DATE:	COURSE /YEAR/ GROUP:	NAME:

UNIVERSITY OF PLYMOUTH

Department of Communication and Electronic Engineering

EXPERIMENT No: FY4

OPERATIONAL AMPLIFIERS

OBJECTIVES:

(a) To investigate the use of operational amplifiers in comparator and inverting/non-inverting amplifier applications.

(b) To investigate the use of the operational amplifier in an oscillator mode of operation.

INTRODUCTION:

Operational amplifiers are integrated circuits containing the equivalent of at least 20 transistors. Operational amplifiers (op-amps for short) get their name from the fact that they are high-gain amplifiers, and that they can be used to perform mathematical operations, e.g. addition, subtraction, multiplication and division. They may also be used in integration and differentiation applications. Using this latter facility, a simple analogue computer can be constructed from a few simple op-amps. However, op-amps can also be used in a great variety of other ways and we will sample some of them in this course.

There are a fair number of different types of op-amp available, ranging from the familiar but now rather antiquated 741 costing around 30p to CMOS types e.g. 7611 costing around 100p. Fortunately, electrical differences in properties are unimportant in an initial study. Fortunately also, most types come in the standard 8-pin package with a standard pin-out arrangement, the exception being larger packages with two or four op-amps in them.

THE PIN-OUT:

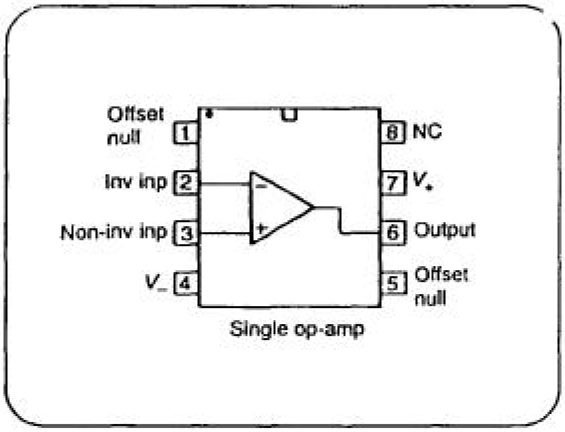
Five pins out of the eight MUST be used (See Fig 1 a and Fig 1 b).

The two power supply pins 7 and 4.
The TWO inputs, pins 2 and 3.
The output pins 6.

The balance terminals and 5 may prove useful in certain applications (see Fig lb).
Pin 8 is not connected.

Note particularly that:

The ground rail is not connected to the op-amp,
though input and output signals are always referenced to it.



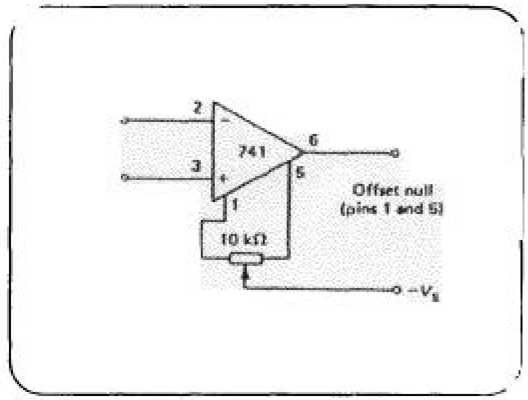
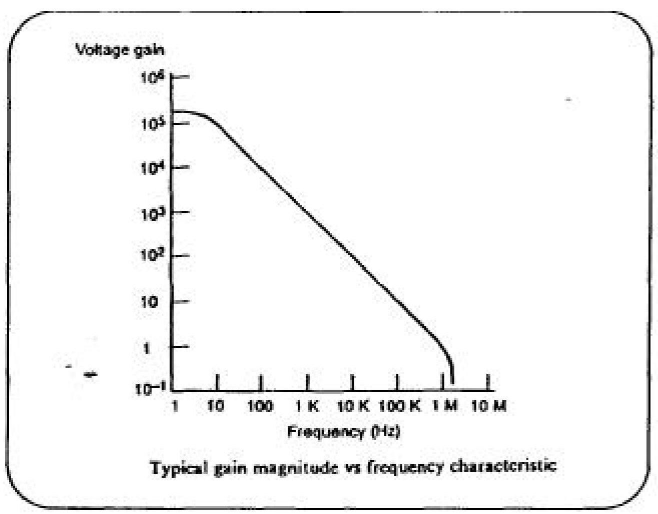


Fig. 1 a. Fig. l b.

