DEPARTMENT OF MECHANICAL AND PRODUCTION ENGINEERING
AARHUS UNIVERSITY

DIGITALIZING CLASSIC MACHINERY FOR INDUSTRY 4.0: REFERENCE DOCUMENT FOR SENSOR SELECTION

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INTRODUCTION

This reference document, introduces the selected sensors for each of the three setups constructed by Aarhus University for the Digitalizing Classic Machinery for Industry 4.0 project. A schematic of each setup is depicted. After that, the sensors that are used are listed, along with their relevant information.

In the Digitalizing Classic Machinery for Industry 4.0 project, 3 different setups have been built for the three involved users:

1. Bast&Co;
2. DAMRC;
3. Niebuhr Gears.
4.

Please note that the setup architecture for Bast&Co and DAMRC are similar, except for the number of the sensor that has been used in them. Therefore, the sensor type and characteristics are also similar to each other.

Each setup is depicted in the following sections.

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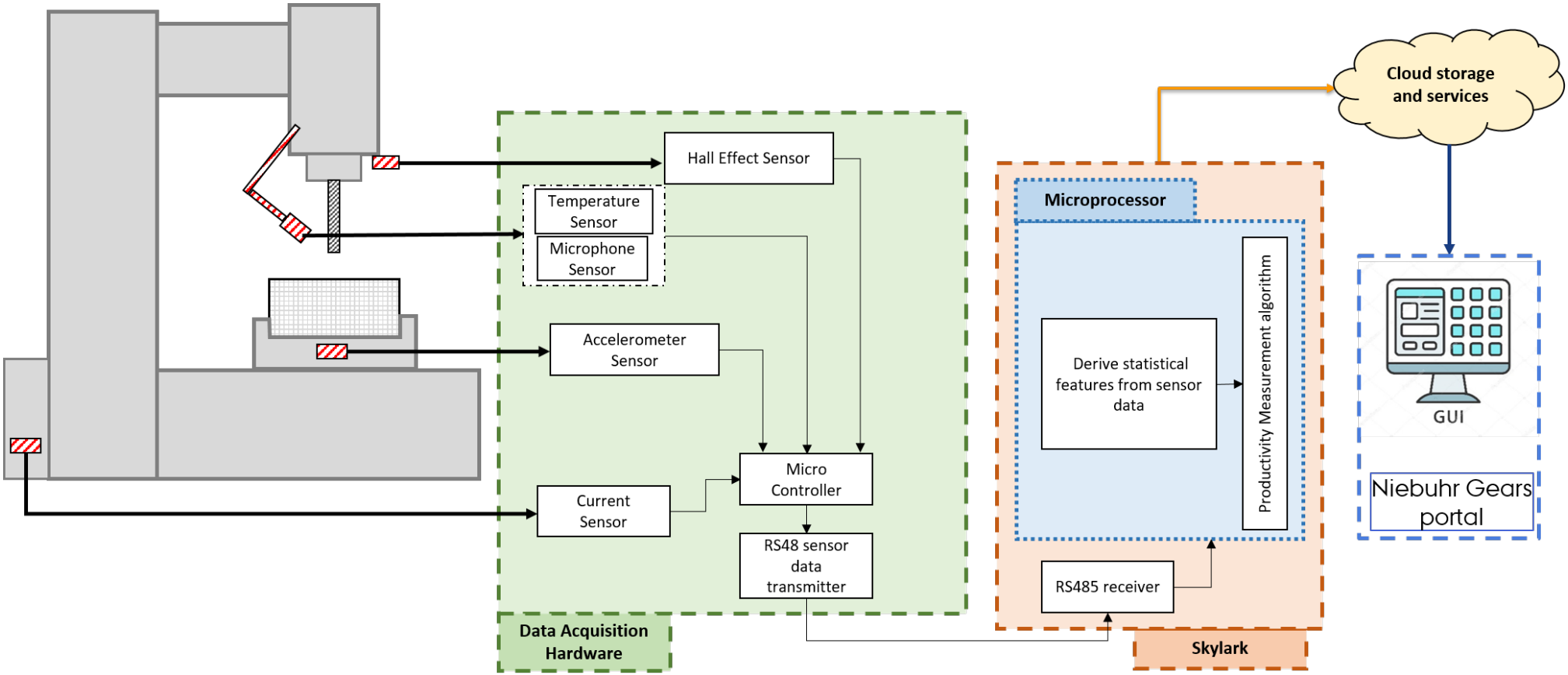
BAST&CO SETUP

