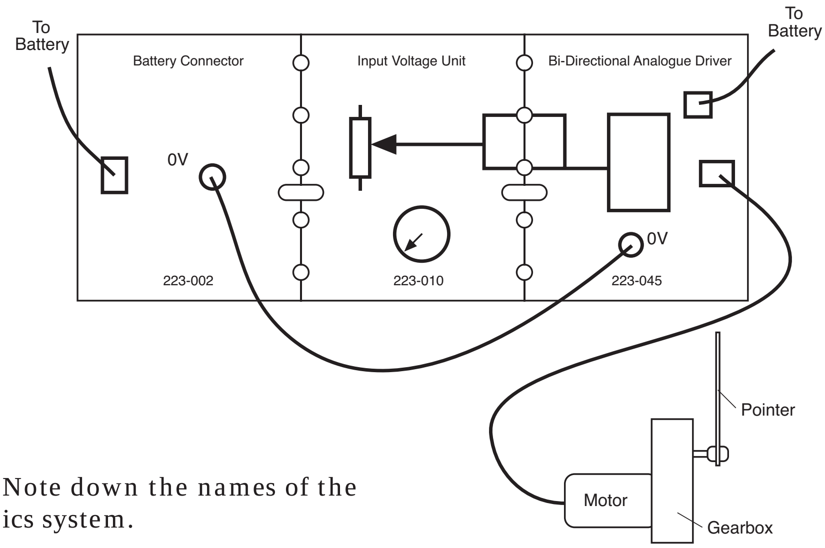
INVESTIGATING CONTROL SYSTEMS USING ALPHA BOARDS

Note: Refer to Study File 8 for details of block diagrams.



Note: for investigations 1 and 2 motor unit has potentiometer detatched and a pointer attached to the output spindle.

OPEN LOOP CONTROL

Investigate a system that has no feedback loop. To do this you will need to set up the circuit shown in the diagram;

Adjust the thumbwheel on the input voltage unit and observe the effect on the motor.

Report

- Draw a diagram of the system. Note down the names of the sub-units used in your electronics system.
- Describe the way the circuit operates.

Adjust the thumbwheel on the input voltage unit until the motor is stationary. The thumbwheel should be around the half way point.

Investigation 1

- Note the position of the pointer on the motor. Using the thumbwheel, turn the pointer exactly 90˚.
- Once you think you can do this, try doing it with the pointer hidden from your view.

Report

- How easy was it to control the motor with the thumbwheel? If it was not easy to control the position of the pointer, try to explain why you think it was hard.
- Describe what happened when you couldn't see the pointer. How accurate were you?
- Draw a block diagram of this control system

  Are there different block diagrams depending on whether the person controlling the system can see the pointer?
- Look for the **demand**, **sensor**, **controller** and **actuator** in your system (see page xx). Label them on your diagram if they are present. If you think any of these features are missing, explain why.

Investigation 2

- Set the thumbwheel on the input voltage unit so that the motor is stationary. Turn the pointer by hand and see how the control system reacts.
- Set the thumbwheel on the input voltage unit so that the motor is turning slowly. try to slow down the pointer by hand and, again, note how the control system reacts.
- With a partner turning the pointer by hand, try to use the control system to keep it in the same place.

