Title

Building and testing an amplification circuit to test strain gauges.

Summary

The four week sessions cover theoretical concepts, practical circuit design, construction, and testing of an instrument amplifier connected to strain gauges to measure mechanical vibrations of a cantilever. The amplified vibrations are then recorded by a digital oscilloscope for later analysis so theoretical and experimental frequencies can be compared.

Aim

The aim of this four-part teaching series is to provide participants with knowledge and hands-on experience in building and testing an amplification circuit for strain gauges and to analyse the vibrations of a cantilever.

What was the context / background?

It has been stated that a lack of “Practical, hands-on electronics” training amongst job candidates is a key area of concern for young workers and employers the UK Space Sector. To address this need Foundation Engineering and Physical Sciences students, many with enthusiasm but no higher level scientific competencies are ‘skilled up’ in practical and scientific analysis competencies in a space-based context. able to solder multiple components onto a printed circuit board. This work has been done in collaboration with other engineering departments so enhances the students ability to make a smoother transition to year 1.

How was it organised and who was involved?

This was a collaboration between Foundation staff, the mechanical and electrical engineering departments to help address skills shortages of future departments and the space industry.

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What resources did you need?

Financial and human

- A printed circuit board for an amplification and bridge circuit (Gerber file available)
- Light dependent resistors, variable resistors, Operational Amplifiers (741), various fixed resistors, light sources, bread boards, Veroboard, (all components shown on the four laboratory sheets)
- A dual DC power supply
- Soldering iron and associated equipment
- ~40 cm steel beam with strain gauges attached to the top and bottom and a G-clamp
- Micrometer, vernier callipers and metre rule
- An oscilloscope (e.g. a PicoScope 2000 and USB connection to a computer).

Describe the activity (Max 1000 words)

Please include times taken for the activity and any advice.

General advice:

Pre-watch videos are available for every laboratory activity and highlight any issues that students may face before the hands-on sessions (like knowing how a breadboards work). As the Foundation students go on to Maths, Computer Science, Physics and all engineering courses many different applications from a range of sectors are highlighted in the documents.

Many of the learning points here in a university context may be oversimplified but hopefully they should be able to be upgraded and expanded.

Session 1: Introduction to Wheatstone Bridges

Objectives:

1. State the definition of a Wheatstone Bridge.
2. Describe the method of building and soldering a Wheatstone Bridge circuit.
3. Interpret Wheatstone Bridge outputs
4. Calculate outputs from Wheatstone Bridge circuits

Laboratory aim:

The aim of this experiment is to determine what the output of a Wheatstone Bridge circuit means and learn how to solder.

Activities:

Lecture on strain gauges and applications. (1 hour)

Hands-on activities: Building and testing a Wheatstone Bridge circuit and learning to solder. (1.5 hours)