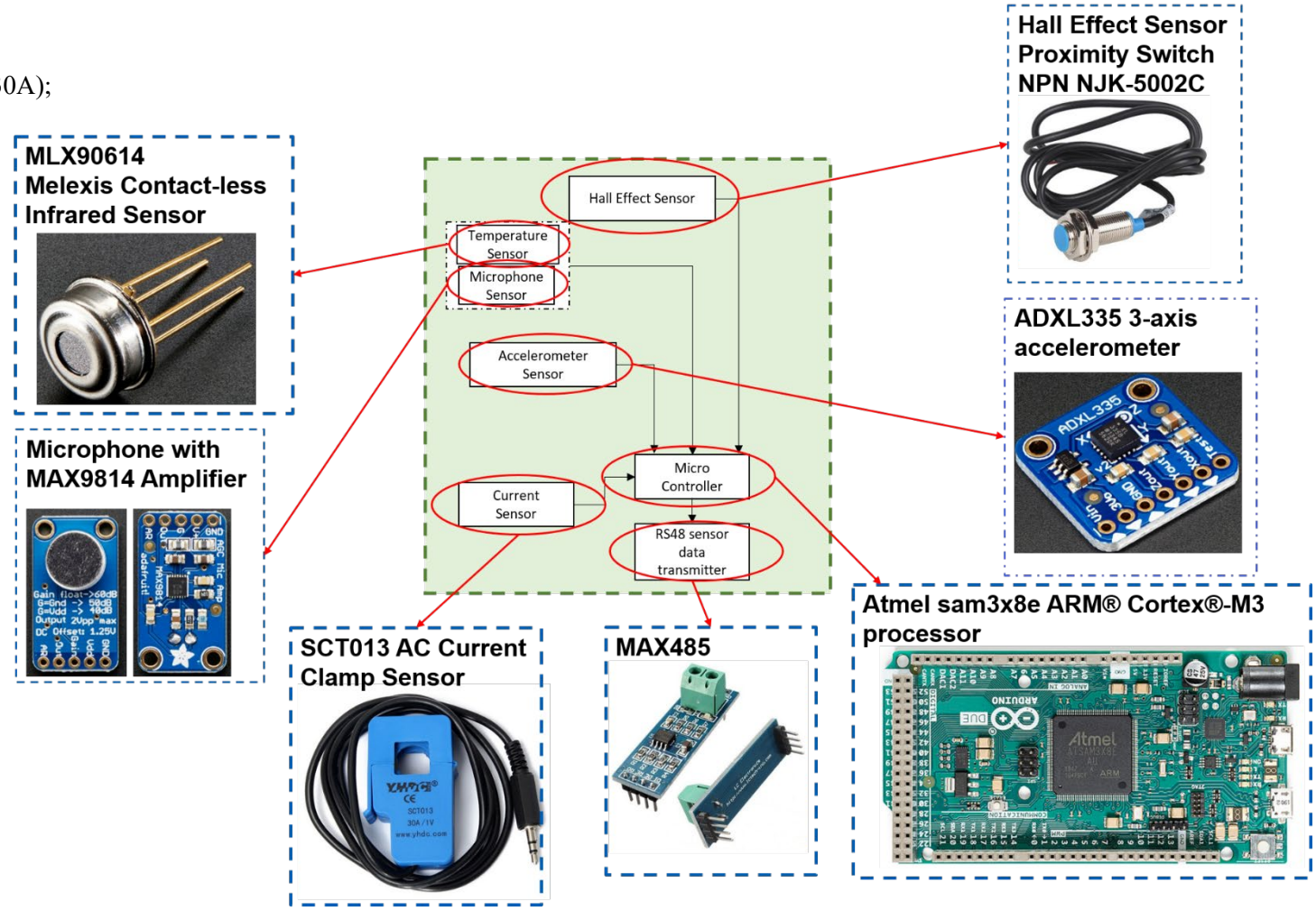
The overall architecture of the designed setup for Bast&Co can be seen in the following picture.



This setup includes the following sensors:

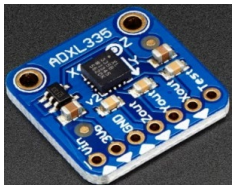
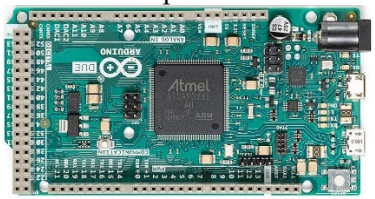
- Temperature sensor,
- Microphone;
- Hall effect proximity sensor;
- Hall effect clamp current sensor (30A);
- 3 axis accelerometer;
- RS485 module;
- ARM® Cortex®-M3 processor.

The individual characteristics of each of these sensors are listed in the following table.