Report

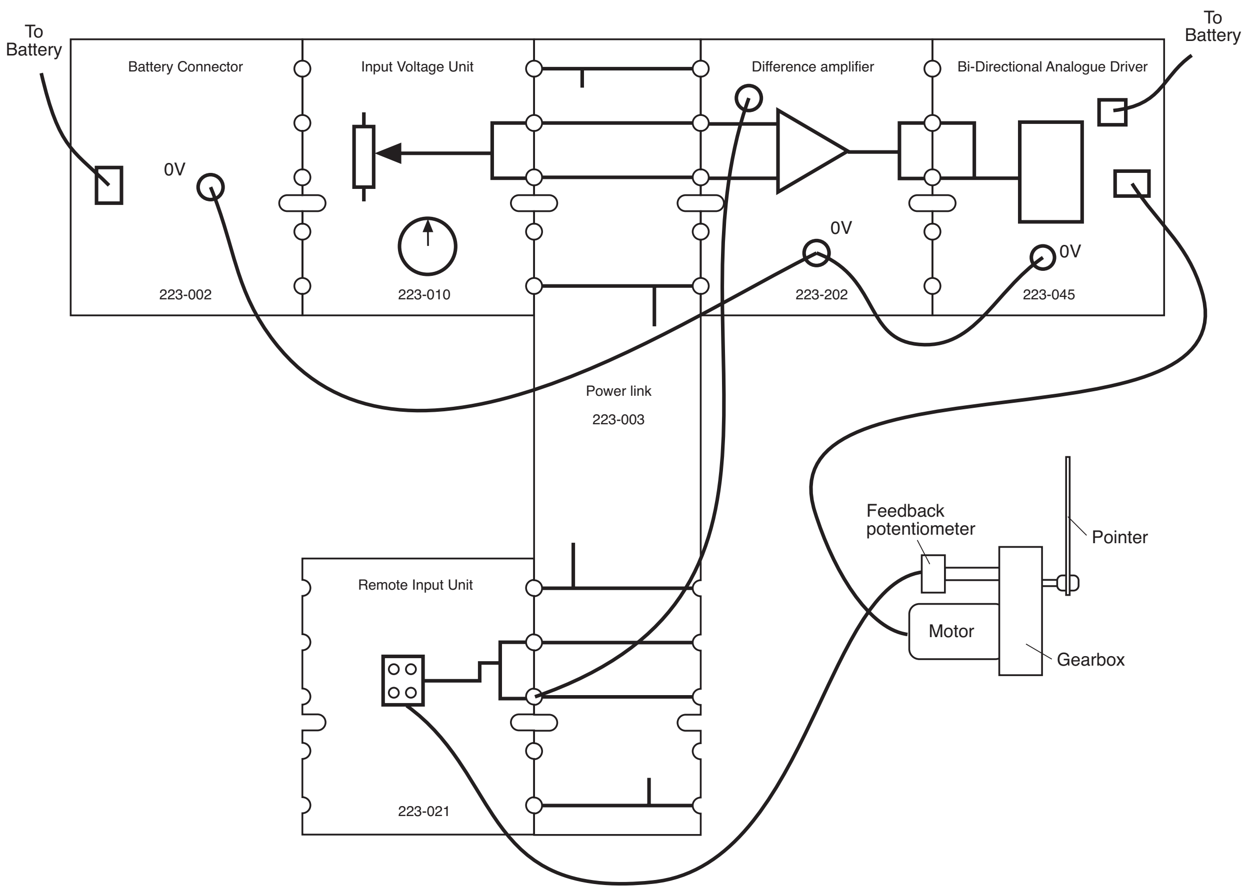
- Describe how the control system reacted when you turned the pointer by hand.
- How easy was it to control the position of the pointer with someone else trying to move it? If it was not easy to do this, try to explain why you think it was hard.
- Draw a block diagram of this control system. Does the person operating the control system fit into the diagram?

CLOSED LOOP CONTROL

Investigate

In the previous section you examined a control system that had no feedback. Now you are going to investigate a system that does have feedback; a closed loop control system.

To do this you will need to set up the circuit shown in the diagram;



Start with the input voltage unit at about half way.
Connect the power and note what the motor does; if it drives right to the end of its travel, swap round its connections to the driver board.

Investigation 1

- Adjust the thumbwheel on the input voltage unit and observe the effect on the motor.
- Note the position of the pointer on the motor. Using the thumbwheel, try to turn the pointer exactly 90˚.

  Try doing this with the pointer hidden from your view.
- Try to move the pointer by hand. Note how the control system reacts.

Note that moving the thumbwheel and moving the pointer are both ways of putting an **error** into the control system.

Report

- Draw a diagram of the system. Note down the names of the sub-units used in your electronics system.
- Describe the way it operates. Describe how this is different to the system in section 1.
- How easy was it to control the motor with the thumbwheel, compared to the system in section 1?

