, which is good for high vibration environments. However, I didn't find any inrunners (or outrunners) with a kV that low that would fit in the wand and had a shaft diameter of 3.18mm. So I started looking at brushed motors with low kV's. It turns out that the 80 turn (80T) RC4WD 540 brushed motor fit the bill. It's kV is around 750, has a 3.18mm diameter shaft, and fits the bolt pattern of the mounting plate. At 12V and just a vibration load, this motor will barely be working, so it shouldn't overheat even when it's inside the wand's case.

The next step was to find a small brushed (not brushless!) ESC with a BEC that didn't have to ship from China. The one listed in materials is the cheapest one I found. You need one that can handle at least 12V (rated for at least 3 Lipo cells, 10 NiMH cells). With just a vibration load, the current will be fairly low, so it shouldn't have overheating problems inside the wand's case either. The servo tester listed above is the smallest one with a knob I could find. The universal power supply can be any 12V, 3A supply. Try to look for one that comes with the female socket (the one I got was very convenient because it has the kind you just push the wires into).

Turns out that that motor already had a flat spot ground on the shaft. However, the flat spot wasn't ground down enough, and the shaft was about 3mm too long, so I had to grind it with the rotary tool. I first wrapped the motor in duct tape to prevent metal filings from getting inside the motor.

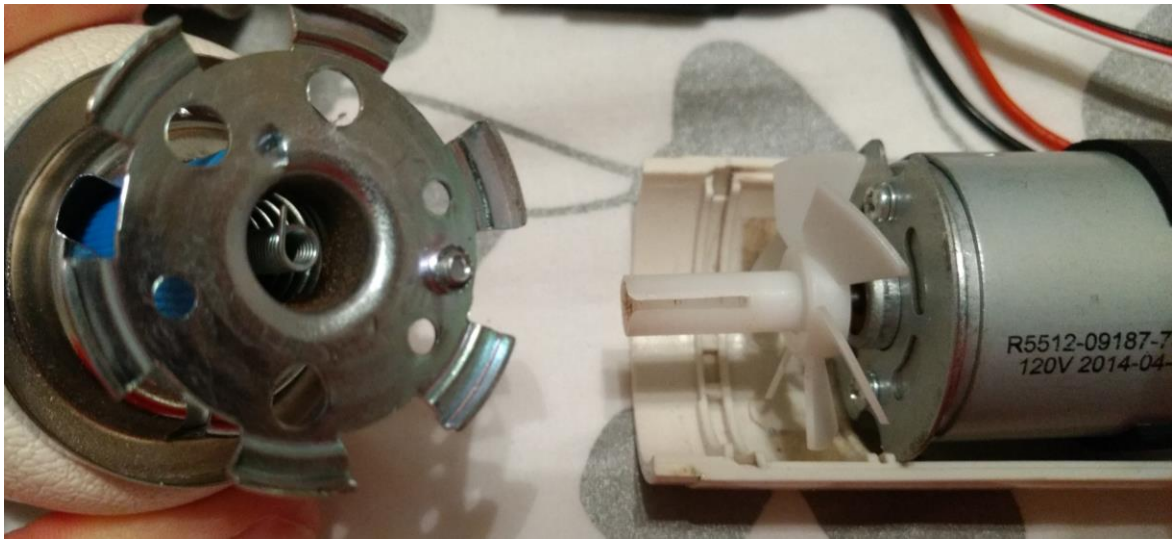
The ESC wires ended up being the perfect length.

Build Steps:

1. Unplug the wand.
2. Remove the screw in the handle of the wand.
3. Loosen the screw in the head of the wand most of the way. Pry up the silver ring around the wand end. It has an open slot that fits around the screw; this can be wiggled off.

4. Pry apart the wand case. Should pop open. Try to keep everything in one side. Set other side of case to the side

5. Pull up the motor.
6. Pull the head off (the spring will come out of the plastic adapter/fan on the motor). Set aside



7. Pry off the plastic adapter/fan piece. Be very careful: the blades are fragile. If you break one, you can fix it with lots of CA.