Sensor	Type	Sampling rate*	Output	Comments/Selection criteria	Link
MLX90614 Contactless infrared temperature sensor	Digital I^2C	1000ms	0 and 3.3v	Setup required a noncontact IR temperature sensor capable of measuring +250 degrees	https://www.adafruit.com/product/1747
Microphone with MAX9814 Amplifier	Analog	1MHz	0-3.3v	Microphone should capture up to 20kHz (higher frequencies are not required). Amplifier need to have auto gain to amplify low sounds while not over amplify load sounds.	https://www.adafruit.com/product/1713
NJK-5002C Hall Effect Sensor Proximity	Digital	----	5-24v (depending on the input voltage)	Any proximity sensor is suitable. RPM is calculated by measuring the number of pulses in specific and fixed time interval.	https://arduinotech.dk/shop/njk-5002c-hall-effect-sensor-proximity-switch-npn-3-wires-normally-open/

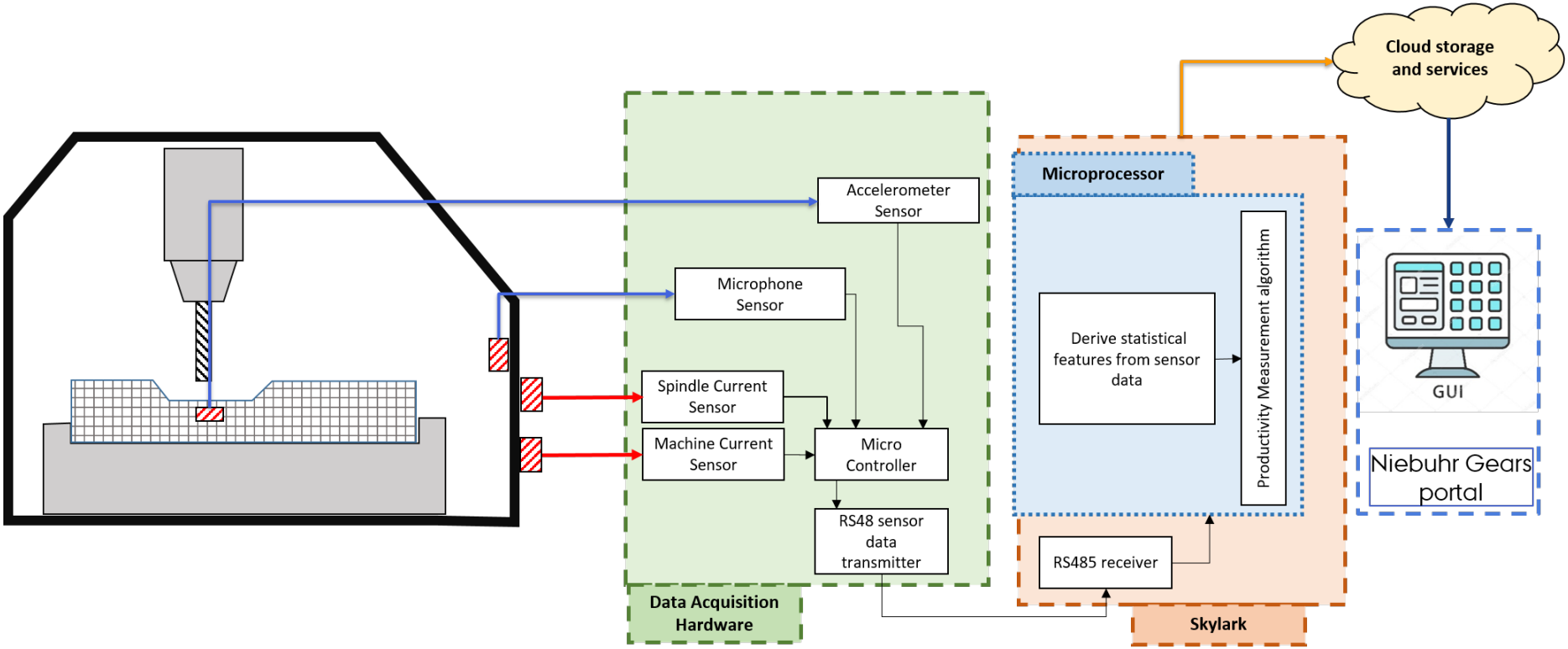
* Sampling rate is only written when applicable.

