



CORROSION

ENABLING WIDESPREAD ELECTRONIC CORROSION
MONITORING IN MARINE OFF-SHORE INSTALLATIONS

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WHAT IS CORROSION?



Surface corrosion – ugly but not yet structurally dangerous

http://www.european-coatings.com/var/ezflow_site/storage/images/european-coatings/home/raw-materials-technologies/applications/protective-marine/corrosion-behaviour-analysed/504626-1-eng-GB/Corrosion-behaviour-analysed.jpg

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WHAT IS CORROSION?



http://www.daviddarling.info/images/pipeline_corrosion.jpg

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Surface corrosion – ugly but not yet structurally dangerous

More serious corrosion – function is impaired

WHAT IS CORROSION?



More serious corrosion – function is impaired

Corrosion can occur in one place

http://www.monkeywrenchps.co.uk/wp-content/uploads/2012/08/Corrosion_Steel1.jpeg

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WHAT IS CORROSION?



www.shutterstock.com · 282324041

Corrosion can occur in one place

Corrosion can occur catastrophically

MARINE ENVIRONMENTS



<http://www.rfsales.com.au/ndt-solutions/underwater/>

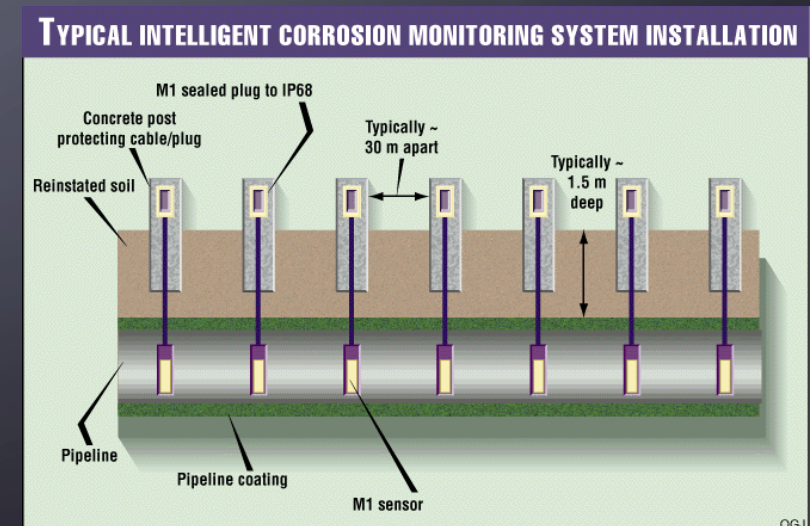
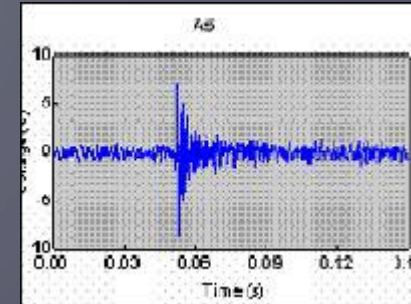
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CORROSION IN MARINE ENVIRONMENTS

- Huge problem
- Aimed to find a corrosion detection method that could be hooked up to our wireless sensor network developed in WIDESENSE project last year
- Had to be small, low cost, scalable and surface-based
- Looked at corrosion detection products that were already available

EXISTING CORROSION DETECTION METHODS

- Forth Road Bridge used microphones to sense when corroded steel cables snapped – this led to the decision to create the Queensferry crossing
- Florida authorities are using SAW technology to monitor corrosion in steel reinforced concrete bridges
- Ultrasonics and acoustics are used extensively but require embedding or acoustic impedance matching