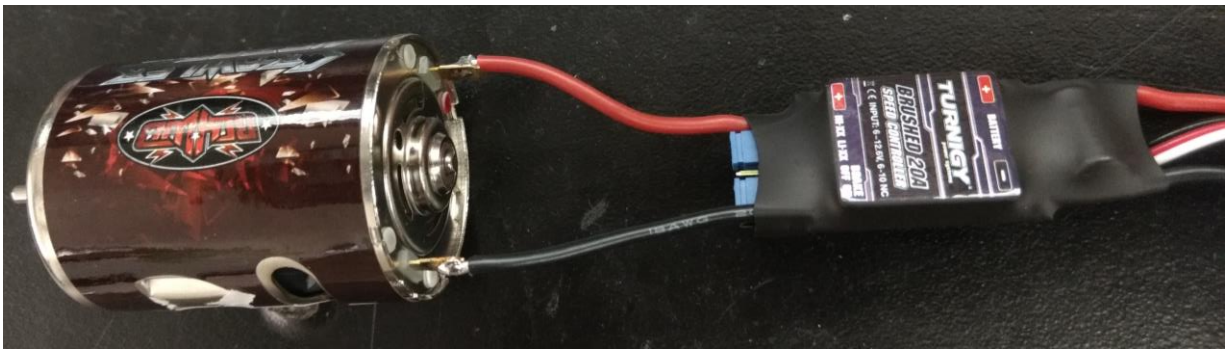
8. Unscrew the metal mounting plate from the old motor. Take care not to lose the tiny screws and split washers.
9. Cut the label to side of switch and remove part of label around switch. Do this before removing the switch or the label will bend up like in below picture.

10. Use something, e.g. flat head screwdriver, to push the tabs on the switch in order to push it out.

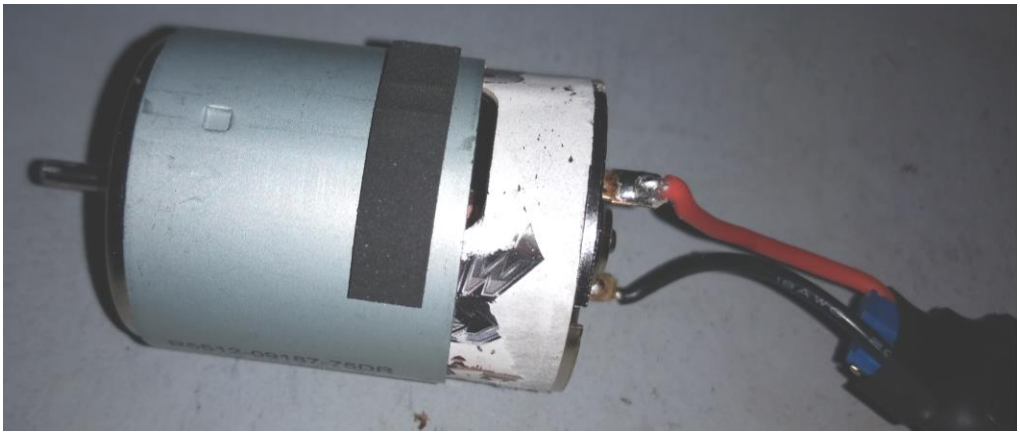
11. Use the rotary tool to grind the flange of plastic around the switch off so that you can pull it back through the case. They assemble this by pushing the switch through and soldering it to the small PCB. If you don't want to mess with grinding the switch, you could try to desolder the switch from the PCB.
12. Pull out the switch/PCB, motor, and electrical cord and set aside. Note how the motor mounting plate is keyed to the case, i.e. note where the notches go.

13. Wrap the new motor in duct tape. Cover all holes
14. Mark how much of the shaft that needs to be ground off with a sharpie
15. With the rotary tool, grind the shaft shorter and the flat spot more until it matches the original motor's shaft. The plastic adapter/fan piece should fit tightly.

16. Take off the duct tape. Be careful not to let metal shavings fall into motor.
17. Peel off the motor's sticker/decal (optional)
18. Solder the ESC motor leads to the motor



19. Take the metal flux ring (the metal band with the foam stuck on it) from the old motor and put it on the new motor. There is a little tab that lines up with a small hole to hold it in place.

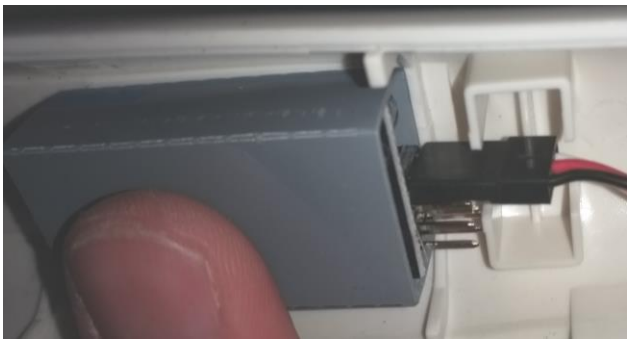


20. Screw the motor mounting plate onto the new motor. Tighten the screws.
21. Grind the plastic case halves for the female socket. Go slow. You want the case to be able to close, but you also want a very snug fit. You may need to grind the rubber around the socket a little. This took me the longest of any of the steps.