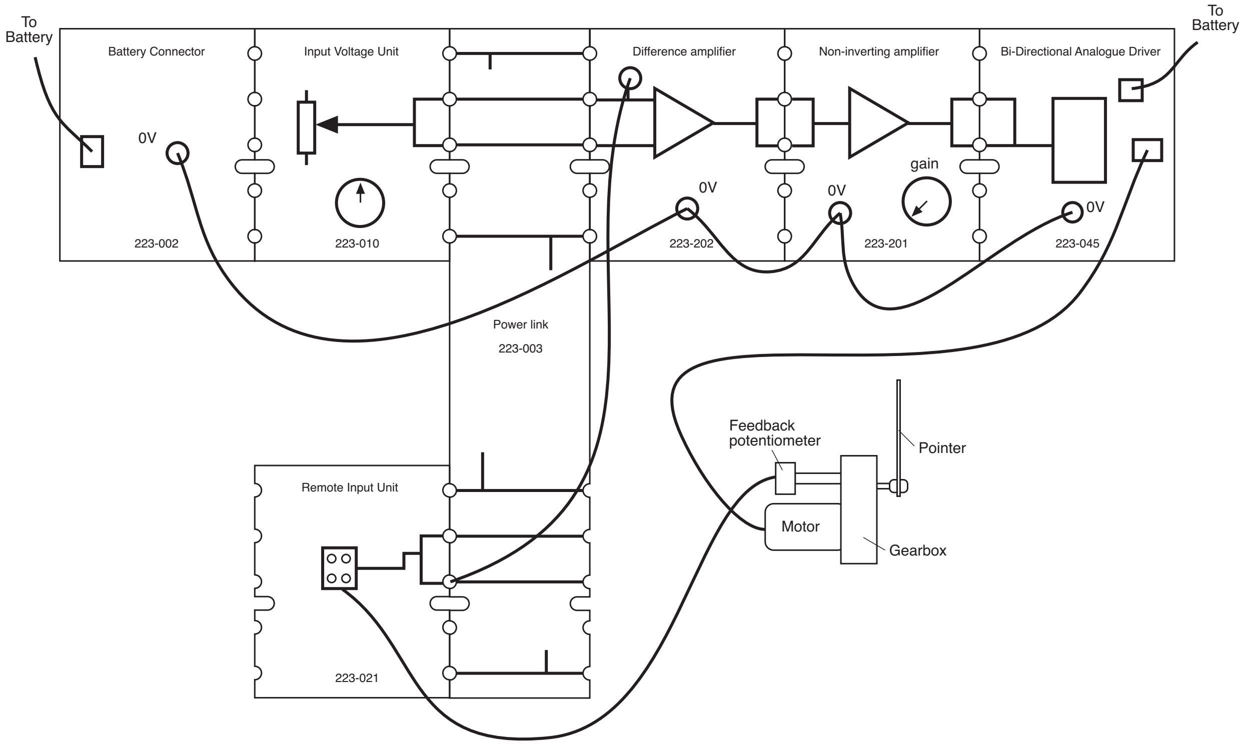
  Comment on:

  The **accuracy** of this system (what happened when you couldn't see the pointer? How accurate could you be?).

  The **stiffness** of this system (how hard did the motor try to correct the error when you pushed the pointer by hand?).

  The **repeatability** of this system (does a particular position of the thumbwheel always turn the pointer to the same position?).
- Draw a block diagram of this control system.
- Look for the **demand**, **sensor**, **controller** and **actuator** in your system. Label them on your diagram if they are present. If you think any of these features are missing, explain why.

Investigation 2
Add a variable gain amplifier to your circuit, as shown in the diagram;



Start with the input voltage unit at about half way and set the gain thumbwheel to its minimum.

- Adjust the thumbwheel on the input voltage unit and observe the response of the motor. In particular, note the speed of the motor's response to this error.
- Try to move the pointer by hand. Note how the control system reacts.
- Increase the gain a little and examine how this changes the response of the system.
- Keep increasing the gain, bit by bit, until the maximum is reached.

Report
- Draw a diagram of this new system. Note down the names of the sub-units used in your electronics system.
- Describe the effect of changing the gain setting in this system. Explain what you think the effect of the added amplifier is.

  Comment on how the gain affects the **accuracy**, the **stiffness**, the **repeatability** and the **speed of response** of this system.
- Explain which gain setting you would choose for the best control of this motor.
- Draw a block diagram of this control system. Label the **demand**, **sensor**, **controller** and **actuator**.

Investigation 3

Use the same control circuit that you had in the previous investigation:

Use a voltmeter to measure the size of the signal driving the motor. The connections are shown in the diagram alongside.

