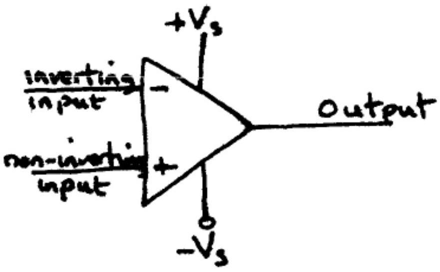
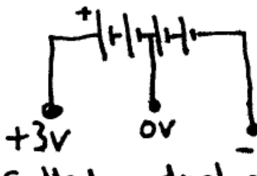
ET1: Introduction to Digital and Analogue Systems

1.4 Operational Amplifiers (worth 30% of marks → Chapter 9).



What does it do? Amplifies difference between the voltages at + and − input. (A voltage amplifier)

Power supply (p8) needs $+V_s$ and $-V_s$ eg. +15V and −15V to work. 0Volts is halfway between the two.



Called a dual power supply

Voltage of output (p9)

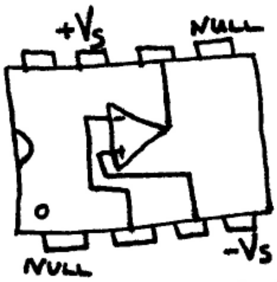
Output is positive when + is higher than −
Output is zero when + = −
Output is negative when − is higher than +.

Open loop gain (p4)

Gain means 'how many times the signal is amplified'. A gain of 10 would mean output is 10 times bigger than input.
Open loop gain is called A_o

$$A_o = \frac{V_{out}}{V_{in}}$$

The 741 is (p8) an 8 pin DIL chip with an op-amp on it



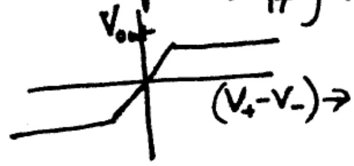
Properties of an Op-Amp (p11)

1. Very high open loop gain (A_o)
   - Ideally infinite
   - Actually about 100,000
2. Very high input impedance so that it takes only a very tiny current from input signal
   - Ideally infinite – no current taken.
   - Actually a few MΩ (↑ mega (million))
3. Very low output impedance so it can deliver a big current
   - Ideal: zero
   - Actual ~ 100Ω
4. Very wide bandwidth so it can amplify low and very high frequency signals well.
   - Ideal: infinite bandwidth
   - Actual: a few kHz. (↑ kilo = 1000)

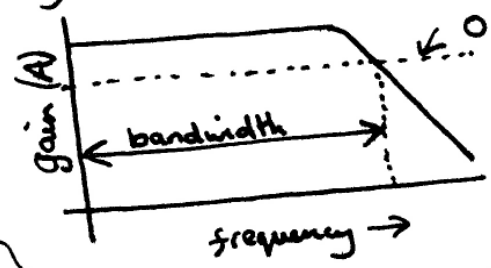
1.4 Operational Amplifier – (continued)

High gain doesn't mean massive output voltage!!

A gain of 10,000 and a difference in V+ and V– of 0·1V should mean an output of 0·1×10,000 or 1,000 Volts. This is impossible because the output cannot be higher than the supply voltage. In practice it only goes up to about 85% of the supply voltage. This is called <u>saturation</u> see (p10)



(p6)
<u>Bandwidth</u> – If the frequency of the input increases, the <u>gain</u> should stay the same for the output. However, eventually the gain drops.



Look for where the gain drops to 0·7 of its maximum value. The <u>frequency</u> of this point is the bandwidth.

Slew rate (p6)

The output takes a while to increase or decrease its voltage. Slew rate is the maximum rate of change of output voltage.

Slew rate = 10V/µs
↑ micro (millionth)

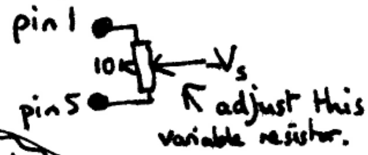
It takes 2µs to change by 20V.

