Introduction to Electronics

Part 2: Operational Amplifiers and Digital Circuits

An operational amplifier is a very high gain amplifier. Op amps can be used in many different ways. Two of the most common uses are:
a)   as comparators
b)   as amplifiers (either *non-inverting* or *inverting* amplifiers)

An op amp has two inputs; one non-inverting (called the "+" input) and one inverting (called the "-" input).
The voltage at the output (V_o) depends on the *difference* between the voltage at the non-inverting input (V^+) and the voltage at the inverting input (V^-). Expressed mathematically:
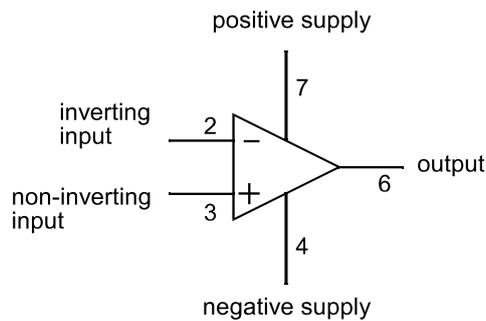
$$V_o = A.(V^+ - V^-)$$

where A is the *gain* or *voltage amplification* of the op amp (typically 100000)
The diagram below shows an op amp together with its circuit symbol.
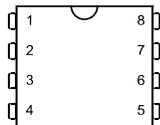
Op amp   circuit symbol

N.B.
Op amps must, of course, always have a battery or some other supply of energy connected to them.
However, in many circuit diagrams the supply connections are not drawn.
In the experiments which follow, use digital voltmeters.

Op Amp as COMPARATOR

In the circuit below, the non-inverting input is connected to "ground", so $V^+ = 0$.
Use the +7·5v 0 -7·5v rechargeable battery packs made specially for op amp experiments.
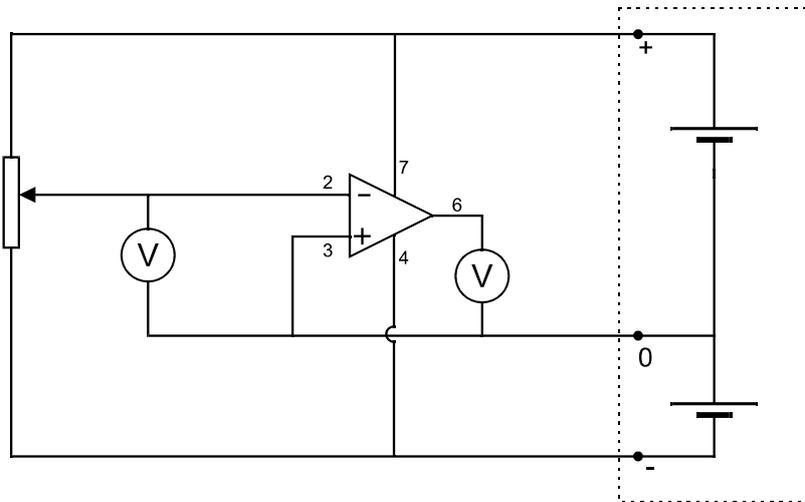
Vary the voltage applied to the inverting input (using the variable potential divider) to show that:

if $V^- > 0$ then $V_o =$ _____

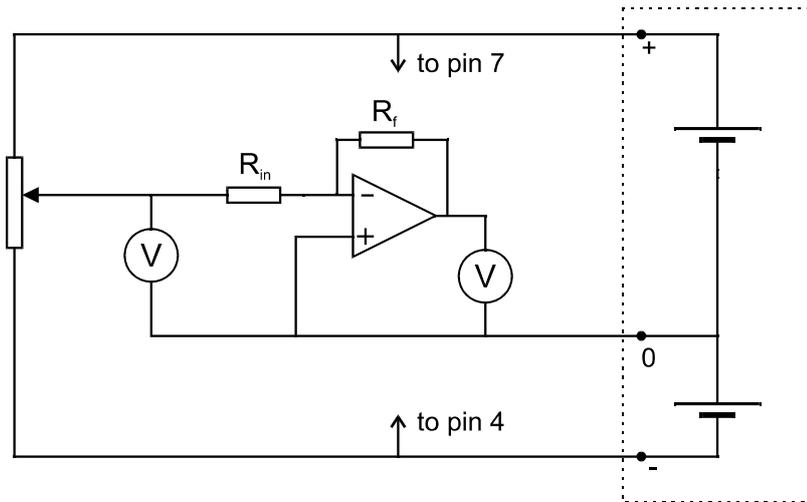and if $V^- < 0$ then $V_o =$ _____

Repeat the experiment with the INVERTING input connected to ground and the non-inverting input connected to the variable potential divider. Now we find:

if $V^+ > 0$ then $V_o =$ _____

and if $V^+ < 0$ then $V_o =$ _____

Op amp as INVERTING AMPLIFIER

A "feedback" resistor is used to reduce the gain of the op amp.

In general, the definition of the gain (A) of an amplifier is:
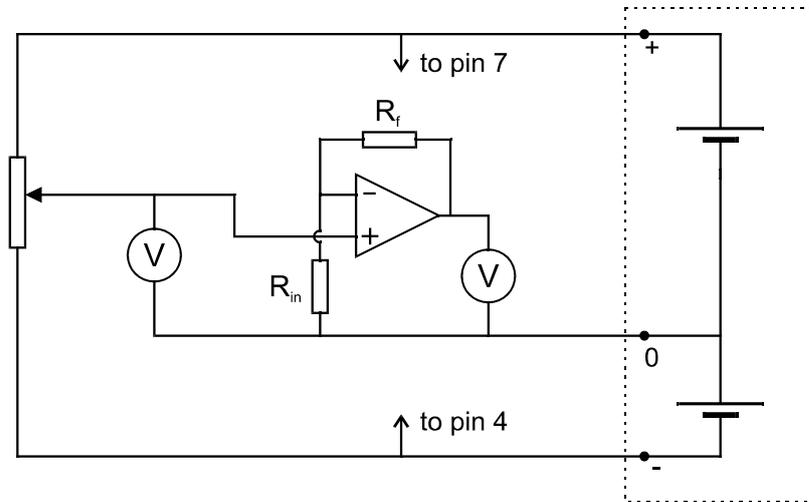
$$A = \frac{V_o}{V_{in}}$$

In the particular case of an op amp with negative feedback (as in this circuit) it can be shown that the gain can be calculated using:

$$A = -\frac{R_f}{R_{in}}$$

Using R_{in} = 10k and R_f = 33k, take at least two readings of V_{in} and V_o in order to verify this relation.

Op amp as NON-INVERTING amplifier

Try a similar experiment but using the circuit shown below:
(again, use R_{in} = 10k and R_f = 33k)

In this case you should be able to prove that the gain is given by:

$$A = 1 + \left(\frac{R_f}{R_{in}} \right)$$

Digital Electronics

Digital circuits are constructed from electronic switches. The switches are **either ON or OFF; there are no half-way states** so the only voltages present in a digital circuit are the supply voltage Vs (usually +5v) and zero. If a point in a digital circuit is said to be "high" we mean that it is at a voltage very nearly equal to Vs. If the point is said to be "low", it means its voltage is very nearly zero. A high state is represented by "1" and a low state by "0".

Experiments with LOGIC GATES

Logic gates are special switches. One logic gate by itself is not much use. When many gates are connected together, they become very useful; a computer, for example, is basically made from thousands of gates (and other types of special switches).

All the gates in the kit (except the inverters) are two-input gates. The voltage which appears at the output depends on the voltages applied to the two inputs. A *truth table* is a table which shows how the output is related to the inputs.
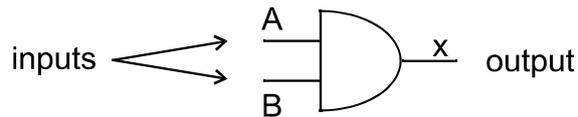
The INVERTER
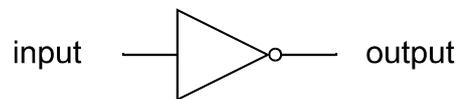
This is sometimes called an inverting gate or NOT gate. The inverter is the simplest logic gate. You can make one (not a very good one) using one transistor and two resistors. If its input is at 1 its output is at 0. If its input is at 0, its output is at 1.
In other words, the output is 1 if the input is NOT 1, hence the name NOT gate.