The device is essentially a DIFFERENTIAL amplifier, looking at the difference in voltage on the two input pins and amplifying this difference by a large factor. The amplification factor or OPEN-LOOP GAIN is very large (about 100,000) at low frequencies, but falls off at higher



frequencies as shown in Fig 1 c.

Fig. 1 c.

Power Supply Requirements.

Most operational amplifiers require dual rail power supplies, i.e. a +ve supply and a -ve supply connected in series. Typically the supplies would be +/- 15 V or +/- 12 V. These supplies are usually symmetrical about the zero volt line, (the reference potential). This is not always the case and some op-amps may be used on a single supply or with a dual rail supply which is not symmetrical, e.g +12 V and -6 V.

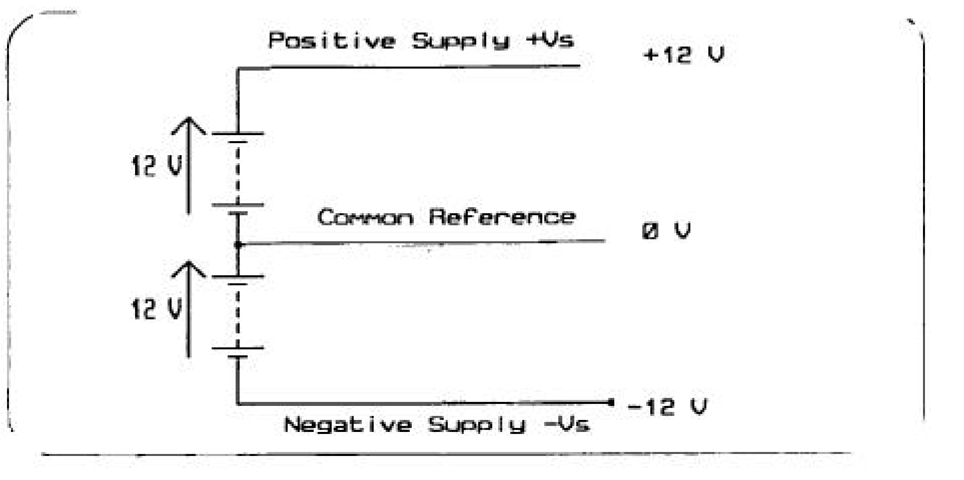


Fig. 2.

APPARATUS:

Standard "Work Station" equipment available in Laboratory Room 304. Locktronics connection board and selection of plug in components.

SECTION 1: THE OP-AMP AS A VOLTAGE COMPARATOR.

Consider first a simple d.c. situation where two steady voltages are presented to the op-amp and it tries to magnify the difference by a factor of about 100,000. Unless the two inputs are exactly equal, the magnification cannot be 100,000, because the output voltage is limited by the supply rails. The output can be no more than the +ve supply voltage nor less than the -ve supply voltage, and with some types of 741 it will fall a little short of these limits. So the output is digital rather than analogue, high or low, e.g. +12 V or -12 V.

The action of the two input (pins 2 and 3) is defined as follows:

If the voltage on the INVERTING input (pin 2) is greater than that on the NON-INVERTING input (pin 3), the output is negative.

If the voltage on the NON-INVERTING input (pin 3) is greater than that on the INVERTING input (pin 2), the output is positive.

These ideas are illustrated in the following circuits which can be used for sensing critical light levels, temperatures, etc. or for building an oscillator circuit.