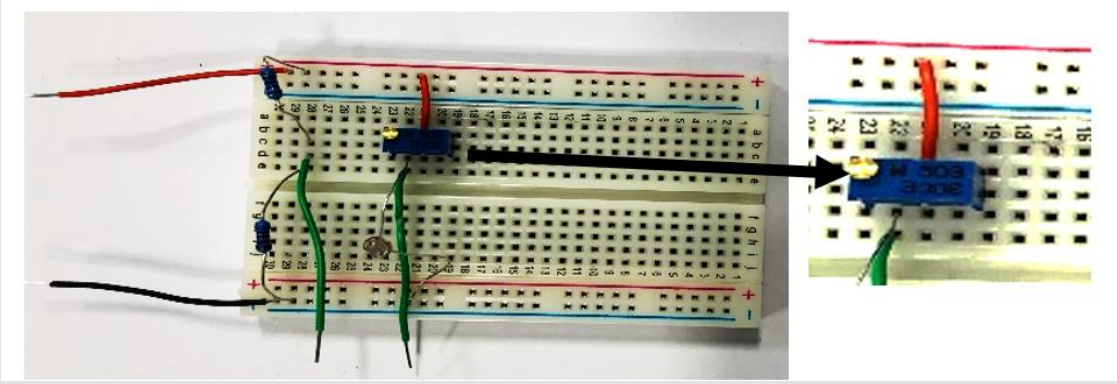


Figure 1: Typical image of the built Wheatstone Bridge circuit

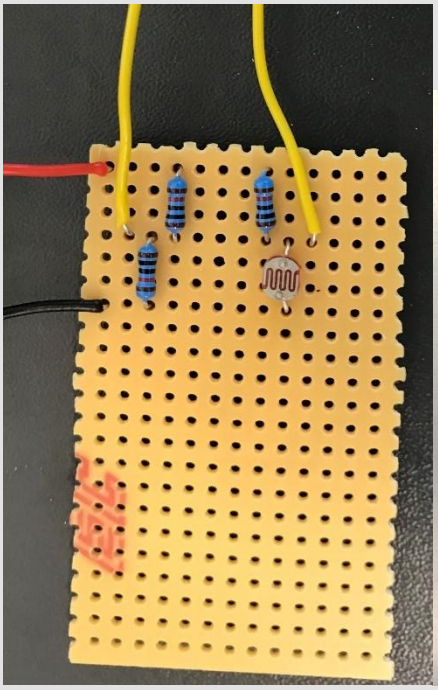
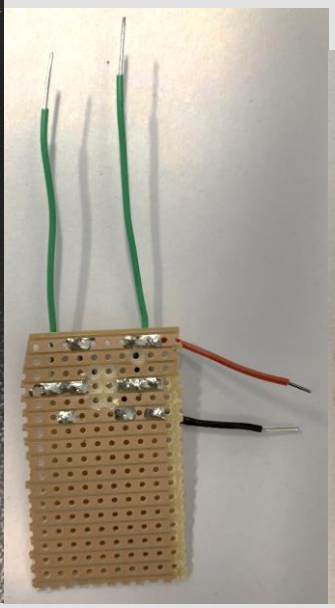
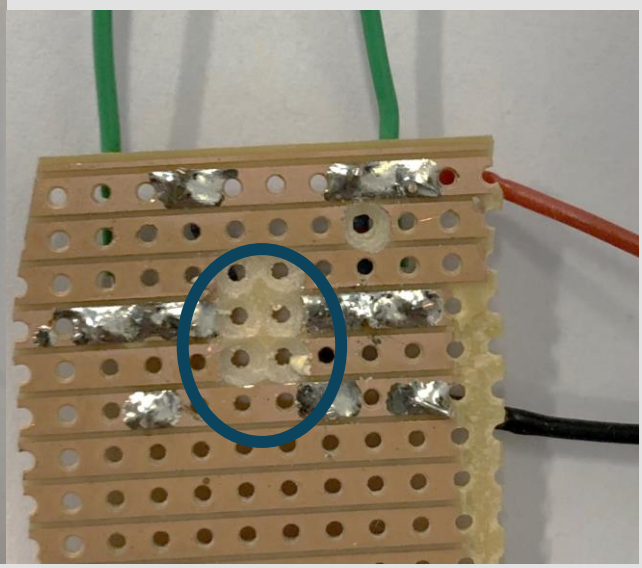


Figure 2 – a soldered Wheatstone Bridge circuit with three fixed resistors and an LDR.





Figures 3 and 4 – the reverse side of the (not perfectly soldered) Veroboard with drilled out sections in the middle.

Session 2: Amplification and Operational Amplifiers

Objectives:

1. State key features of amplification
2. Calculate Op-Amp amplification in dB
3. Evaluate the 'trade-off' between bandwidth and gain
4. Describe how to build an Op-Amp circuit.

Laboratory aim:

The aims of this experiment are to build a working inverting Op-Amp circuit, determine what the output of an Op Amp means and relate this to real world applications (including monitoring spacecraft).

Activities:

Lecture on amplification and applications. (1 hour)

Hands-on activities: Building and testing an inverting OpAmp circuit. (1.5 hours)

