**Motor Project Research**

The purpose of this research is to accurately pick the most suitable microcontroller board for the task of sampling motor current for a single phase of a BLDC motor. This is accomplished by providing a rough set of constraints based on data from eVTOL vehicle concepts developed by other companies.

To consider typical switching frequencies in a BLDC motor, the RPM and application must be considered. For a motor at 15kW to 100kW power the expected **maximum RPM can be up to 5000 – 6000** on an eVTOL vehicle[[1]](#footnote-1).

The number of pole pairs determines the relationship between the mechanical revolutions (RPM) and electrical revolutions (frequency). For eVTOL vehicle motors this number tends to be **around 10**. It is worth noting that the greater the number of poles, the greater the operating frequency must be to achieve the same RPM[[2]](#footnote-2).

Using this assumption and that the motor function on **a 6-step commutator**, the sampling frequency needed is approximately 20 multiplied by the RPM[[3]](#footnote-3).

For the maximum RPM this would be a minimum of 120kHz. The next commonly available speed processor is 1MHz – this would also enable higher frequency operation with more poles.

The current and voltage values powering the phases of the motor will be averaging 500V and 500A. For a system with a low power factor[[4]](#footnote-4) of 0.8, with voltage ranging from 200 to 800V line to line, the current ranges from 270 to 1080A. With a higher power factor, the current range will decrease as the maximum current will be lower. The sensor is therefore required to process current as high as 1000A, with headroom for higher values. The frequency requirement of the sensor is the same as the controller.

The Rogowski coil is a common method for sensing AC current in a conductor. It can be applied to a complete system retrospectively. It has a high input current range, meeting the requirements of the motor application. As it is a split core device and non resistance based, it can be applied to a conductor within a circuit without reducing the power in the line. The device outputs a voltage which is directly proportional to the rate of change of current, this signal is then passed through an integrator to determine the current in the conductor. It can sense high rate current up to around 1MHz and very low to under 1Hz. However, for low frequency currents, an amplifier is often required to retrieve a useful signal.[[5]](#footnote-5)

A Hall effect sensor uses a core instead of a coil. The core can be solid or split to determine current in a DC conductor without any power loss. The magnetic flux that is induced in the core causes a signal that can be amplified for a reading. The hall effect sensor can sense high input current however does not have a response frequency as high as the Rogowski coil.

Another current sensing option using the magnetic field of a DC conductor is the Neel effect current sensor. These are less common and measure the current through the Neel effect. However, these types of sensor work best with very low frequency signals. Open loop hall sensors are much more cost effective and simple devices, however, are limited to lower frequencies[[6]](#footnote-6). While close loop hall sensors allow for higher frequency applications, up to 100kHz, but are more costly due to the feedback loop.

Sensorless control of a BLDC motor is achieved by measuring the back-EMF from the motor and detecting the zero-crossing point of the voltage for each phase. This can then be used to commutate the motor. Commutation can also be achieved through field-oriented control. Using the flux vector to determine the change in direction of the interacting magnetic fields between the rotor and the stator. These methods remove the need for external.[[7]](#footnote-7)

In summary, the requirements for this application are common to the majority of microcontrollers. Therefore, it is suitable to select one based on ease of use and language rather than technical requirements. The required sample rate is around 120kHz, while 6 PWM outputs are required to control the motor. The Arduino UNO Rev3 is suitable for this application as it fulfils those requirements and includes ADC inputs – to be used with the sensor. By using an Arduino for this project, the need for a custom board is removed and the simplicity of use is increased.

Requirements:

* Sampling speed over 120kHz
* ADC input on microcontroller
* Current sensing up to 1000A
* 6 PWM outputs for motor

1. https://www.engineeringtoolbox.com/synchronous-motor-frequency-speed-d\_649.html [↑](#footnote-ref-1)
2. https://www.engineeringtoolbox.com/synchronous-motor-frequency-speed-d\_649.html [↑](#footnote-ref-2)
3. Manual for EMRAX motors EMRAX 268, <https://www.bbaa.de/fileadmin/user_upload/02-preis/02-02-preistraeger/newsletter-2019/02-2019-09/02_Siemens_Anton.pdf> [↑](#footnote-ref-3)
4. <https://www.irjet.net/archives/V3/i7/IRJET-V3I7431.pdf> [↑](#footnote-ref-4)
5. http://www.power-mag.com/pdf/feature\_pdf/1222952626\_PEE\_Issue\_8\_2007\_Curent\_Sensing-Selecting\_the\_Most\_Effective\_Current\_Sensing\_Technology.pdf [↑](#footnote-ref-5)
6. http://www.power-mag.com/pdf/feature\_pdf/1222952626\_PEE\_Issue\_8\_2007\_Curent\_Sensing-Selecting\_the\_Most\_Effective\_Current\_Sensing\_Technology.pdf [↑](#footnote-ref-6)
7. Current measurement in power electronic and motor drive applications.pdf Asha Patel [↑](#footnote-ref-7)