22. Install the ESC battery wires into the female socket. On mine, I just had to push down on the red and black buttons and push the wires in as far as they'd go, then release the buttons. You might have a solder-on or screw-terminal type.
23. Plug the ESC signal cable (3 small wires) into the servo tester. Make sure polarity is correct.
24. Switch the servo tester to manual. This is very important.

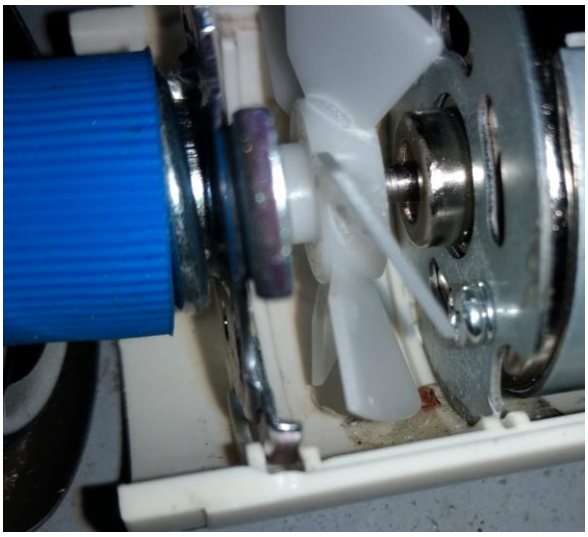
25. Turn the servo tester knob to 0.
26. Plug in the universal power supply and plug in the new electronics. You should hear a beep when ESC is ready. Hold the motor and turn the servo tester knob. The motor should spin. If it doesn't, check connections.
27. Unplug the power supply.
28. Pull the knob off of the servo tester.

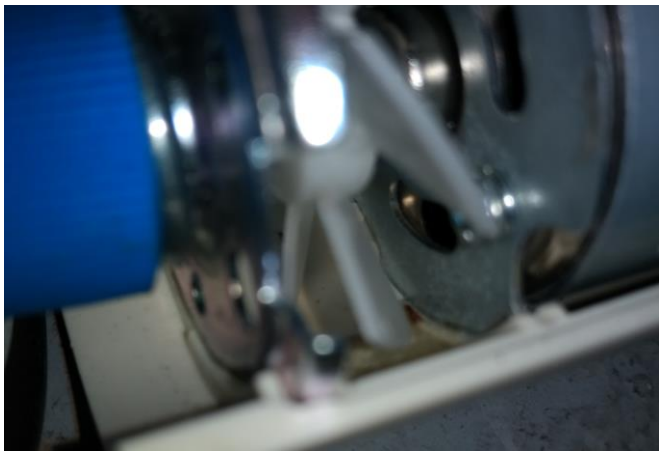
29. Put servo tester into case half and push the knob back on to hold it there. Align it where you want it. Apply glue to case to hold it in place. Let the glue dry.



30. Put motor in case half with servo tester. Align notches/tabs.
31. Put a piece of double sided tape on the back of the servo tester. Stick the ESC to this so that the ESC label is up.

32. Push the plastic adapter/fan piece onto the new motor.
33. Push head back on. Make sure spring goes into place in the plastic adapter, and that the metal tabs on the head mount line up with the slots in the case.





34. Close up the case. Put metal ring back on. Tighten screws.
35. Plug in the wand and make sure it still works by spinning the control knob.
36. Enjoy!

Future Improvements:

- The servo tester wiggles around a little and doesn't feel very secure. The next iteration will probably include a custom servo tester circuit and/or a 3D printed adapter to fit the original switch slot better. It might be possible to take the tester's PCB out of the little plastic sheet case and install it in a 3D printed adapter.
- If it's already running on DC voltage, why not make it battery powered?
    - Assuming it uses 10W and you want the battery to last 1 hour, you need a 10Whr battery. If the nominal voltage is 7.4V (2 cell Li-ion…really wouldn't trust LiPo's in this), then you need a 1.35Ahr capacity battery capable of at least 1C (C*capacity = Amps) discharge.
    - 18650 li-ion cylindrical cells are 65mmx18mm. There isn't room for two of those in the handle.
    - If you got rid of all of the internal structure in the handle, you might be able to fit a pouch-type 2S LiPo or LiFe pack. You'd have to carry a separate charger/balancer around, though that's not that different in size than the universal power supply.
    - The cheap knock-off battery powered magic wands put the (much smaller) motor and counterweight in the head, which leaves more room for the battery.
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