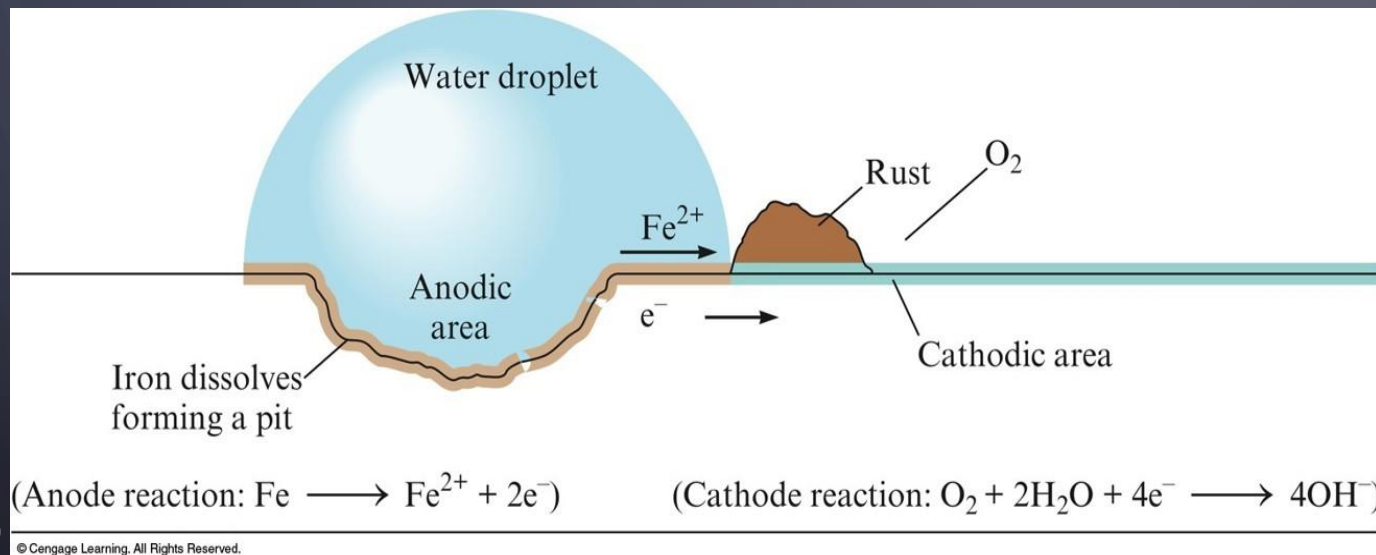
PROJECT SCOPE

- Decided to limit to steel corrosion (rust)
- Decided to investigate corrosion sensing electronically
- What happens when steel rusts?

WHAT HAPPENS WHEN STEEL RUSTS?

- Physics

- Chemistry



Eliminating the electrons,
 $2\text{Fe} + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{Fe}^{2+} + 4\text{OH}^-$

Above a low concentration, Fe^{2+} and OH^- combine to make ferrous hydroxide:
 $2\text{Fe} + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{Fe}(\text{OH})_2$

Ferrous hydroxide reacts with dissolved oxygen in water to form hydrated ferric oxide (rust):
 $4\text{Fe}(\text{OH})_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} + 2\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$

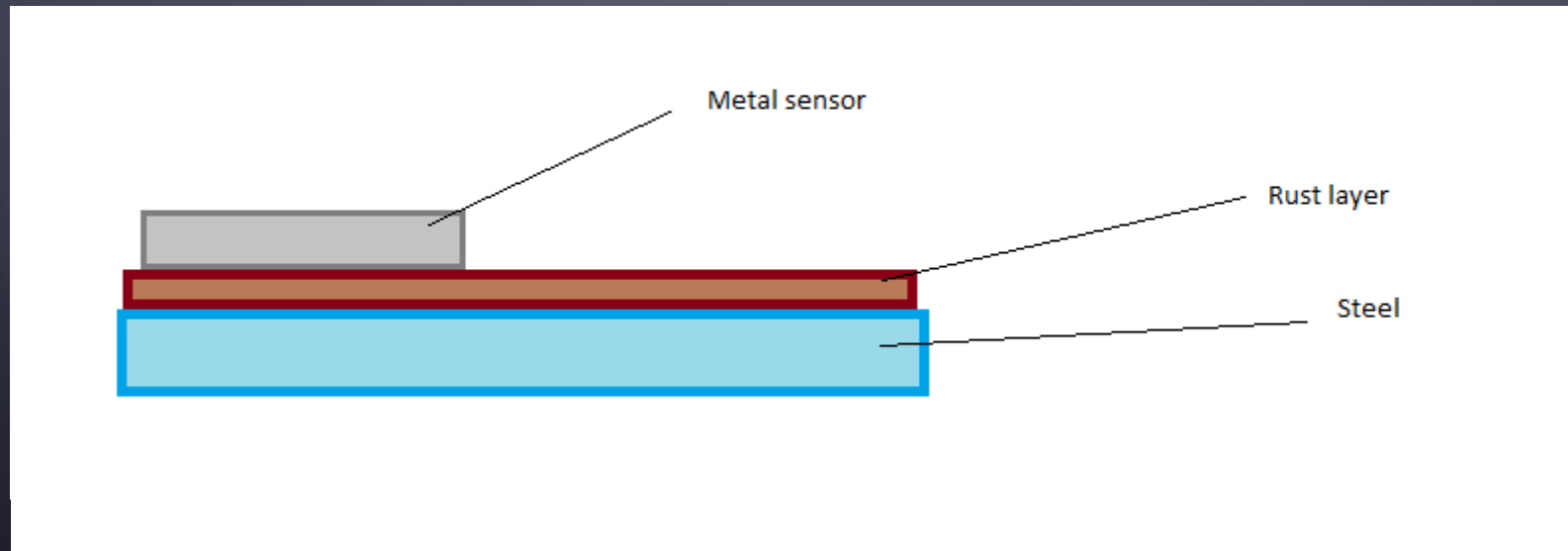
So leaving out intermediate steps, the whole equation for rust is:
 $4\text{Fe} + 3\text{O}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$

HOW IS RUST DIFFERENT TO METAL?

