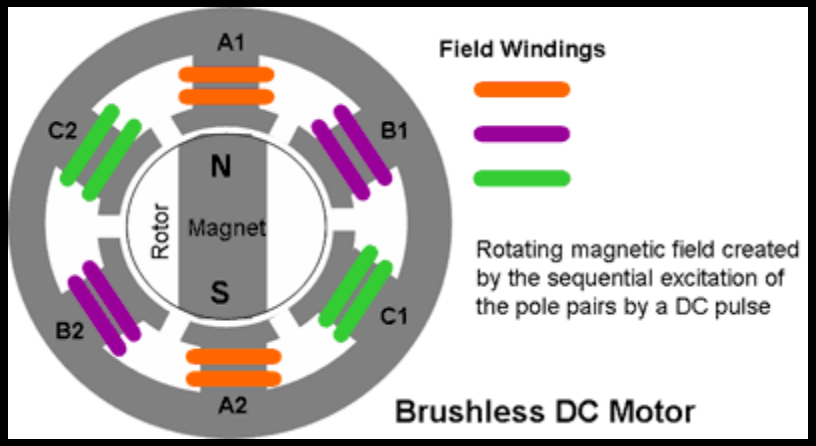
BRUSHLESS DC MOTORS *(AND COMPARISON TO OTHER MOTORS)*

Brushless DC Motor (BLDC)



Uses **pulsed DC** to energize coils in a rotating fashion.

Has small torque ripple.

These work very similarly to a stepper motor, but used when high speed is desired.

Always have a permanent magnet(s) in the rotor. The permanent magnet usually consists of some rare earth metal. The permanent magnet makes manufacturing cheaper and the rotor has a lower rotational inertia allowing for faster speeds. One drawback to permanent magnets is heating past the Curie temperature can cause demagnetization.

Can obtain speeds up to 100,000 RPM!

BLDC Example (a fan)

I spun the blades with my hand so you can see the stator coils with the picture on the right.

BLDC vs. Brushed DC Motor

BLDC Motor Advantages:

- Lasts 10x longer (~10,000 hrs)
- More efficient (which means higher torque per amp)
- More power per weight
- Less maintenance since brushes don't exists (no contacts)
- Higher speed range
- Smaller

Brushed Motor Advantages:

- Cheaper to manufacturer
- Cheaper controller costs (however, BLDC controller costs keep trending to be cheaper)

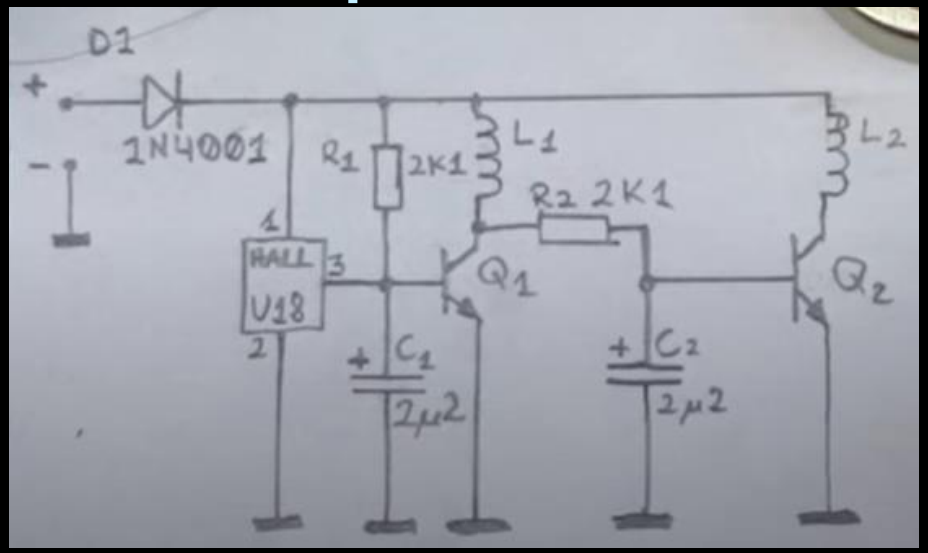
BLDC Motors are slowly phasing out Brushed DC Motors

Features of Some BLDC Motors

You can find BLDC motors that have the motor drive built into them.