Sensor	Type	Sampling rate*	Output	Comments/Selection criteria	Link
Hall effect clamp current sensor	Analog (30A)	1MHz	Output is current, proportional to the measured current	Any non-intrusive, clamp current sensor with the specified rating is suitable.	https://arduinotech.dk/shop/sct013-30a-ac-current-clamp-sensor/
ADXL335 3-axis accelerometer 	Analog	1MHz	0-3.3v	Low power consumption; ±3g range (higher range is not required); At least 1500Hz bandwidth in X and Y axis	https://www.adafruit.com/product/163
MAX485 module	Digital	---	0 and 3.3v		https://www.digikey.dk/da/products/detail/analog-devices-inc-maxim-integrated/MAX485CUA-T/1499478
Atmel sam3x8e ARM® Cortex®-M3 processor 	---	----	----		https://store.arduino.cc/products/arduino-due?selectedStore=eu

DAMRC SETUP

The designed setup for DAMRC has in essence, the same structure as Bast&Co setup. Except that instead of proximity and temperature sensor, it has one additional current senor to measure machine current.

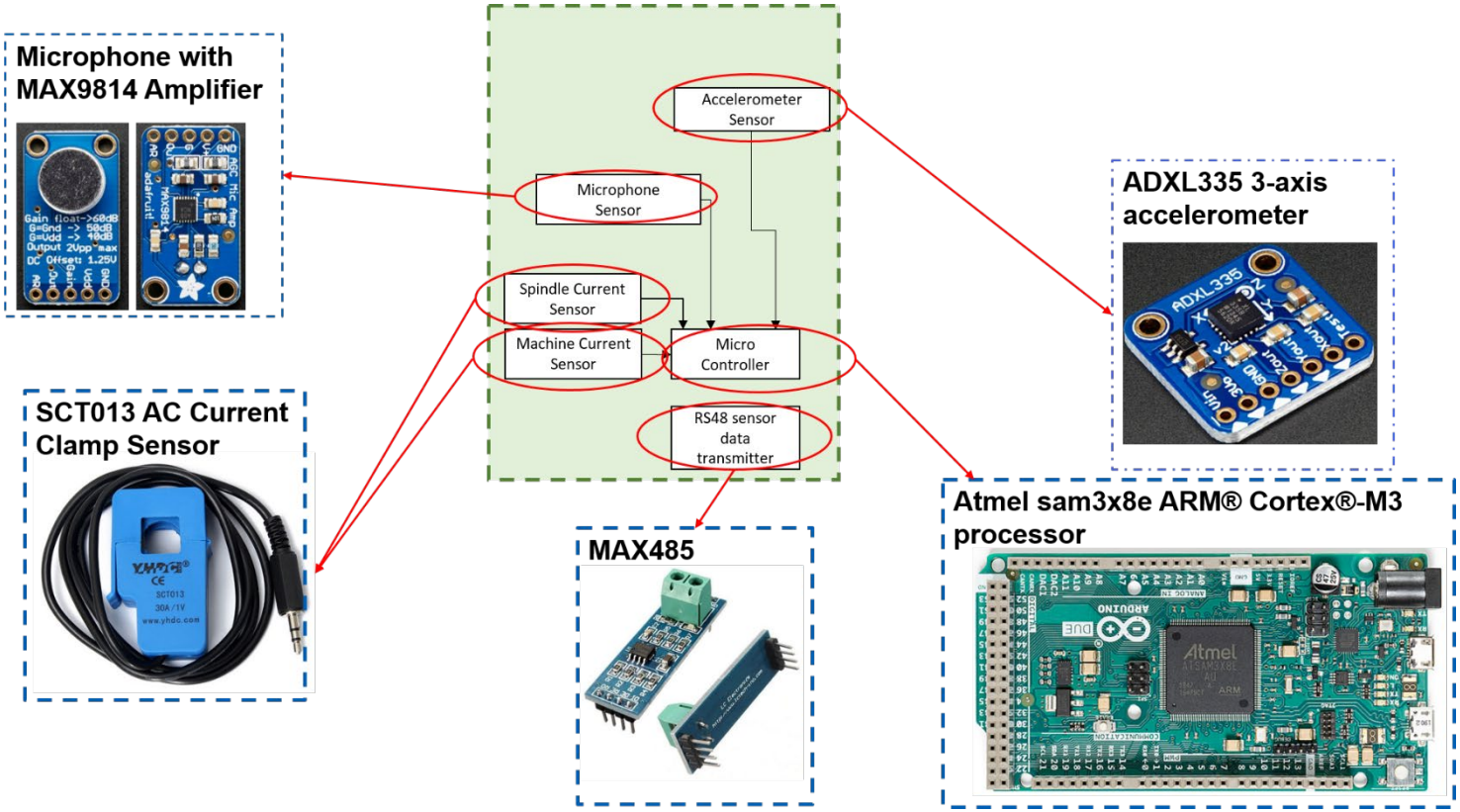
This architecture is shown in the following figure:

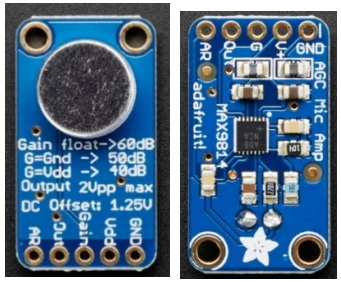


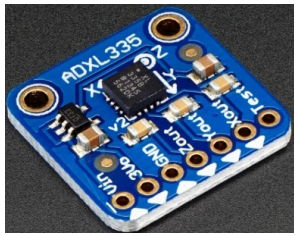
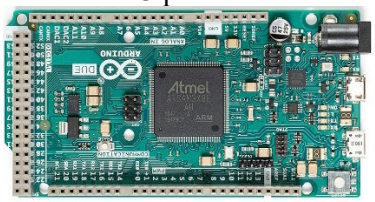
This setup includes the following sensors:

- Microphone;
- Hall effect proximity sensor;
- Hall effect clamp current sensor(30A);
- Hall effect clamp current sensor (100A);
- 3 axis accelerometer;
- RS485 module;
- ARM® Cortex®-M3 processor.

The individual characteristics of each of these sensors is presented in following table:

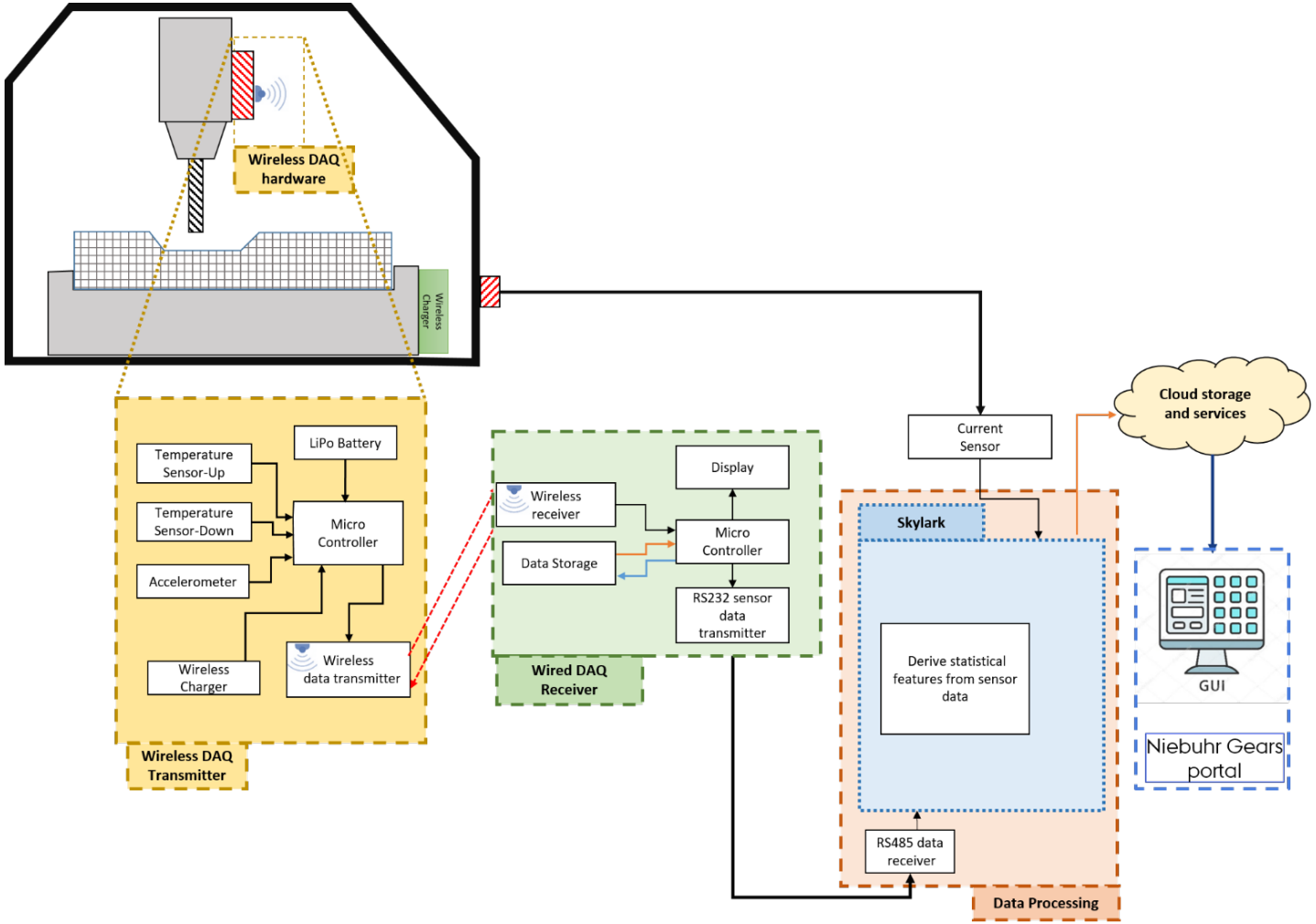


Sensor	Type	Sampling rate*	Output	Comments/Selection criteria	Link
Microphone with MAX98814 Amplifier 	Analog	1MHz	0-3.3v	Microphone should capture up to 20kHz (higher frequencies are not required). Amplifier need to have auto gain to amplify low sounds while not over amplify load sounds.	https://www.adafruit.com/product/1713
Hall effect clamp current sensor	Analog (30A)	1MHz	Output is current, proportional to the measured current	Any non-intrusive, clamp current sensor with the specified rating is suitable.	https://arduinotech.dk/shop/sct013-30a-ac-current-clamp-sensor/
Hall effect clamp current sensor	Analog (100A)	1MHz	Output is current, proportional to the measured current	Any non-intrusive, clamp current sensor with the specified rating is suitable.	https://arduinotech.dk/shop/sct013-30a-ac-current-clamp-sensor/

Sensor	Type	Sampling rate*	Output	Comments/Selection criteria	Link
ADXL335 3-axis accelerometer 	Analog	1MHz	0-3.3v	Low power consumption; ±3g range (higher range is not required); At least 1500Hz bandwidth in X and Y axis	https://www.adafruit.com/product/163
MAX485 module	Digital	---	0 and 3.3v		https://www.digikey.dk/da/products/detail/analog-devices-inc-maxim-integrated/MAX485CUA-T/1499478
Atmel sam3x8e ARM® Cortex®-M3 processor 	---	----	----		https://store.arduino.cc/products/arduino-due?selectedStore=eu