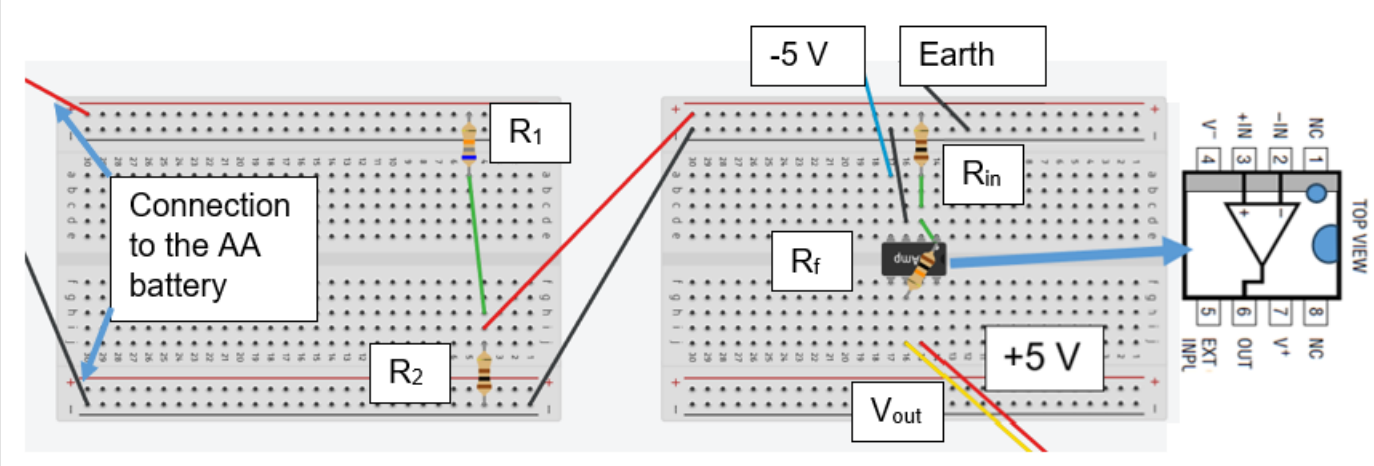


Figure 5 – Example potential divider and OpAmp circuits

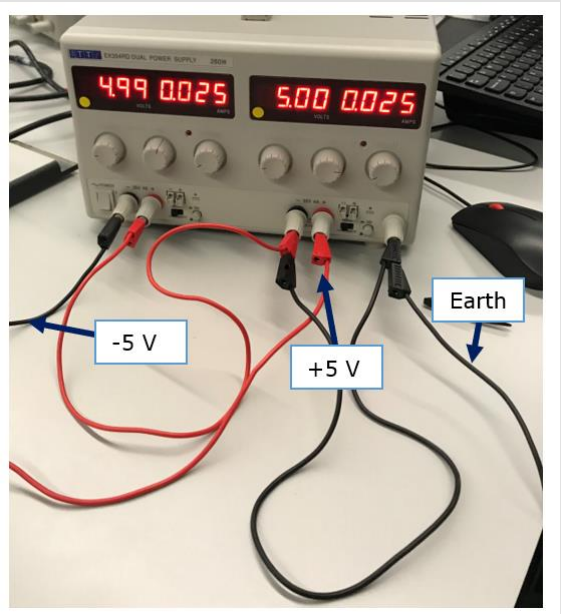


Figure 6 - showing the variable power supply current and voltage settings with connecting wires (note the wires leading off the image all have crocodile clips on the ends).

Session 3: Differential Amplifiers & Strain Gauges

Objectives:

1. Describe how strain gauges work and where they are used (including Max-Q)
2. Explain uses of a differential amplification circuit (limited to **when $R_1 = R_2$ and $R_3 = R_4$**)
3. Calculate outputs of strain gauges and differential amplifiers
4. Build and test a differential amplifier on a printed circuit board (PCB)

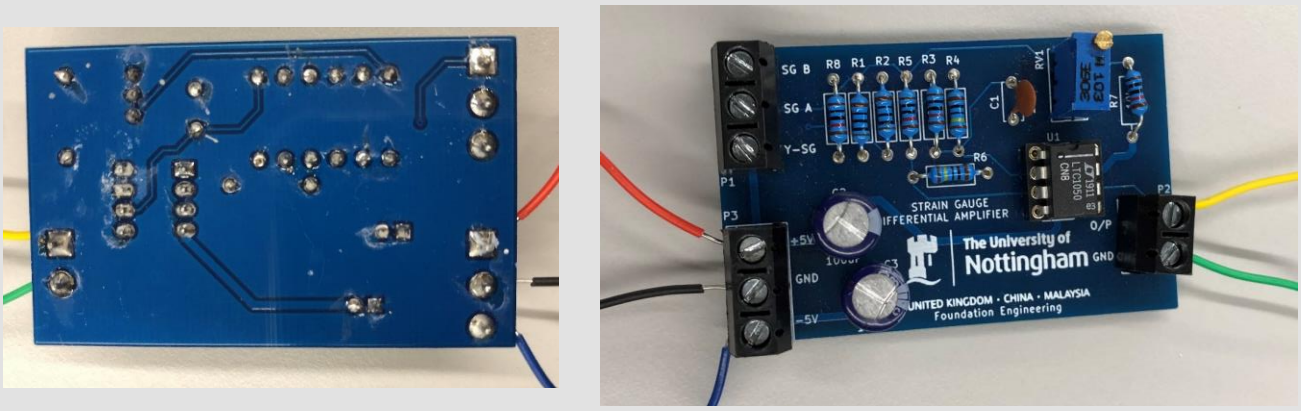
Laboratory aim:

The aims of this experiment are to build and test a differential amplifier circuit on a printed circuit board (PCB). Then determine what the output from a differential amplifier circuit means and relate this to real world applications (including monitoring spacecraft).

Activities:

Lecture on strain gauges and differential amplification with applications. (1 hour)

Hands-on activities: Building and testing a differential amplification circuit on a printed circuit board. (1.5 hours)



Figures 7&8 – a student soldered PCB who had little experience of soldering at the start of semester 2

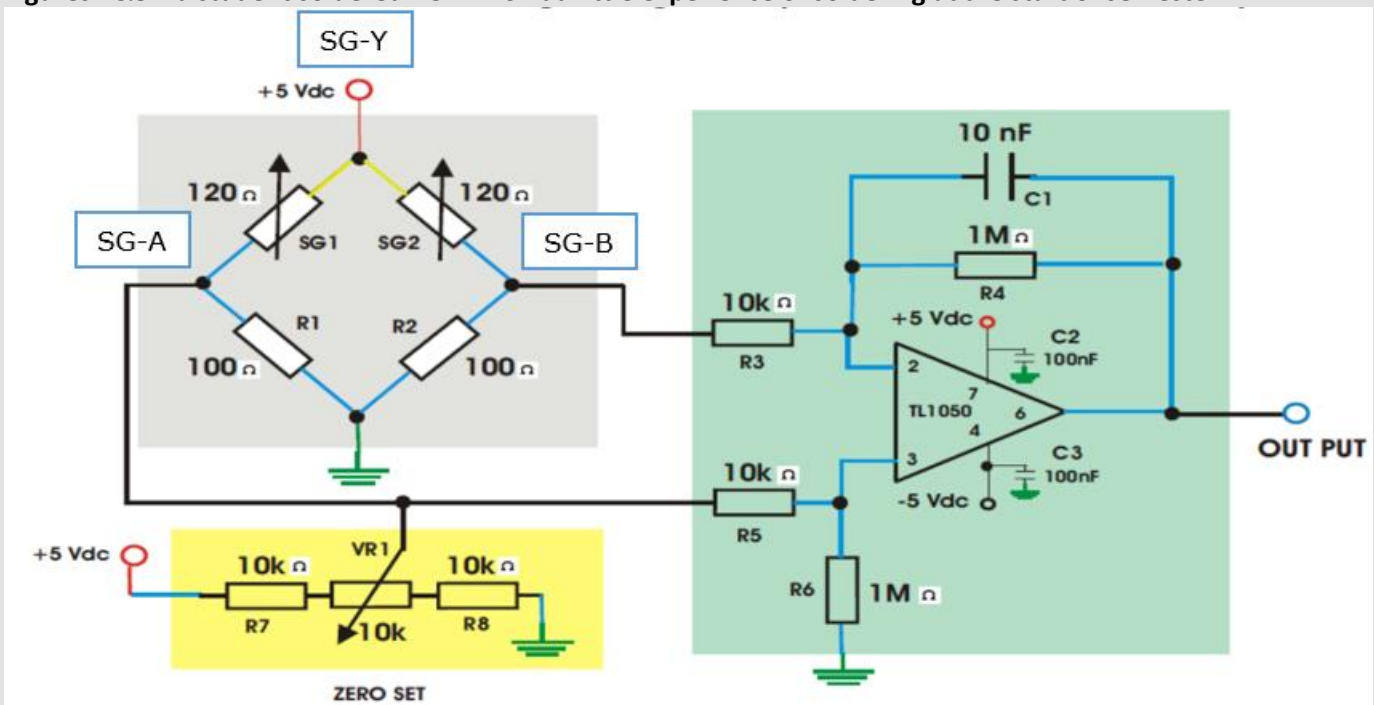


Figure 9 - circuit diagram of the printed circuit board showing the positions of SG-Y, SG-A and SG-B for the light dependent resistor and 10 kilo ohm resistor used for testing. (needs updating)

Session 4: Determining the Damping Ratio of a Vibrating Cantilever

Objectives:

1. State what the natural frequency of objects is
2. Describe how to measure damped oscillations
3. Explain how to calculate damped and undamped oscillations of a beam
4. Evaluate uncertainties in measurements

Laboratory aim:

The aim of this experiment is to use an amplifier and PicoScope to determine the damping ratio, damped frequency and the natural angular frequency of vibrations for a cantilever and then compare the theoretical and experimental angular frequencies.

