Project plan documentation

**Products**

Accelerometers

<http://www.pcb.com/products/productfinder.aspx?tx=15>

SlamStick

<http://info.mide.com/hubfs/slam-stick-vibration-data-loggers-datasheet.pdf?hsCtaTracking=c32024f3-178f-4f3b-bbf1-6ec4d131432f%7Cbba56a47-81d6-4103-a678-76dc75b24772>

£20 accelerometer

<https://www.mouser.co.uk/datasheet/2/418/NG_DS_3058A_Accelerometer_A1-1130495.pdf>

Output data rate 2kHz

<https://www.murata.com/~/media/webrenewal/products/sensor/accel/sca800/sca820-d04_accelerometer_datasheet_82%20700%2000%20d.ashx>

Evaluation board ADXL1002 – linear response from DC to 11kHz

<http://www.analog.com/en/products/sensors-mems/accelerometers/ADXL1002.html#product-overview>

Cheaper MEMS to 1.6kHz only

<http://www.analog.com/en/products/sensors-mems/accelerometers/adxl316.html#product-overview>

Max Output Data Rate 800Hz

<https://uk.rs-online.com/web/p/products/8016876/?grossPrice=Y&cm_mmc=UK-PLA-DS3A-_-google-_-PLA_UK_EN_Semiconductors-_-Sensor_Ics%7CAccelerometer_Ics-_-PRODUCT+GROUP&matchtype=&gclid=EAIaIQobChMI44KMqszz2gIVAxbTCh2Ipw7cEAQYAyABEgLjtPD_BwE&gclsrc=aw.ds>

Application Note on DFT and FFT for embedded microcontrollers

<https://www.nxp.com/docs/en/application-note/AN4315.pdf>

Useful NXP Discussion

<https://community.nxp.com/thread/391923>

Flat response to 15 kHz piezoelectric

<https://uk.rs-online.com/web/p/accelerometer-ics/8937266/>

Freescale FFT implementation

<https://www.nxp.com/docs/en/application-note/AN4255.pdf>

Vendors

<http://www.ni.com/white-paper/52461/en/>

MPU6050 could be surprisingly useful

<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8278482>

MSP432 Launchpad (Possible board) – ordered one

<http://uk.farnell.com/texas-instruments/msp-exp432p401r/dev-board-msp432-performance-launchpad/dp/2473128?mckv=73kNSYYh_dc|pcrid|78108290469|&gross_price=true&CATCI=aud-294759717834:pla-77217964501&CAAGID=14983481469&CMP=KNC-GUK-GEN-SHOPPING-TEXAS_INSTRUMENTS&CAGPSPN=pla&gclid=EAIaIQobChMIzYSqwo322gIV7ZXtCh0aqgBSEAQYASABEgJLU_D_BwE&CAWELAID=120173390000555085>

FFT Library

<http://www.kurims.kyoto-u.ac.jp/~ooura/fft.html>

FFT Library 2

<https://sourceforge.net/projects/kissfft/?source=typ_redirect>

Arduino SD Card expander

<https://www.gearbest.com/other-accessories/pp_218078.html?currency=GBP&vip=4444261&gclid=EAIaIQobChMIv4qO2K742gIVh7TtCh0_3AxGEAQYASABEgIvEPD_BwE>

Arduino LCD screen

<https://www.gearbest.com/other-accessories/pp_216639.html?wid=1433363>

LCD code convert from Arduino to MSP432

<https://forum.43oh.com/topic/8859-connecting-msp432-to-1602-lcd-via-i2c/>

SD Card MSP432

<https://e2e.ti.com/support/microcontrollers/msp430/f/166/t/637416?MSP432P401R-Official-Library-support-for-SD-card-with-MSP432-launchpad>

SD Card in Arduino

<https://rydepier.wordpress.com/2015/08/07/using-an-sd-card-reader-to-store-and-retrieve-data-with-arduino/>

Useful references here for investigation:

<https://www.emeraldinsight.com/doi/pdfplus/10.1108/SR-05-2013-675>

Wireless Sensor Node Implementation

[www.mdpi.com/1424-8220/17/3/469/pdf](http://www.mdpi.com/1424-8220/17/3/469/pdf)

**CBM**

Condition Monitoring of Wind Turbines

<https://ac.els-cdn.com/S1364032107001098/1-s2.0-S1364032107001098-main.pdf?_tid=e6971b77-3198-4381-a0dc-8329f65ddcaf&acdnat=1525541054_874a239d8e8e7cd4a30a3c110bfe83bc>

