FREQUENCY RESPONSE OF A CAPACITOR

NAME: .... HOUSE: ....

CLASS: .... DATE: .... TEACHER: ....

Aims of this experiment:

1. Assemble a series circuit consisting of a signal generator, capacitor, resistor, multi-meter (in AC current mode). Record the potential difference across the signal generator and the capacitor using a dual-input oscilloscope.
2. Use the voltage traces and RMS current to plot the ratio of capacitor to input voltage amplitudes vs frequency, and also RMS current vs frequency.
3. For a fixed frequency (200Hz), plot RMS current vs capacitance.
4. EXTENSION: Investigate what happens when the signal generator produces a square or ‘sawtooth’ output.

TASK 1. Use the multi-meter (in resistance mode) to work out the actual resistance of the 100Ω rated resistor.

R = ... Ω

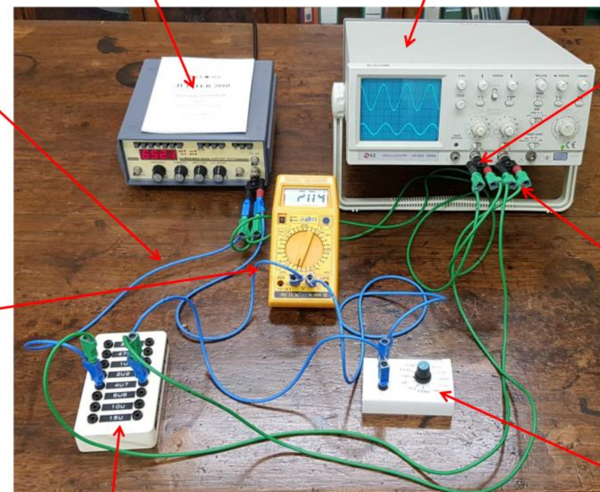
TASK 2. Set up the circuit using the diagram on the right. **Check with your teacher before proceeding.**

General settings:

- Signal generator set produce a sine wave of amplitude about 3.0V.
- Resistance is fixed at 100Ω (but with more precise reading measured above)
- Frequency range is 0 to 3,000Hz.
- Signal generator output on oscilloscope channel 1 (CH1), capacitor potential
- difference on channel 2 (CH2).
- Check the fine scale dials are fully turned to the right on the voltage divisions. This means the scale is calibrated and what you think it should be.

TASK 3. Set the capacitor to be 4.7μF. Explain in words in the boxes below how the capacitor voltage trace differs from the signal generator input as one increases frequency from 0 to 3,000Hz. How does the RMS current vary?

Equipment



Task 4a: Fill in the table below and plot the ratio of capacitor to input voltage amplitudes, and RMS currents vs frequency using the graph axes on the next page.

Frequency /Hz	Signal generator voltage /V (V_{in})	Capacitor potential difference /V (V_c)	'Gain' V_c/V_{in}	RMS current /mA

CAUTION: AS YOU CHANGE FREQUENCY V_{in} MAY CHANGE. CHANGE THE AMPLITUDE DIAL TO FIX IT AT 3.0V

Choose a capacitance from the list below for each plot

Capacitance:

(Delete as appropriate)

1.0μF
2.2μF
4.7μF

Plot each graph using a different colour, and don't forget to clearly label each trace with the corresponding capacitance.

Aim to plot the curves for 1.0mF and 4.7μF capacitors.

If you have sufficient time, do the 2.2μF also.

Task 4b: Fill in the table below and plot the ratio of capacitor to input voltage amplitudes, and RMS currents vs frequency using the graph axes on the next page.

Frequency /Hz	Signal generator voltage /V (V_{in})	Capacitor potential difference /V (V_c)	'Gain' V_c/V_{in}	RMS current /mA

CAUTION: AS YOU CHANGE FREQUENCY V_{in} MAY CHANGE. CHANGE THE AMPLITUDE DIAL TO FIX IT AT 3.0V

Choose a capacitance from the list below for each plot

Capacitance:

(Delete as appropriate)

1.0μF
2.2μF
4.7μF

Plot each graph using a different colour, and don't forget to clearly label each trace with the corresponding capacitance.

Aim to plot the curves for 1.0mF and 4.7μF capacitors.

If you have sufficient time, do the 2.2μF also.

Task 4c: Fill in the table below and plot the ratio of capacitor to input voltage amplitudes, and RMS currents vs frequency using the graph axes on the next page.