Start with the input voltage unit at about half way and set the gain thumbwheel to its minimum.

- Repeat investigation 2, but this time observe how increasing the gain affects the size of the signal driving the motor.

  Record the gain setting (marked on the thumbwheel) and the size of the signal.

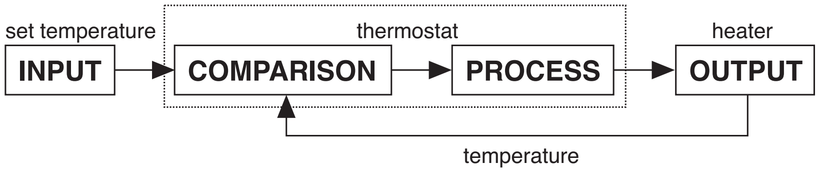
- Keep increasing the gain, bit by bit, until the maximum is reached.

Report

- Describe the effect that the gain has on the size of the signal driving the motor.

STABILITY OF A CLOSED LOOP SYSTEM

Introduction
The diagram shows a closed loop control system.



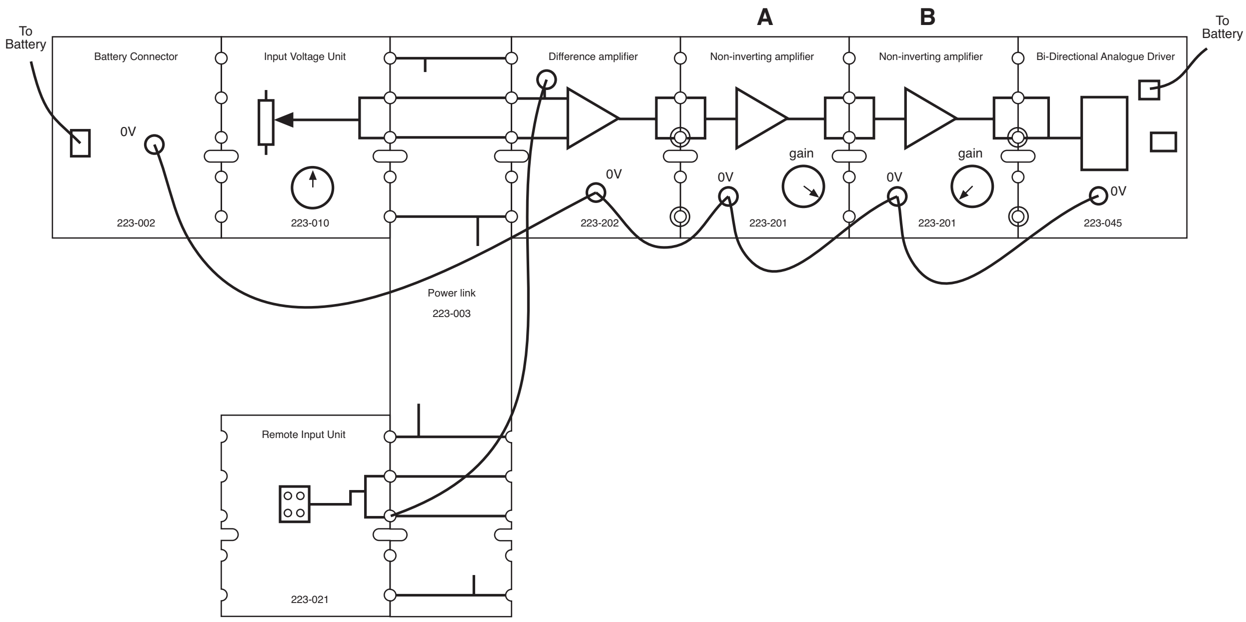
You used a system like this to control the position of a pointer in sub-section 2.

In that sub-section you found that the system’s **gain** is important. A system with higher gain reacted more quickly to an error. It also reacted to smaller errors.

Does this mean that you should try to make the gain of a system as high as possible? In the following investigation you are going to find out how high gain systems behave.

Investigate
You are going to investigate the consequence of high gain in a system.

To do this you will need to add a second amplifier into your position control system. This new system is shown in the diagram;



Start with the input voltage unit at about half way. Remember, this is used to put an error into the control system.