- Some can control the speed with PWM input.
- Some have a direction pin so that a TTL input can change the direction.
- Some have a Hall Sensor to provide frequency output to determine the speed of the motor.

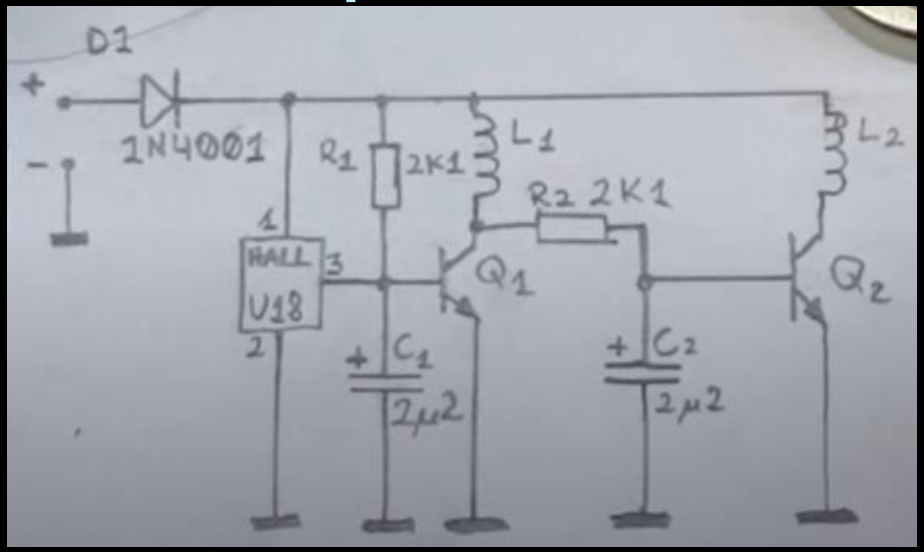
Circuit Inside Computer Fan



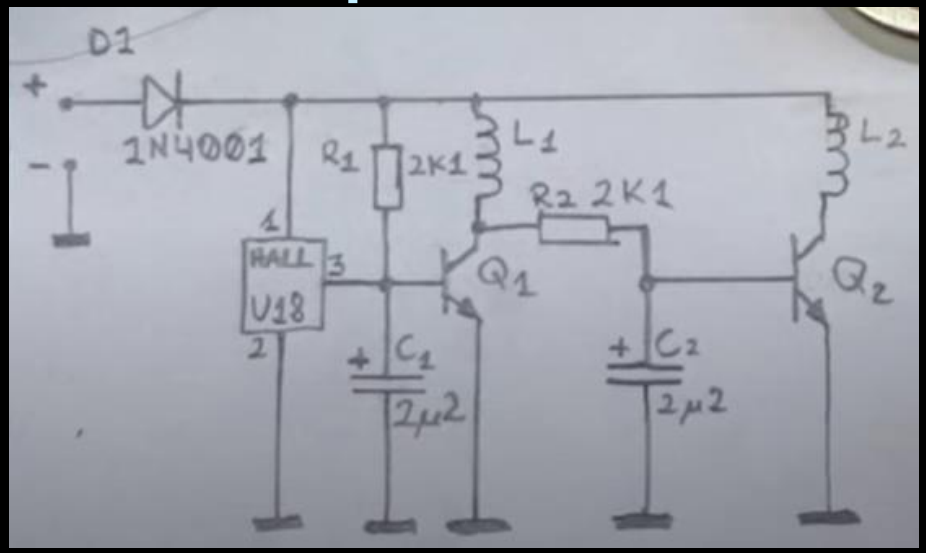
The motor has 2 phases on the stator coils: L1 and L2. The motor has a magnet that spins around and gets in close proximity to the Hall sensor. When the magnet is far away from the Hall sensor, pin 3 goes high (otherwise it goes low).