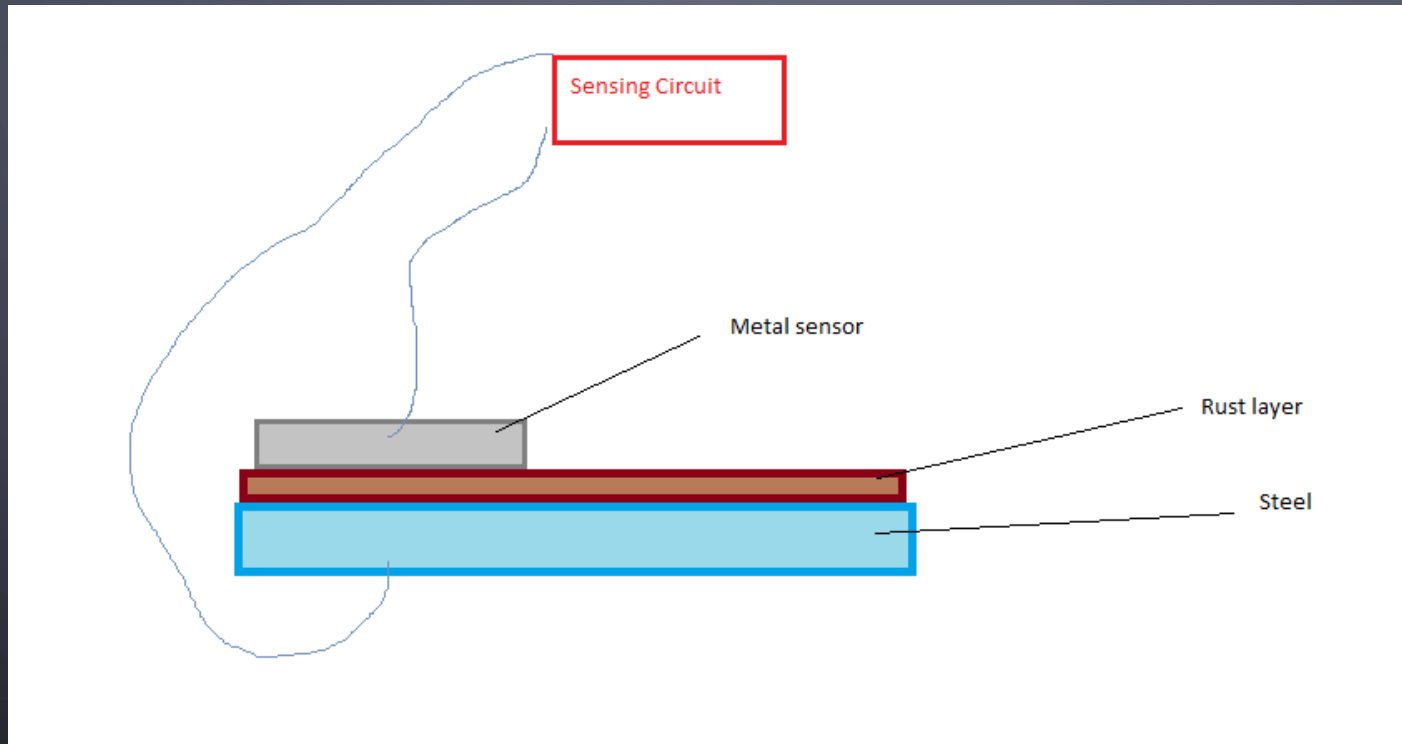
- No longer rigid
- No longer crystalline
- Visually different
- Rough
- Flaky
- Non-conductive

NON-CONDUCTIVE

- When a layer of rust is present, with steel underneath, a metallic sensor in contact with the rust would make an electric capacitor