VOLTAGE COMPARATOR:

Set up the circuit shown in Fig.3. The voltage divider circuit connected to pin 3 should establish a 6 V input on this pin. Check this with the digital voltmeter.

Change the voltage on the other input, monitoring it with the voltmeter and observe the output using the C.R.O. This output should suddenly switch from +12 V to - 12 V.

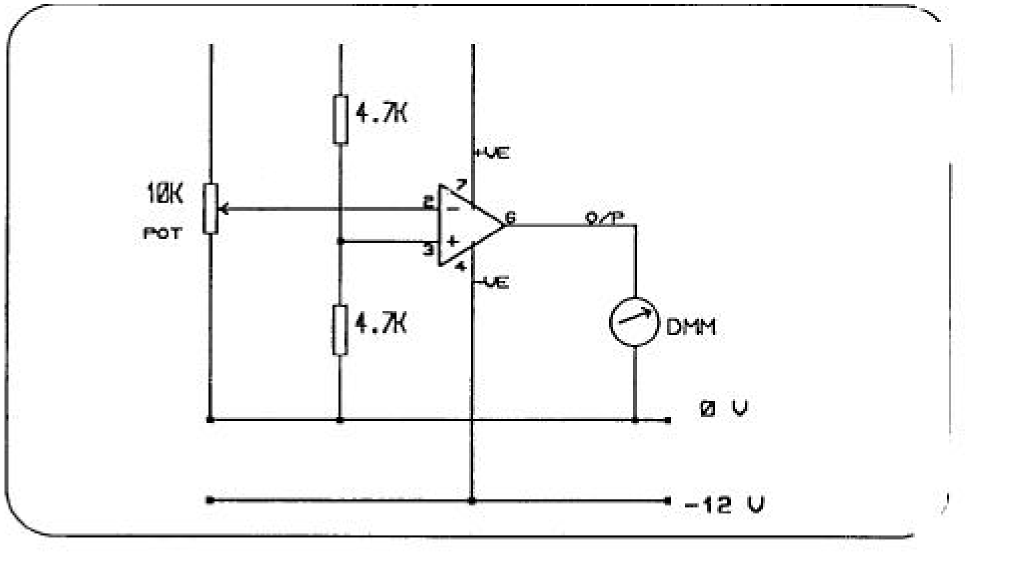


Fig. 3.

Questions:

At what input voltage does the output suddenly change level ? volts

Is it possible to adjust the input voltage on pin 2 to give zero output voltage ? YES/NO

(c) If pin 2 (the inverting input) is higher than 6 V, is the output voltage +12 V/-12 V.

Further Investigations:

(i) What is the effect of changing one of the resistors in the potential divider connected to pin 3 ?

Observations:

(ii) What happens if both inputs are negative with respect to ground ?
Investigate this by taking the voltage dividers to -12 V rather than 0 V and arranging the resistors to give a negative voltage on pin 3.

Explanation:

NOTE: THE CIRCUITS WHICH FOLLOW ARE VERY SIMILAR, SO DO NOT DISMANTLE YOUR CIRCUIT COMPLETELY.

LIGHT SENSITIVE CIRCUIT:

In this system the light dependant resistor (LDR) replaces one of the potential divider resistors and acts as a light sensor. The modified circuit is shown in Fig. 4. below.