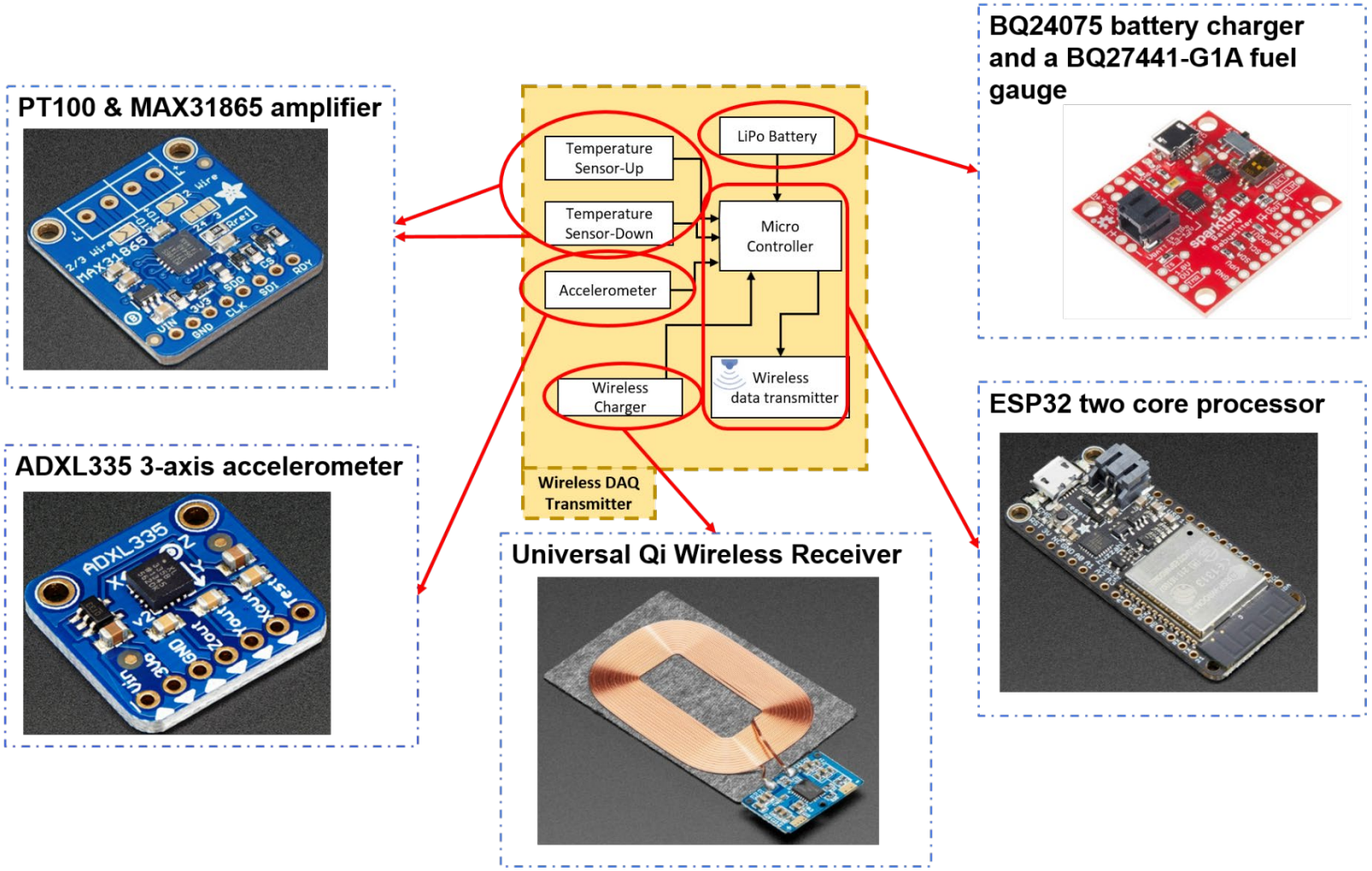
NIEBUHR GEARS SETUP

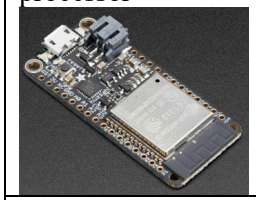
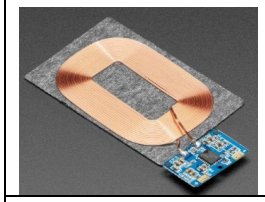
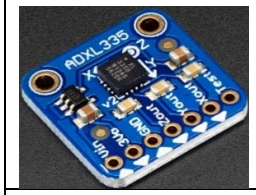
In case for Niebuhr Gears, a wireless data acquisition system (WDAQ) had to be designed. The WDAQ requires a receiver to enable Skylark to receive the recorded data from it. The following picture shows the architecture of the designed system.

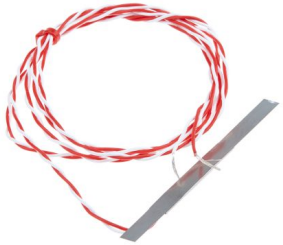
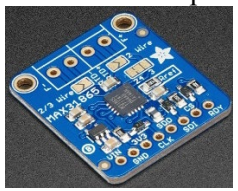
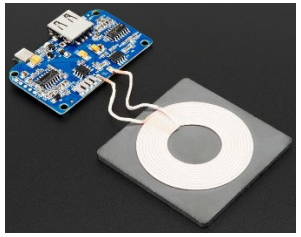


Wireless Data Aquisition system (WDAQ)

The individual components used in the WDAQ is shown in the following picture, while their requirements are listed in the table.