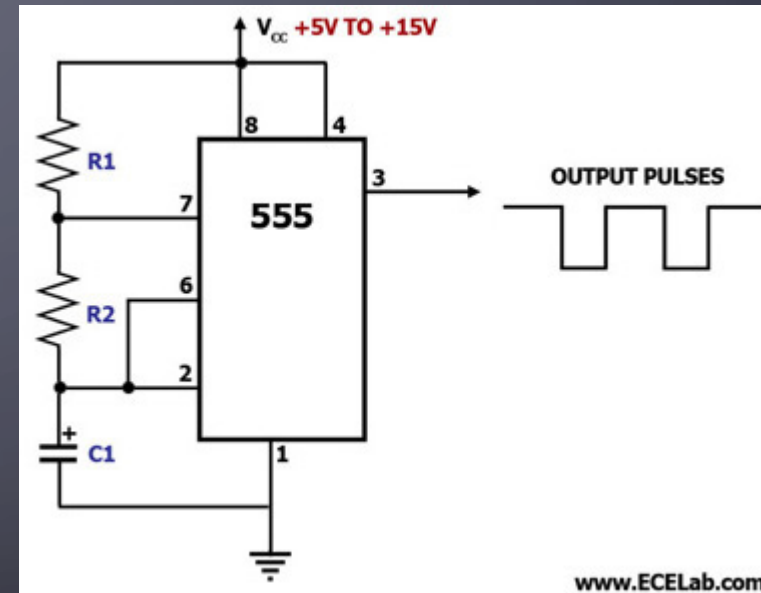


SENSING RUST

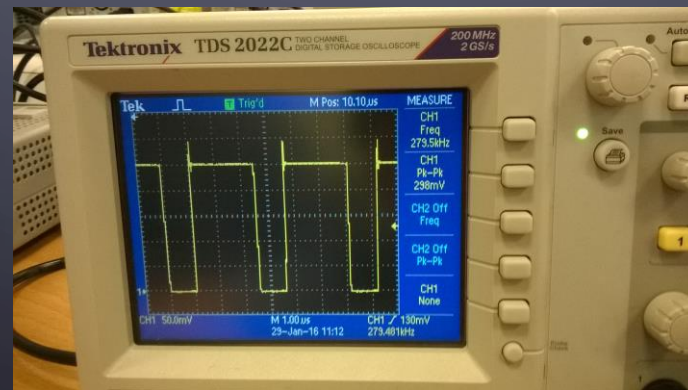
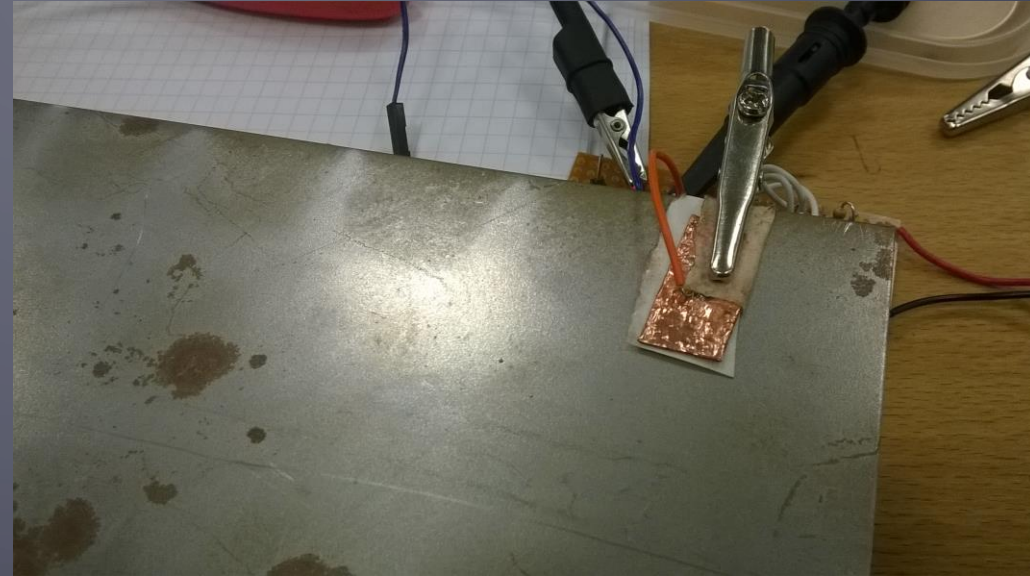
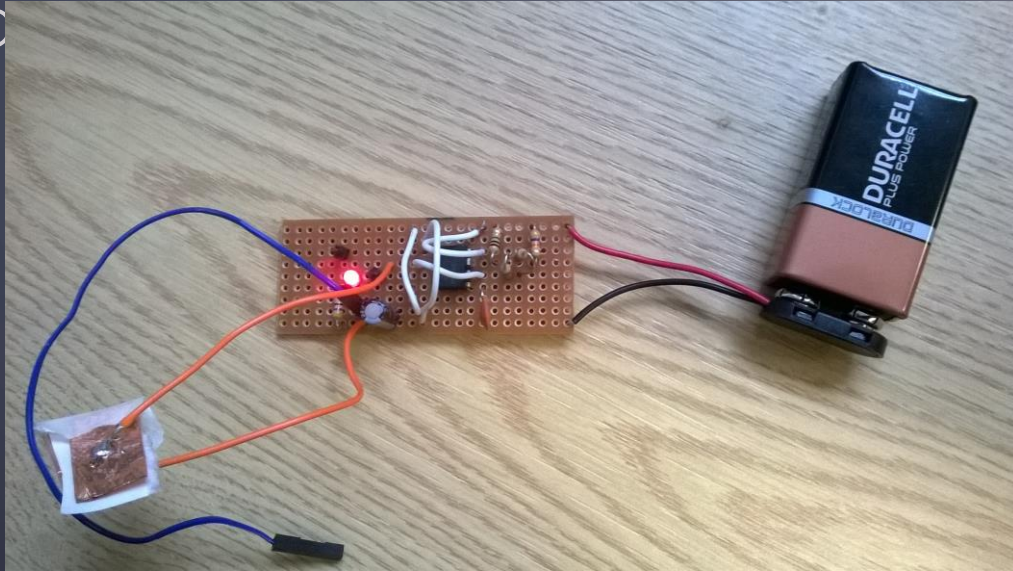