Turn the gain of the first non-inverting amplifier (labelled A) to nearly full. This starts your system with a quite high gain.

The second non-inverting amplifier (labelled B) is used to further increase the gain of your system. You should start with its gain quite low.

Investigation 1
Investigate how the response of your system changes as the gain increases.

Hints
- Make sure that you test the system response fairly. You should make sure that any changes you see are due to the changing gain.
- Change the gain by the same amount between each observation.
- Keep a record of what you see.

Report
- Describe how you carried out your investigation.
- What is a control system with high gain like?

  Summarise your observations.

  Comment on how the very high gain affects the **accuracy**, the **stiffness**, the **repeatability** and the **speed of response** of this system.
- Draw a diagram of this new system. Note down the names of the sub-units used in your electronics system.
- Draw a block diagram of this control system. Label the **demand**, **sensor**, **controller** and **actuator** .

Investigation 2
Investigate how the response of your system changes as the controlled object gets heavier. To do this you will need to load the motor.

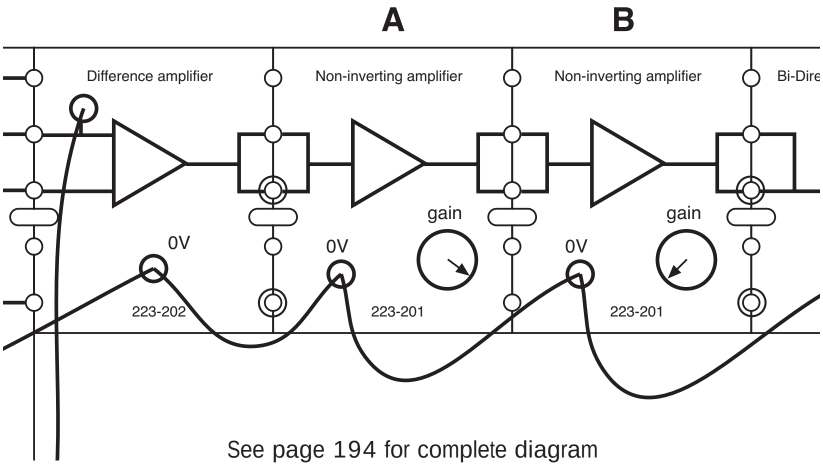
Hints
- Make sure that you test the system response fairly. You should make sure that any changes you see are due to the changing mass.
- Change the load on the motor by the same amount between each observation.
- Keep a record of what you see.

Report
- Describe how you carried out your investigation.
- What are the features of a control system with a lot of mass?

  Summarise your observations.

  Comment on how the increasing load affects the **accuracy**, the **stiffness**, the **repeatability** and the **speed of response** of this system.
- Draw a diagram of this new system. Note down the names of the sub-units used in your electronics system.
- Draw a block diagram of this control system. Label the **demand**, **sensor**, **controller** and **actuator** .

Investigation 3
Use a computer linked to a control system with high gain to record the detailed response.



See page 194 for complete diagram

Hints
You should record the output from the difference amplifier and from the second non-inverting amplifier (labelled B opposite).

You will need a printout of the graph from the computer.

Report
Using the computer printout to help you, describe the way a system with high gain behaves. Try to explain why you think the system acts like this.

SUMMARY

Overshoot
When the gain in a closed loop control system is high the system tends to drive the output past the demanded level.

This is called **overshoot**. The higher the gain, the bigger the overshoot will be.

Stability
A control system that suffers from overshoot is called unstable. A **stable** system does not overshoot.

Settling Time
An unstable system may overshoot the demanded value a number of times before a steady value is reached. The time that it takes for the system to settle down to the demanded value is called the **settling time**. Some systems never settle at all and continue to oscillate around the demand value.

Practical Consequences

- You will always need to try out any control system that you have designed with the physical device that it has been designed to control. You cannot tell until you do this whether the system is going to be unstable.

- Often you will need to make a compromise in your systems between having high gain (and an accurate system with a fast response) and stability.

PROPORTIONAL AND ON/OFF CONTROL

Introduction
There are two ways to control an actuator in a closed loop system;

Proportional control **-** The drive signal to the actuator is proportional to the error. This means that a big error will lead to a big drive signal and the output will change quickly, a small error produces a slow change in the output.