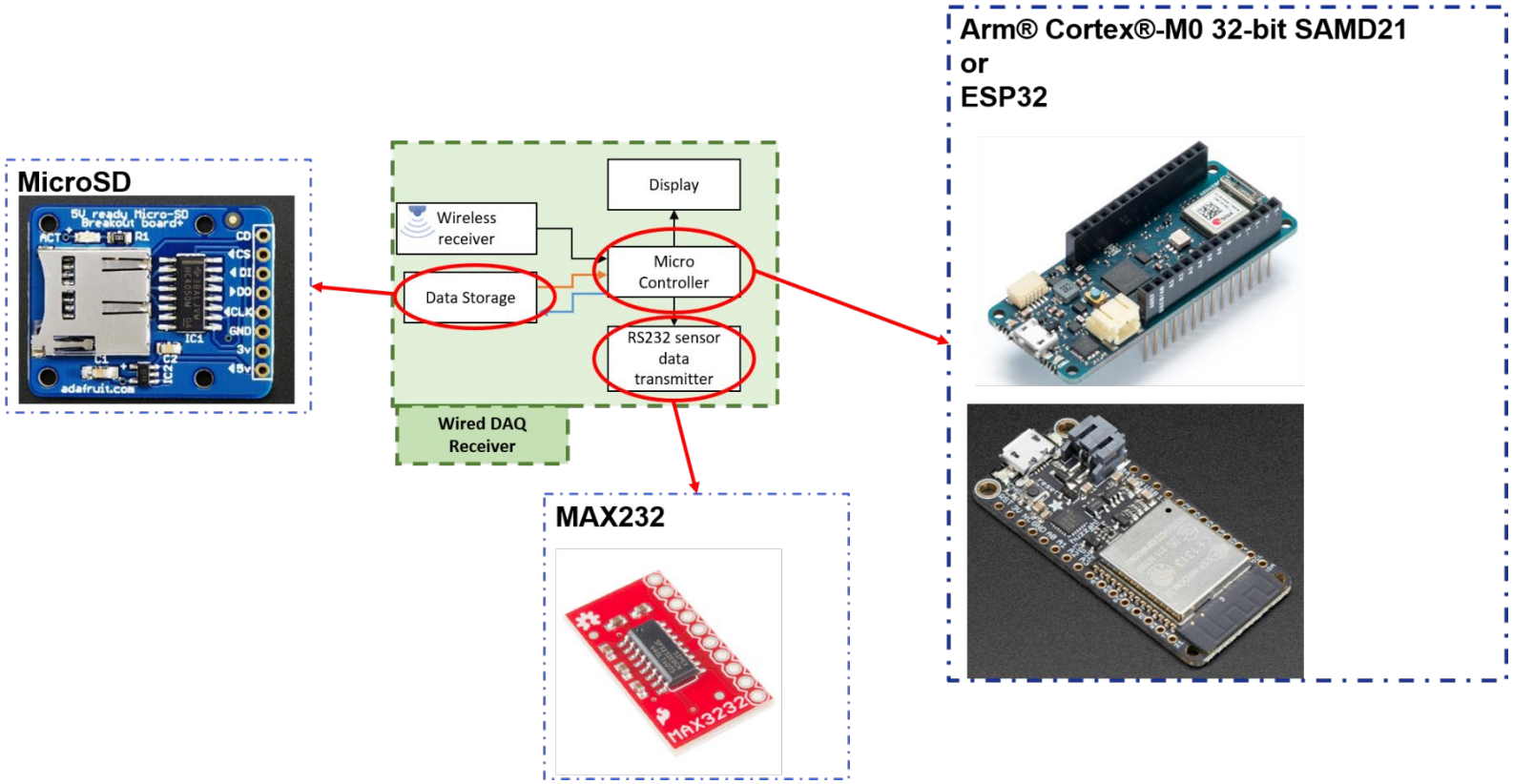


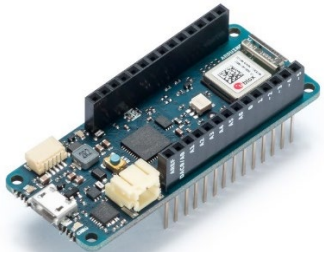
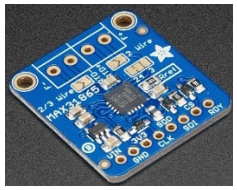
Sensor	Type	Sampling rate*	Output	Comments/Selection criteria	Link
ESP32 two core processor 	----	----	----	Microprocessor with built in WiFi. Otherwise a separate WiFi module is required	https://www.adafruit.com/product/3405
Universal Qi Wireless Receiver 	----	----	----	Any wireless charger receiver compatible with LiPo batteries are acceptable.	https://www.adafruit.com/product/1901
ADXL335 3-axis accelerometer 	Analog	5kHz	0-3.3v	Low power consumption; ±3g range (higher range is not required); At least 1500Hz bandwidth in X and Y axis	https://www.adafruit.com/product/163
BQ24075 battery charger and a BQ27441-G1A fuel gauge	Digital-I^2C	Depends on the software	-----	Any battery compatible **battery monitoring** and **battery charging** chip can be used	Ti.com Digikey.dk

Sensor	Type	Sampling rate*	Output	Comments/Selection criteria	Link
PT100 Temperature sensor 	Analog	Defined in the amplifier	Depends on the amplifier	A contact-temperature sensor accurate in lower range (0-80 °C)	https://dk.rs-online.com/web/p/rtd-sensorer/7621134/
MAX31865 amplifier 	Digital-SPI	1Hz	0 and 3.3v	Compatible amplifier with PT100 temperature sensor	Digikey.dk
Universal Qi Wireless transmitter 	----	----	----	Any wireless charger transmitter compatible with the selected wireless charger receiver can be use.	https://www.adafruit.com/product/2162

DAQ Data receiver

The data recorded by WDAQ can only be passed to Skylark using a wired system. For this purpose, a compatible data receiver is designed to receive the data from WDAQ and sends the data to Skylark using RS232 protocol. This setup comprises of the following components:



Sensor	Type	Sampling rate*	Output	Link
Arm® Cortex®-M0 32-bit SAMD21* 	----	----	----	http://store-usa.arduino.cc/products/arduino-mkr-wifi-1010
MicroSD card 	Digital- SPI	---	----	https://www.adafruit.com/product/254
MAX232 	Digital	----	0 and 3.3	https://www.sparkfun.com/products/11189

* Instead of Arm® Cortex®-M0 32-bit SAMD21, ESP32 can also be used.

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