Gain-Bandwidth Product (p7)

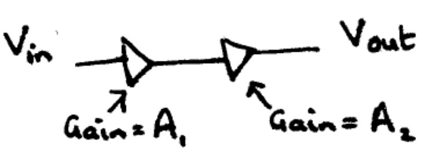
Gain × bandwidth = constant.
<u>so</u> increasing <u>gain</u> will <u>decrease</u> bandwidth + vice versa

Offset Null (p9)

If $V_+ = V_-$ the output should also be <u>0</u>V. However sometimes an adjustment has to be made so that it is actually zero. pin 1 and 5 make this possible



Amplifiers in Series (p7)



Total gain = $A_1 \times A_2$

Feedback

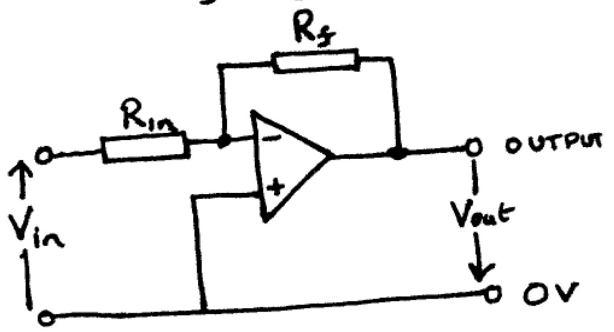
Sending part of output <u>back</u> into input.
Effect: reduces <u>Gain</u> (A)

1.4 Operational Amplifier – ctd

2 practical circuits Inverting Amplifier and Non Inverting Amplifier

Both circuits → resistors are added to give negative feedback to reduce the gain (A). This makes the amplifier more stable.

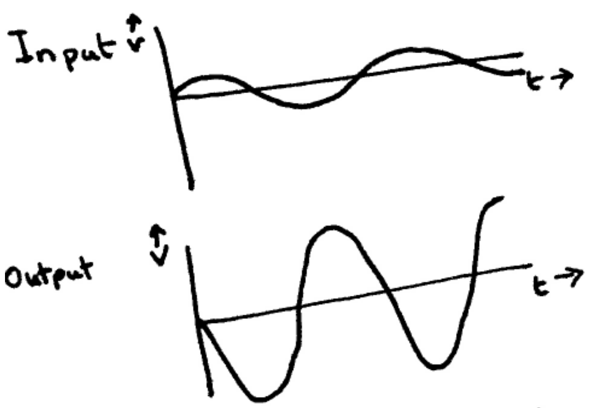
Inverting Voltage Amplifier



$$\text{Gain (A)} = -\frac{R_f}{R_{in}}$$

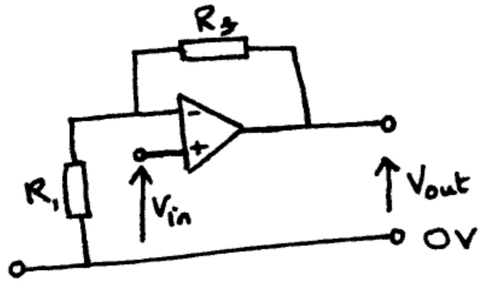
The output is amplified and inverted

Input impedance is R_{in}



Note: output is inverted and amplified

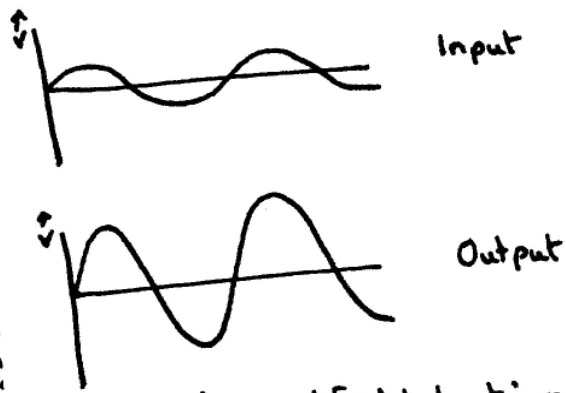
Non-inverting voltage amplifier



$$\text{Gain (A)} = 1 + \frac{R_f}{R_1}$$

The output is amplified but not inverted.

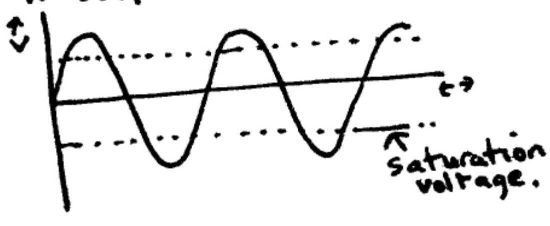
Input impedance is the same as op-amp.



output is amplified but not inverted

Clipping The output can only go upto the saturation voltage.
What happens if it goes higher → it can't so stays at saturation voltage.

If output should be this.



It is like this. Clipping has occurred