IoT in homes

<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6516934>

Distributed Embedded CBM

<https://ac.els-cdn.com/S0920548912001109/1-s2.0-S0920548912001109-main.pdf?_tid=61e656fe-b28a-4d59-9889-5f41514d5daf&acdnat=1525542909_c17bcd3af7e51f68490d5f7120a66ba2>

Justification for CMS – Has bathtub curve and comparison of scheduled, corrective, cbm

<https://ac.els-cdn.com/S0960148109004704/1-s2.0-S0960148109004704-main.pdf?_tid=8bd46fe9-a69a-4262-b5a2-8f24f81d12fe&acdnat=1525780991_97b55518d6120f005f344fa788bd34af>

Big table of CMSs for Wind Turbines

<http://dro.dur.ac.uk/12497/1/12497.pdf?DDD10+ttsd23+dul4eg>

Embedded CBM for drill, PCB piezoelectric accelerometer 10kHz range, Endevco to 15kHz with NI module (£1700) used for verification, placement of sensors is important

<https://link.springer.com/content/pdf/10.1007%2Fs00170-017-1251-8.pdf>

Standards for condition monitoring

<https://www.iso.org/committee/51538/x/catalogue/>

Wireless sensor networks

<http://www.mdpi.com/1424-8220/17/3/469/htm>

Condition Based Maintenance Overview:

<https://www.sciencedirect.com/science/article/pii/S0888327005001512>

Time Based vs Condition Based Maintenance

<https://www.sciencedirect.com/science/article/pii/S0360835212000484>

Big data and IIOT in Norway’s Maritime Industry

<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7372918>

CBM in maritime

<http://www.plant-maintenance.com/articles/SPM_ICMES_2003.pdf>

Commercial argument for lifetime service using CBM

<https://www.sciencedirect.com/science/article/pii/S2212827113005179>

Normalization for operational and environmental variability on bridge cbm

<http://rsta.royalsocietypublishing.org/content/roypta/365/1851/539.full.pdf>

Lloyd’s Register Guide to Condition Based Maintenance

<https://www.cdlive.lr.org/information/documents/ShipRight/Linked%20Supporting%20Services/Machinery%20Planned%20Maintenance%20and%20CM/Machinery%20Planned%20Maintenance%20and%20Condition%20Monitoring,%20Annexes%20May%202017.pdf>

Using predictive maintenance and anns on board ships

<https://www.sciencedirect.com/science/article/pii/S0029801817306844>

Wavelet Tutorial

<http://web.iitd.ac.in/~sumeet/WaveletTutorial.pdf>

Cost of Poor Maintenance

<https://www.emeraldinsight.com/doi/pdfplus/10.1108/13552511111116259>

Beyond CBM in shipping

<https://www.dnvgl.com/news/dnv-gl-beyond-condition-monitoring-in-the-maritime-industry-7685>

Lloyd’s Register Paper

<https://dannyshorten.files.wordpress.com/2012/09/marine-machinery-condition-monitoring-sunderland-2012-final.pdf>

Reliability Centred Maintenance book from 1978

<http://www.dtic.mil/dtic/tr/fulltext/u2/a066579.pdf>

**Embedded Systems**

Edge computing

<https://ieeexplore.ieee.org/abstract/document/7488250/>

Embedded System for wireless sensor networks

<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6177670>

Comparison of communication protocols

<http://www.diagnostyka.net.pl/,86409,0,2.html>

Fixed point FFT analysis

<https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4626107&tag=1>

Fixed point FFT analysis 2

<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1162875&tag=1>

IQMath documentation

<http://dev.ti.com/tirex/content/simplelink_msp432p4_sdk_1_60_00_12/docs/iqmathlib/MSP432_IQmathLib-UsersGuide.pdf>

Simple current transducer

<http://files.panucatt.com/datasheets/cs45al_datasheet.pdf>

Energy harvesting for condition monitoring

<https://www.spiedigitallibrary.org/conference-proceedings-of-spie/9433/1/Energy-harvesting-to-power-embedded-condition-monitoring-hardware/10.1117/12.2083852.full>

Tutorial for SD cards (on MSP430 in energia)

<https://43oh.com/2013/12/interfacing-the-launchpad-to-an-sd-card-a-walkthrough/>

PetiteFS (library for FAT file system on MSP)

<http://elm-chan.org/fsw/ff/00index_p.html>

Exiting low power mode

<https://e2e.ti.com/support/microcontrollers/msp430/f/166/t/460736?MSP432-Exiting-Low-Power-mode>