On/Off control **-** The drive signal to the actuator is always either switched fully on (when there is an error) or off (when there is no error).

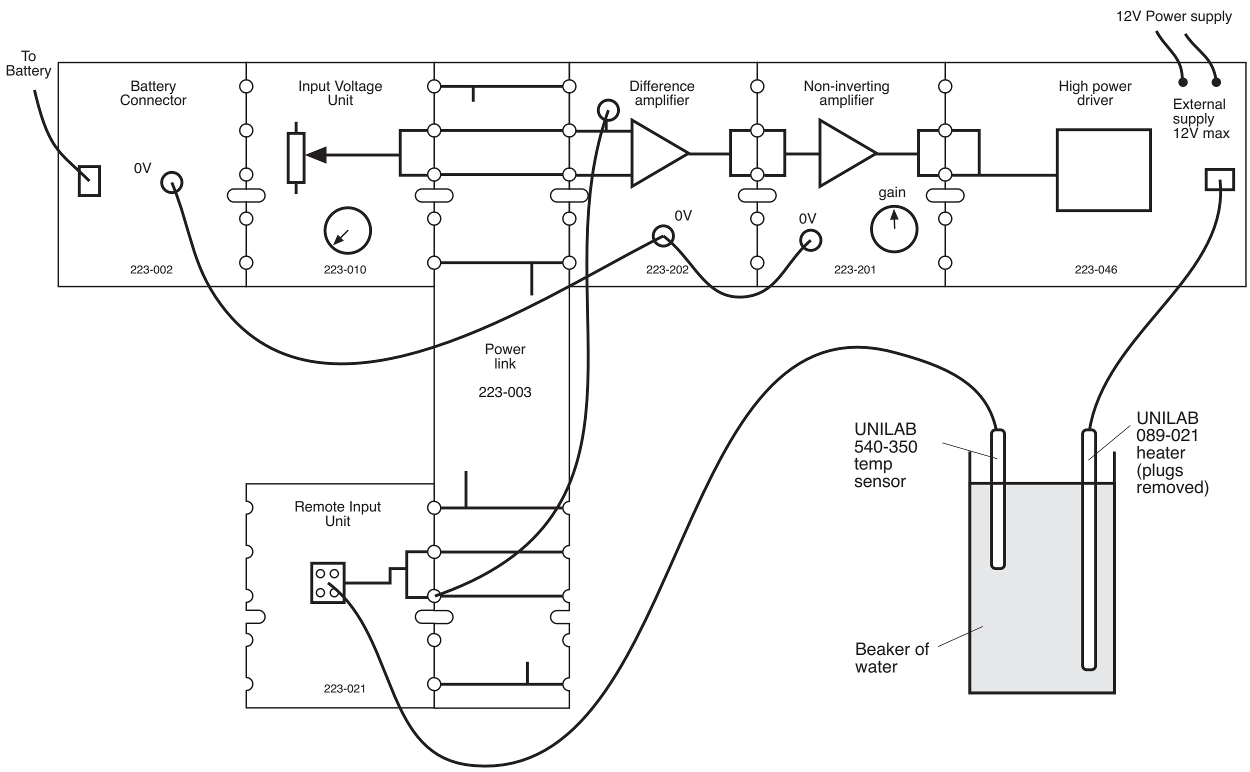
The motor control systems you have been using so far have used **Proportional** control.

Investigate
You are going to investigate the differences between proportional and on/off control systems.

To do this you will first need the proportional control system shown in the diagram:

The input voltage unit is used to set the demanded temperature.

Turn the gain of the non-inverting amplifier to around half way.