The AND gate

Connect input A to "OUT A" and also to "INDIC A"
Connect input B to "OUT B" and also to "INDIC B"
Connect the output to "INDIC C"
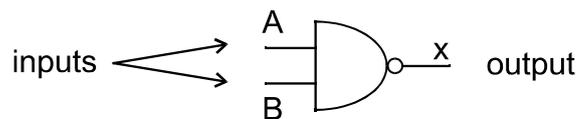
Complete the following truth table:

A	B	X
0	0	
1	0	
0	1	
1	1	

This component is called an AND gate because

_____

_____

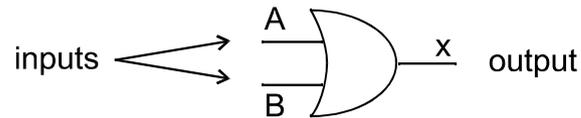Repeat the experiment using the other gates in the kit.

The NAND gate

NAND means "NOT AND"

A	B	X
0	0	
1	0	
0	1	
1	1	

This component is called a NAND gate because

_____

_____

The OR gate

A	B	X
0	0	
1	0	
0	1	
1	1	

This component is called an OR gate because

_____

_____

The NOR gate

A	B	X
0	0	
1	0	
0	1	
1	1	
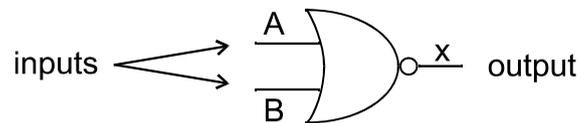
This component is called a NOR gate because

_____

_____

The EXCLUSIVE OR gate
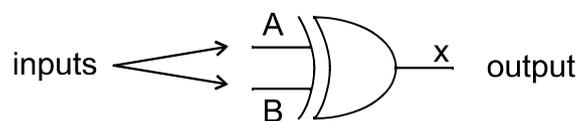
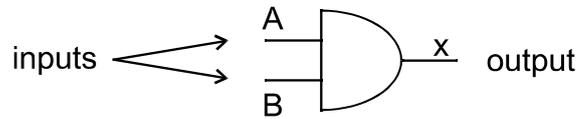| A	B	X
0	0	
1	0	
0	1	
1	1	

Make sure you understand the difference between an OR gate and an EXCLUSIVE OR gate.

Using Logic Gates

Using an AND gate:
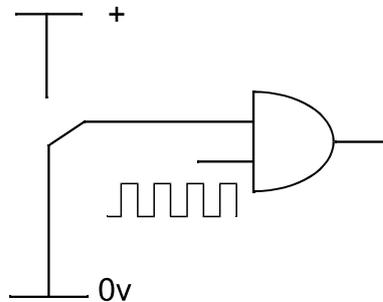Set the oscillator frequency to about 1Hz.
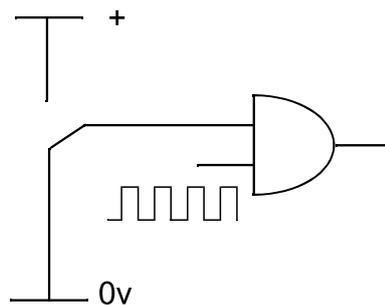

Connect input A to "OUT A" and also to "INDIC A"
Connect input B to "OSCIL" and also to "INDIC B"
Connect the output to "INDIC C"

Look at indicator C (to see what the output is doing) as you connect input A first to 0 then to 1, as shown in the following diagrams.

Gate *closed* (output stays at 0)

Gate *open* (output oscillates)

We see that the state of input A determines whether or not the oscillator pulses will appear at the output. In other words, you can open or shut the gate. Gate open, oscillator pulses are passed on to other parts of the circuit; gate closed the oscillator pulses are not passed on.

Try the same thing with a NAND gate (and other gates too if you have time). What differences do you notice ?