Using low power mode in a safe way

<http://www.ti.com/lit/an/slaa739/slaa739.pdf>

**MCSA**

Wavelet Analysis for gear vibration monitoring (MCSA)

<https://ac.els-cdn.com/S0888327004001128/1-s2.0-S0888327004001128-main.pdf?_tid=af182561-e4a9-4ffd-aabc-a8a232414a28&acdnat=1525542994_5643af3163f3c855a07ce2aa36ec242e>

Similar work performed for wirelessly detecting chatter on machine tools

<https://opensourceoceanweatherbuoy.files.wordpress.com/2016/02/mae-298_final-project-report1.pdf>

Complicated MCSA

<https://ftp.phmsociety.org/sites/phmsocietdefaulty.org/files/phm_submission/2013/ijphm_13_030.pdf>

IoT MCSA/CBM

<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8124386>

MCSA CBM (PhD)

<https://pdfs.semanticscholar.org/b58c/b39c623f060e3eb86d06854acaa02db6edb0.pdf>

Bearing faults – Vibration vs MCSA

<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7409240>

MCSA Case Studies

<https://pdfs.semanticscholar.org/7af1/964ffb69b942ed4efdd2674f2e332d79a77d.pdf>

MCSA Tutorial

<https://resenv.media.mit.edu/classarchive/MAS961/readings/InductionMotorsSignature.pdf>

ISO 20958 – Current Sensing Analysis

<https://bsol.bsigroup.com/Bibliographic/BibliographicInfoData/000000000030243451>

Using CSA to reliably detect winding faults

<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1524544>

Review of MCSA

<https://ieeexplore.ieee.org/document/873206/>

MCSA spectrum for healthy cage rotor induction machines

<https://ieeexplore.ieee.org/document/6063610/>

Lists electrical motor faults and online diagnosis

<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4016382>

MCSA Review (lots of citations)

<https://ieeexplore.ieee.org/abstract/document/930988/>

State of the art condition monitoring for electrical machines

<https://ieeexplore.ieee.org/document/6975204/>

State of the art stator current measurements

<https://ieeexplore.ieee.org/document/6960405/>

MCSA vs vibration for bearing faults

<https://ieeexplore.ieee.org/document/7409240/>

**Vibration Analysis**

ISO 10816-7 – Mechanical Vibration levels for small rotating machines

<https://bsol.bsigroup.com/Bibliographic/BibliographicInfoData/000000000030153986>

ISO 13373 – 1, 2, 3, 9 – Vibration Condition Monitoring

ISO 201826 – Measurement and evaluation of mechanical vibration

ISO 17359 – CM and diagnostics of machines, general guidelines

Moosavian et al

* Maximum of FFT magnitude, standard deviation of FFT magnitude and Root mean square of FFT magnitude identified as useful features
* Selected training data to train a class (machine learning)
* Found no overlapping for these features for a healthy, misaligned pump and loose operating conditions
* Used ANFIS fuzzy logic system

<http://journals.sagepub.com/doi/pdf/10.1177/1475921715591873>

Yiannis Raptodimos, Iraklis Lazakis, Gerasimos Theotokatos, Raul Salinas, Alfonso Moreno

* Bearings provide a good place to measure machine vibration as dynamic loads and forces are applied there
* “Tri-axial measurements should be made at each location with rotating components”
* Faults can be identified from their signatures and used to schedule maintenance
* Vibration used for air compressors, sea water pumps, fresh water pumps, fresh water ejector pumps, oil-water separator, stern-tube lube oil pump, bilge pump, feed water oil purifier pump, 2 blowers and diesel engine generator and main engine
* Ultrasound and thermography technologies also used on most of these components

<https://strathprints.strath.ac.uk/58640/1/Raptodimos_etal_ISOPE_2017_Collection_and_analysis_of_data_for_ship_condition_monitoring.pdf>

**Tutorials**

Texas Instrument ADC Implementation

<http://www.ti.com/lit/an/slaa735a/slaa735a.pdf>

Texas Instrument High Precision ADC

<http://www.ti.com/microcontrollers/simplelink-mcus/wired-mcus/overview/msp432p4.html#highprecision>

Precision ADC Application Note (Up to 1 MSPS)

<http://www.ti.com/lit/an/slaa821/slaa821.pdf>

Converting float to 4 bytes

<https://os.mbed.com/forum/helloworld/topic/2053/>

Fixed point FFT errors

<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1162875>

Ti Interrupt Tutorial

<https://training.ti.com/msp430-workshop-series-5-12-interrupts?cu=1135311>

Ti Timer Tutorial

<https://training.ti.com/msp430-workshop-series-6-12-timers>