Circuit Inside Computer Fan

If pin 3 is high, then Q1 is ON which shorts to ground causing the top of Q1 to be low. This low turns L1 ON as well as turning Q2 OFF. Q2 OFF also means L2 is OFF.



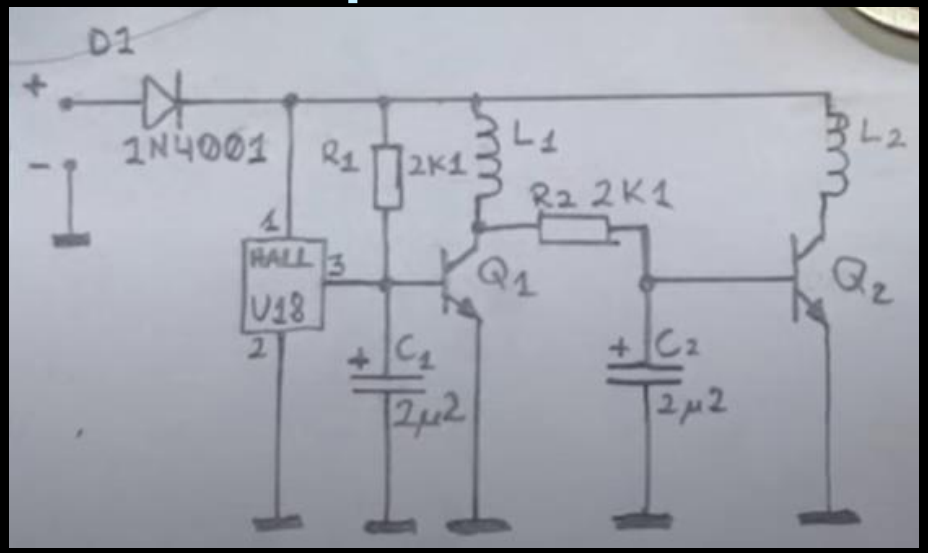
Circuit Inside Computer Fan



L1 being ON and L2 being OFF will cause the motor to spin some which means the magnet becomes in close proximity to the Hall sensor. Therefore, pin 3 is now low turning Q1 OFF and L1 OFF. This Hi-Z on Q1 causes a high on the base of Q2 which makes Q2 ON and L2 ON.

Note that L1 and L2 cycle on & off where neither coil is energized or non-energized simultaneously.

Circuit Inside Computer Fan



The resistors (R1 & R2) and capacitors (C1 & C2) make RC time circuits that control the maximum speed at which the coils (L1 & L2) can turn on/off.

The diode is there as a one-way valve forcing the direction of the current one way.

This is a simple & effective circuit!