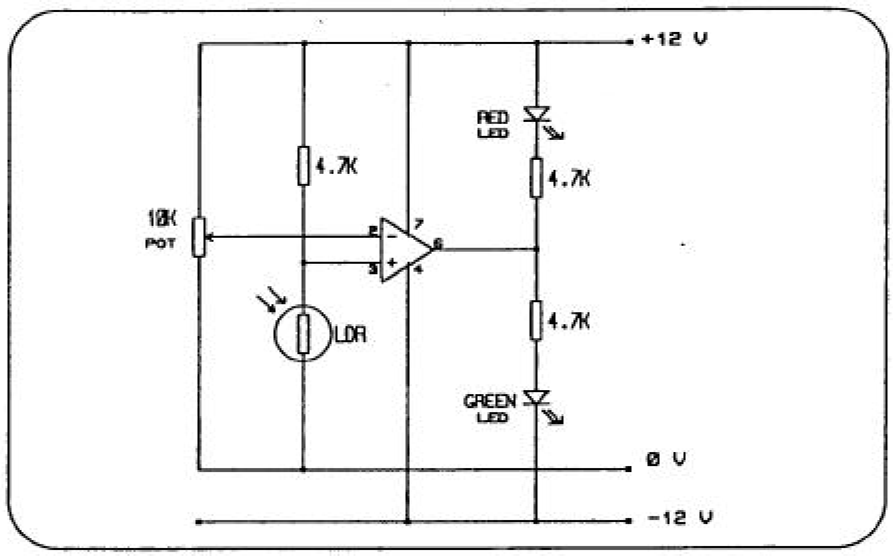


Fig. 4.

Use the multimeter on the resistance range to investigate the variation of the LDR resistance.

When the light is Bright, the LDR has a High/Low Resistance. Typical value =

When the light is Dim, the LDR has a High/Low Resistance. Typical value =

In the above circuit, the 10k resistor is no longer the variable input, but is used to set the light level at which switching of the output occurs.

A visual indication of the output is given on the two LED's. When the output is high, the green LED should come on and when the output is low the red LED should come on. Adjust the 10k resistor to give switching when the LDR is covered.

Which LED is on when the light is bright ? RED / GREEN

Explanation: Explain the action of the circuit when the light is bright:

Investigate the behaviour of the system when the LDR and the 4k7 resistor are interchanged.

Result: Briefly explain the results of the above change.

<u>Thermistor:</u>

At high temperature the resistance of the thermistor is low and at low temperature the resistance if the thermistor is high. Check the thermistor resistance using the multimeter and record typical values (NB do not measured it connected to other components: why?).

Low temperature - thermistor resistance =

Higher temperature - thermistor resistance =

Replace the LDR with a thermistor to sense temperatures and investgate the circuit operation. Note the 4k7 resistor may have to be changed to a more suitable value to match the thermistor variation.

SECTION 2: DEFINED GAIN AMPLIFIERS:

One of the great advantages of operational amplifiers is that by using a few external resistors, a circuit can be built which gives a definite gain. This gain may be set to a wide range of values varying form 1000 to less than 1. The gain produced does not depend on the innate gain or open-loop gain of the op-amp, but is directly related to the values of the resistors used in the circuit. Two circuit configurations are commonly used, one giving an inverted output and the other a non-inverted output.

In the circuits used in the following tests, they have an a.c. input taken from the signal generator. This signal oscillates above and below the 0 V level, but because the op-amp employs the twin (or dual) rail power supply, the circuit has no difficulty in handling the positive and negative signal levels.

THE INVERTING AMPLIFIER:

Set up the circuit shown in Fig. 5. , with R1 = 10k and R2 = 100k. Note that the power supply connections to pins 7 and 4 are no longer shown, but these must be included as before. Continue to use a +12 V / -12 V supply, but you will only be aware of the level of these voltages if the output attempts to become greater or less than them.

Use the signal generator set to a 1 V peak to peak SINE WAVE, at a frequency of 300 Hz. Monitor the output and input voltages with the C.R.O.