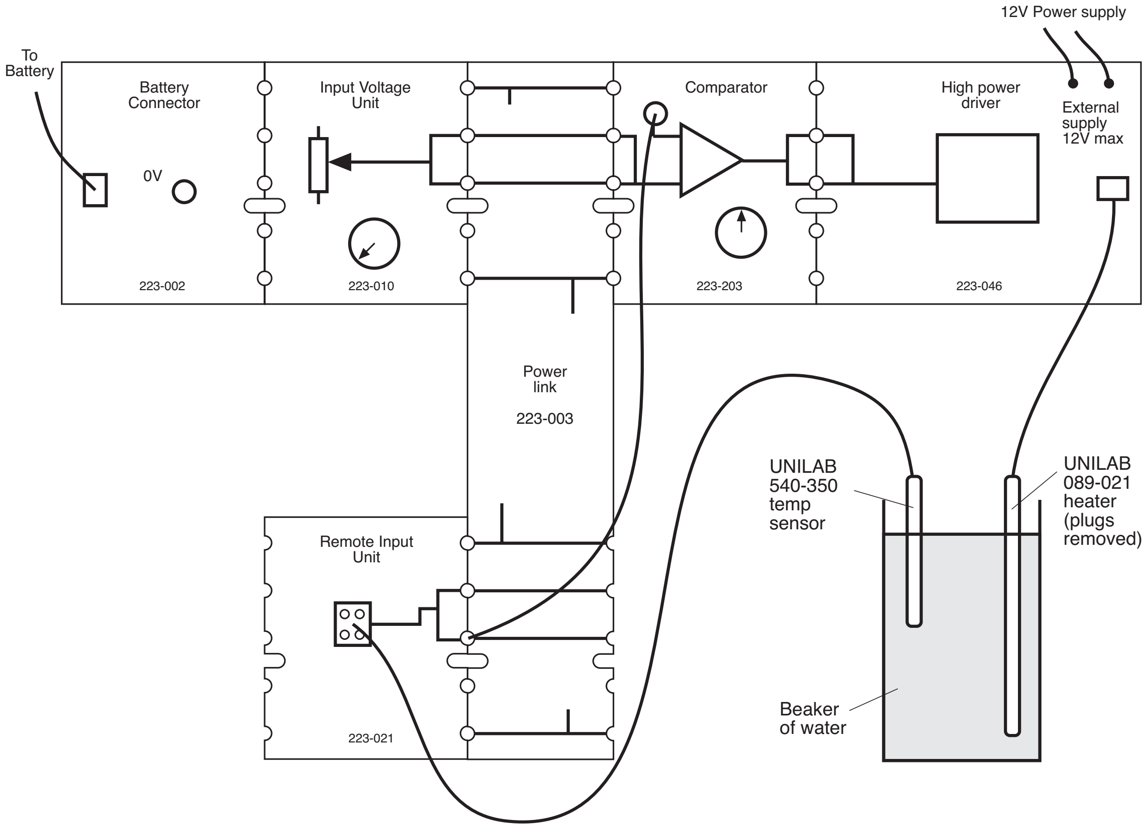
Investigation 1
Observe the response of your system to a change in the demanded temperature.

Hints
- Use a voltmeter to measure the size of the signal driving the heater. The connections are shown in the diagram opposite.
- Monitor the temperature of the water in the beaker.
- Monitor the temperature of the high power driver chip. A digital temperature probe is ideal for doing this.

  WARNING: this may get hot. **Do not** use your fingers.
- Keep a record of what you see.

Report
- Draw a diagram of the control system. Note down the names of the sub-units used in your electronics system.
- Draw a block diagram of this control system. Label the **demand**, **sensor**, **controller** and **actuator** .
- Describe your observations.

  Report the size of the signal and the driver temperature that you see once the temperature in the beaker has settled to a steady value.
- Explain why you think the system behaves as it does. What do you think are the disadvantages of this system?



Investigation 2

In this investigation the proportional control system is replaced by an on/off system;

Set the comparator thumbwheel to about half way.

Observe the response of this new system to a change in the demanded temperature.

Hints

- Use a voltmeter to measure the size of the signal driving the heater. The connections are shown in the diagram above.
- Monitor the temperature of the water in the beaker.
- Monitor the temperature of the high power driver. A digital temperature probe is ideal for doing this.

  WARNING: this may get hot. **Do not** use your fingers.
- Keep a record of what you see.

Report

- Draw a diagram of the control system. Note down the names of the sub-units used in your electronics system.
- Describe your observations.

  Report the size of the signal and the driver temperature that you see once the temperature in the beaker has settled to a steady value.

  What is the **cycle time** of this control system? (The 'cycle time' is the rate at which the system switches on and off)
- Explain why you think the system behaves as it does.
- How does this on/off system compare to the proportional one?

Write down any advantages and disadvantages of the two systems that you can think of.