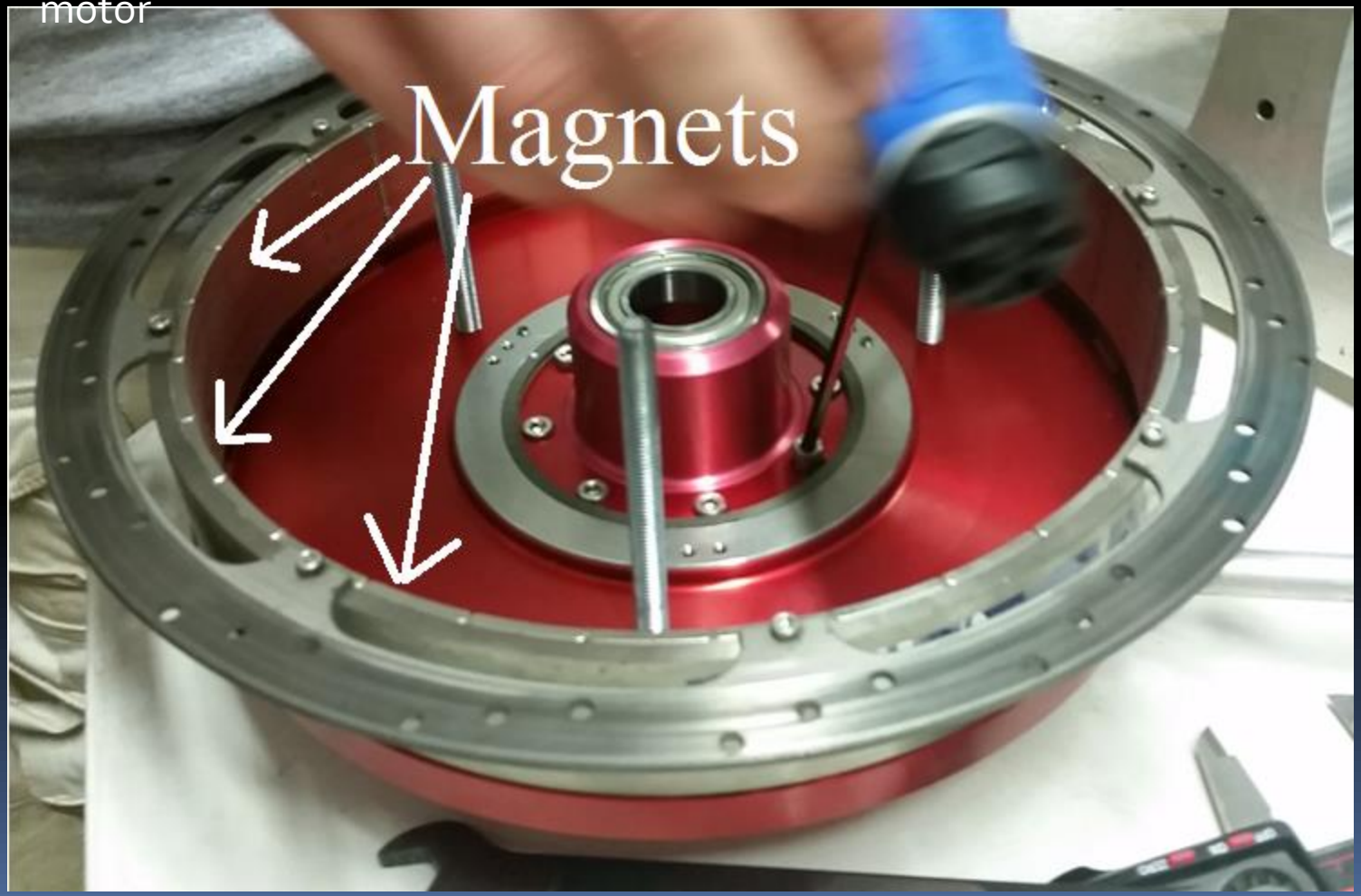
BLDC Windings

Video of winding the field coils of a BLDC

Brushless Motor (stator) from ASU's Solar Vehicle Car - $20k. Note: the stator is on the inside and the rotor (next slide) is on the outside, which is not typical.

BLDC Windings

Rotor of ASU's Solar Vehicle's motor



Applications of BLDC Motors

- Electric Vehicles and Bikes
- Compressors
- Fans, pumps, blowers, HVAC
- Cordless tools (string trimmers, saws, drills)
- Used in some servo motors
- Model aircraft (helicopters & drones)
- Radio controlled cars

BLDC vs. Induction Motors in Electric Vehicles

Older electric vehicles use brushless DC motors and some use Induction motors (GE's EV-1 & Tesla's Roadster - *hence the name Tesla*).

BLDC are more efficient at startup, but at constant speeds going down the interstate, the back EMFs produced by the permanent magnets make them less efficient. With induction motors, you can decrease the current through the rotor windings to reduce this back EMF. This is why some car companies use induction motors.

BLDC have the advantage that since they don't have rotor windings, there is less heat generated. Most of the heat is produced in the stator windings, which is easier to transfer heat away from it.

Also, permanent magnets are expensive and induction motors have the advantage of not needing magnets. Induction motors are harder to control and require more development costs.

Almost all EVs today use BLDC motors with 3 phases.