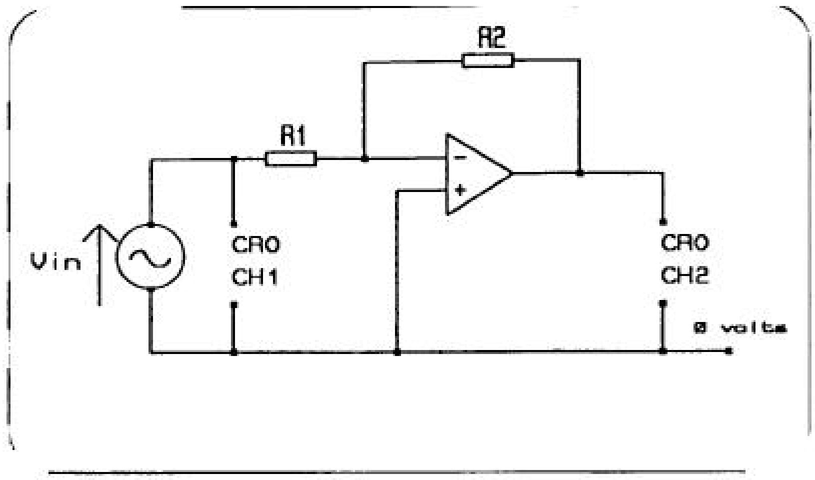


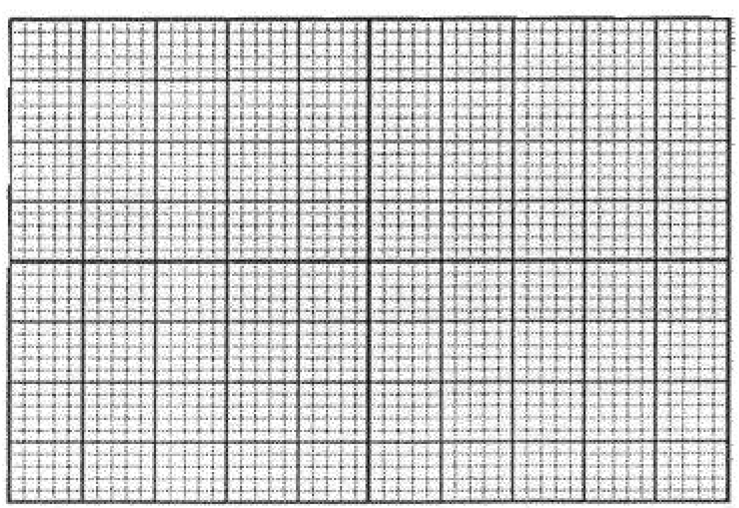
Fig. 5.

Questions: From the test results, answer the following questions.

(i) When the input signal is increased (ensure that the output signal remains sinusoidal), how is the amplifier gain affected ?

(ii) With the input reset to 1 V peak to peak, how is the gain affected by changing to a square or triangular waveform ?

(iii) Increase the magnitude of the input signal until the amplifier "saturates" (hits the supply rails). Sketch the resulting input and output waveforms on the graph below.



(iv) Alter the values of R1 and R2, but maintain the same ratio, e.g. R1 = 100k, R2 = 1M. How is the gain affected ?

(v) Alter the ratio R2/R1. Does this affect the gain ? YES/NO

What values of resistors would produce gains of:

100	R1=	R2=
0.5	R1=	R2=

Choose suitable values available in the laboratory and confirm the results.

(vi) What equation relates the amplifier gain to the values of R1 and R2?