CIRCUIT TO DETECT CHANGE IN CAPACITANCE

- 555 timer circuit
- Gives a signal out that changes frequency based on chosen capacitor value
- Would give different signal if rust were present or absent
- Initial results look promising

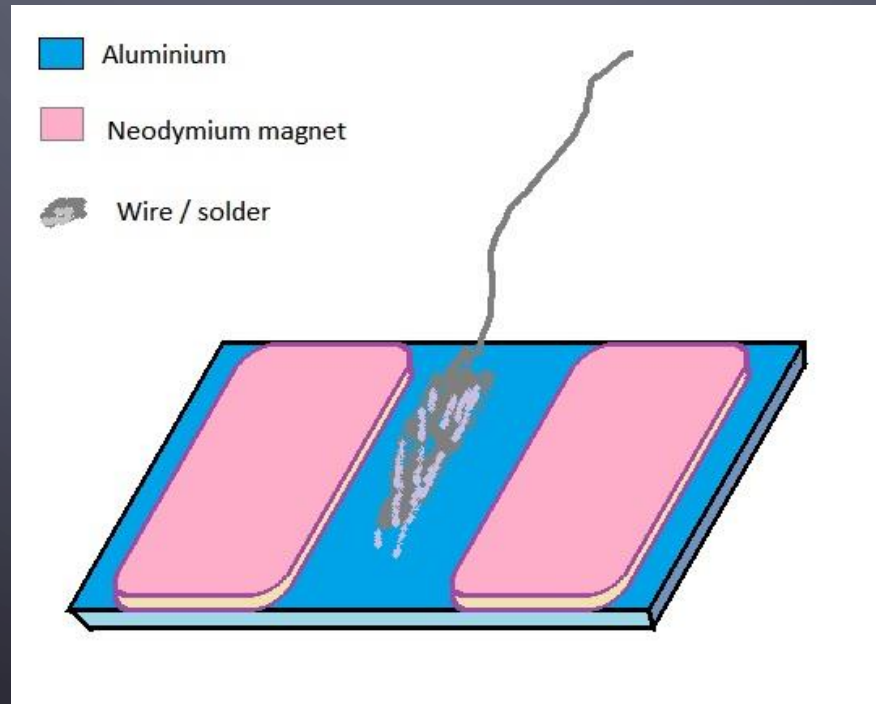


555 TIMER CIRCUIT OUTPUT



DIFFERENT SENSORS

- Steel / Aluminium



DIFFERENT RUST THICKNESSES



OUTCOMES OF THIS PROJECT

- Produced several sensors to detect rust
- Attendance at Oilfield Corrosion conference in Aberdeen, 9th and 10th May
- Potential consultancy work looking at HMS Warrior's moorings that are suffering from Accelerated Low Water Corrosion and its effects



NEXT STEPS

- Experiments to find optimal sensor
- Write up → publication
- Exploring potential for further research grants & consultancy
- **Contact: helena.twigg@solent.ac.uk**