Activities:

Lecture on data collection, applications and laboratory writing skills.

Hands-on activities: Fault finding, collecting beam oscillation data with a (digital) oscilloscope (1.5 hours)

Post laboratory processing: Data analysis of the trace and beam measurements. (1.5 hours)

Laboratory write-up: (3 hours)



Figure 10 - showing a steel beam cantileaver attached to a bench by a G-clamp

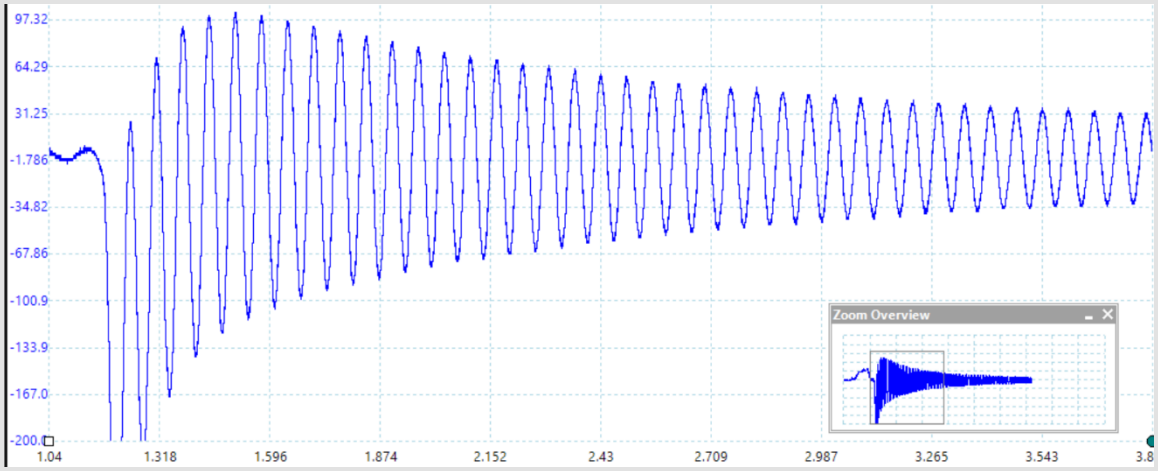


Figure 11 – A damped harmonic response (after the stepped input) from the strain gauges.

Outcome:

Students who have never held a soldering iron before, seen a silicon chip or knew what an oscilloscope is leave the four sessions with a **basic** understanding of, Wheatstone Bridges, operational amplifiers (OpAmps), strain gauges, they gain the ability to build, test and solve faults with circuits. They gain practical experience in testing and calibrating strain gauge systems to get a viable set of oscilloscope data to analyse then compare the processed data with theoretical predictions. This case study provides a structured and hands-on approach to learning, ensuring that participants are well-equipped to apply their knowledge in real-world scenarios, including space related applications.

Feedback:

This work has been evaluated by staff and students and has gone through changes, it was converted to an online laboratory during lockdowns and then a group of 5 students evaluated the whole module and helped re-write the instructions based of student feedback. This work has recently also undergone scrutiny for digital accessibility and the accessibility of the resources has improved…this process is ongoing... The student review process was evaluated, the findings were presented by the author and a student with data at the University of Nottingham Teaching and Learning conference which showed a 5% increase in student satisfaction with the resources compared to the older format. Apart from a few dedicated theoretical physics/mathematics students, there is great appreciation of the practical work in my sessions. The Foundation year are currently undergoing a research project on student motivations (in the initial stages) where students (past and present) are being asked if the practical work they undertook in foundation enhanced their learning and ability to migrate you Y1 more easily. (Surveys are being sent out surveys to all years, post grads, post docs and alumni who undertook a foundation year)

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