<u>THE NON-INVERTING AMPLIFIER:</u>

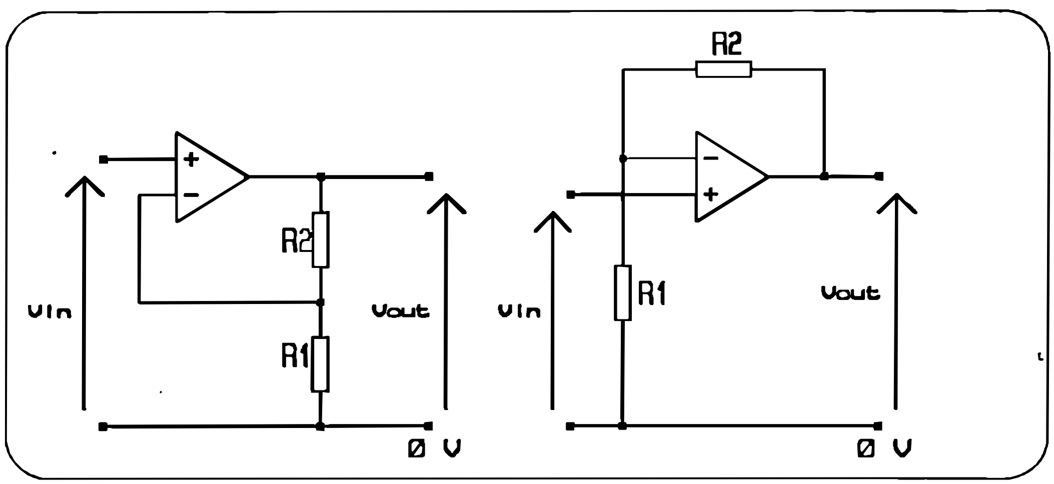


Fig. 6.

Set up the circuit shown in Fig. 6., which has been drawn in two ways.
On the left the + and - input have been inverted and this perhaps may been seen as giving a clearer layout, but could be confusing if you are used to seeing the - input at the top.

(With op-amp circuits, always look carefully and check which input is being used.)

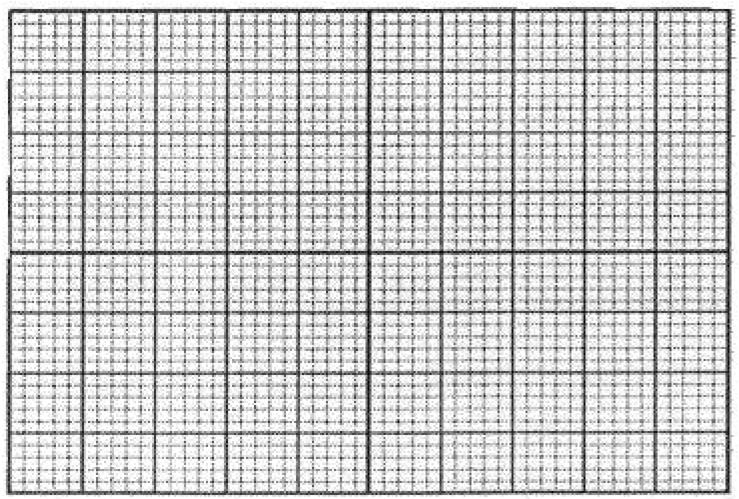
Basically, in this circuit there is a potential divider on the output and a fraction of the output voltage is fed back to the inverting input. The signal input is applied directly to the non-inverting input, pin 3.

Questions: Carry out test on the circuit and use the results to answer the following questions.

(i) When the input signal is increased (ensure that the output signal remains sinusoidal), how is the amplifier gain affected ?

(ii) With the input reset to 1 V peak to peak, how is the gain affected by changing to a square or triangular waveform ?

(iii) Increase the magnitude of the input signal until the amplifier "saturates" (hits the supply rails). Sketch the resulting input and output waveforms on the graph below.



(iv) Alter the values of R1 and R2, but maintain the same ratio, e.g. R1 = 100k, R2 = 1M. How is the gain affected ?

(v) Alter the ratio R2/R1. Does this affect the gain ? YES/NO

Measure the gain for a selection of R and R2 combinations. Hence, answer part (vi).

Results:

(vi) What equation relates the amplifier gain to the values of R1 and R2.

SECTION 3: SOUARE WAVE OSCILLATOR:
If time permits, investigate the circuit shown in Fig. 6. , which is used in the Organ Project. Note that only a single power supply is needed in this application. The advantage of this in the project is that only one battery is needed rather than two, thus reducing the cost.
The battery is represented by setting the d.c. power supply to 6 V.

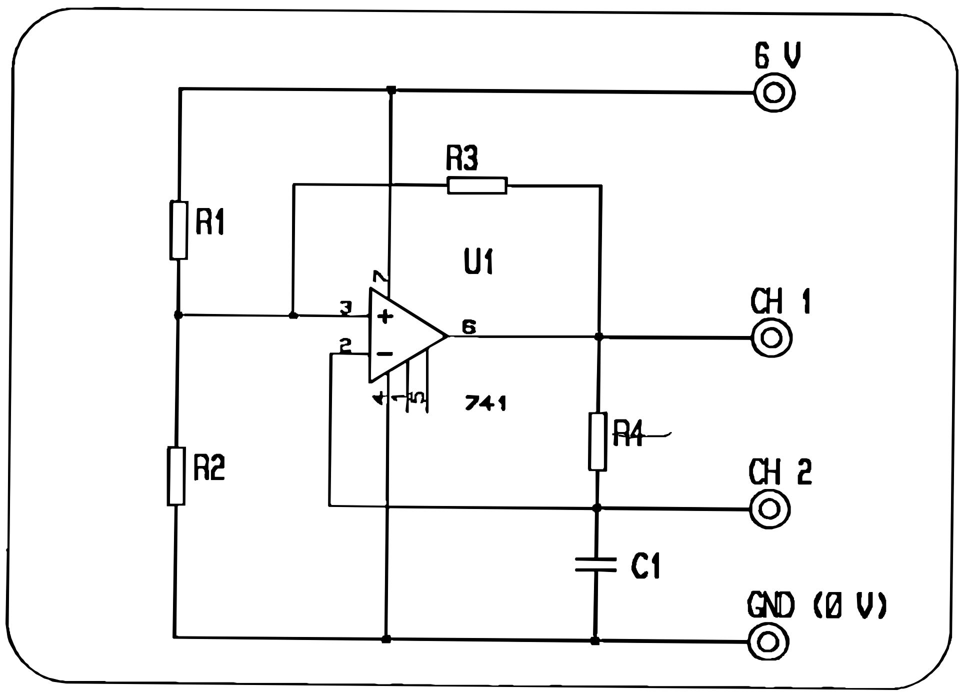
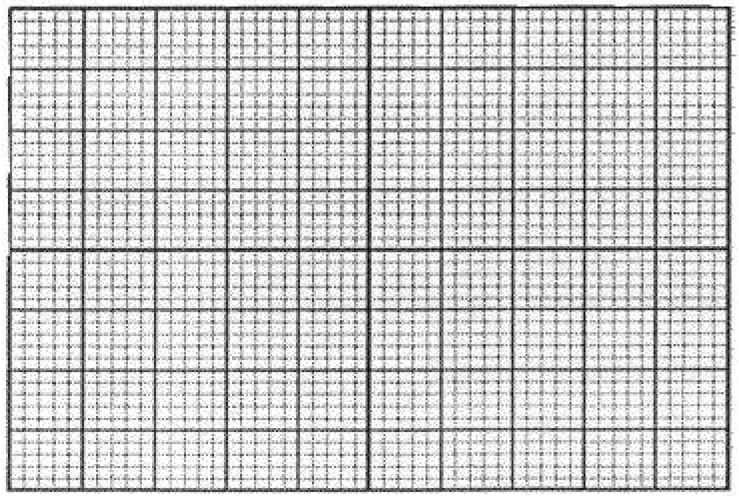


Fig. 7.

Firstly, re-draw the circuit with the + and - inputs of the op-amp swapped over to match the Locktronics module components. Connect up the circuit using initial values of:

R1, R2	50k
R3	100k
R4	30k (use 3 x 10k resistors in series).
C4	100nF

Observe the square wave on channel 1 and the capacitor voltage on channel 2 of the C.R.O.



On the test circuit, the period of oscillation was 2.5 ms, giving a frequency of 400 Hz.

What is the measured value of the oscillator frequency ?

Frequency = ... Hz

<u>Tests:</u>

<u>Varying R4.</u>

(i) Change R4 to 20k. How are the results changed? Explain the changes.

(ii) Change R4 to 10k. What is the result now ?

Varying R3.

Put R4 back to 30k and increase R3 to 200k.

What effect does this have on the switching voltages.

Record and explain the new frequency of oscillation.

Predict the effect of increasing R3 to 500k.

Check the result by changing the circuit and recording the results.