Frequency /Hz	**Signal generator voltage /V (V_{in})**	**Capacitor potential difference /V (V_c)**	**'Gain' V_c/V_{in}**	**RMS current /mA**

CAUTION: AS YOU CHANGE FREQUENCY V_{in} MAY CHANGE. CHANGE THE AMPLITUDE DIAL TO FIX IT AT 3.0V

Choose a capacitance from the list below for each plot

Capacitance:

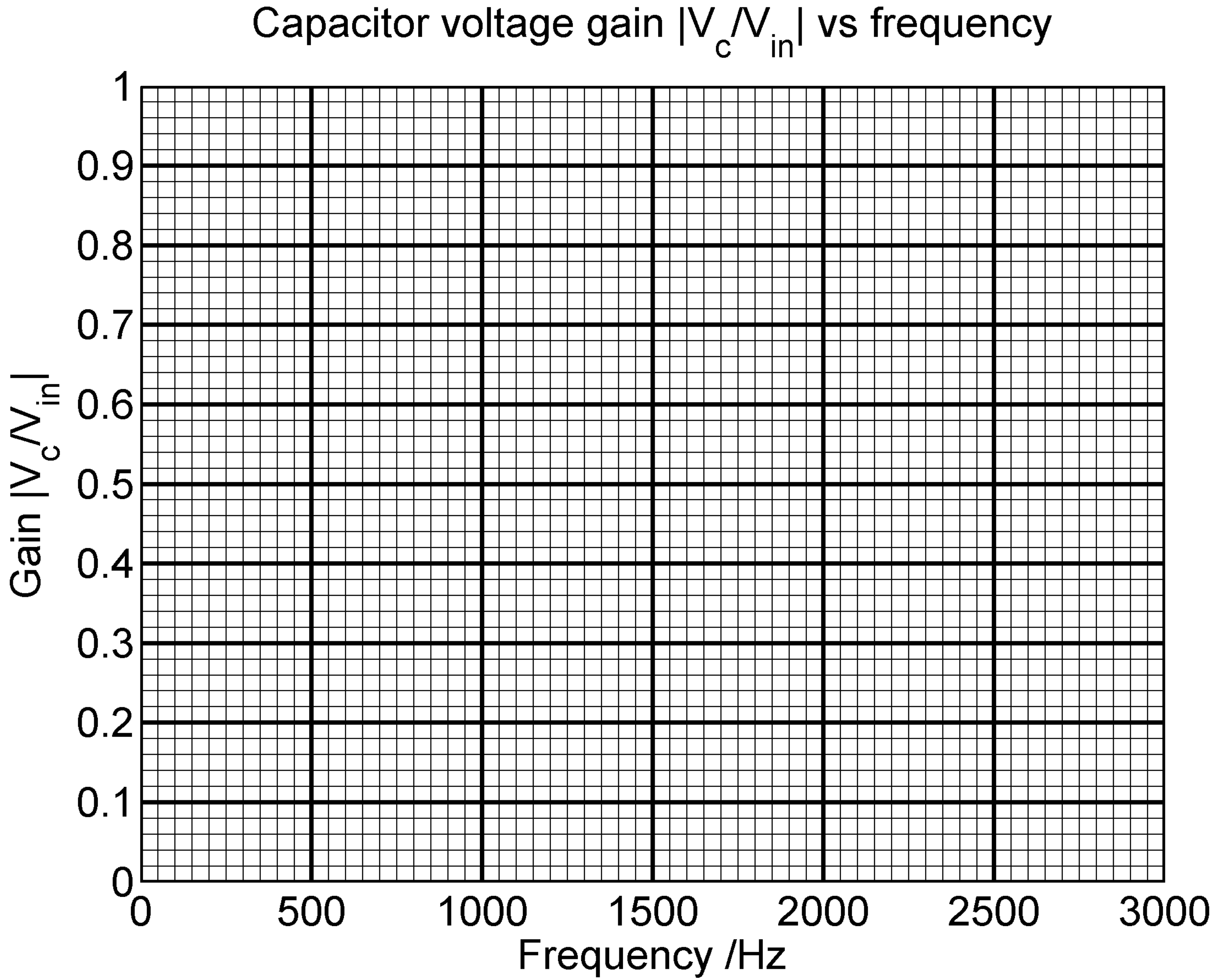
(Delete as appropriate)

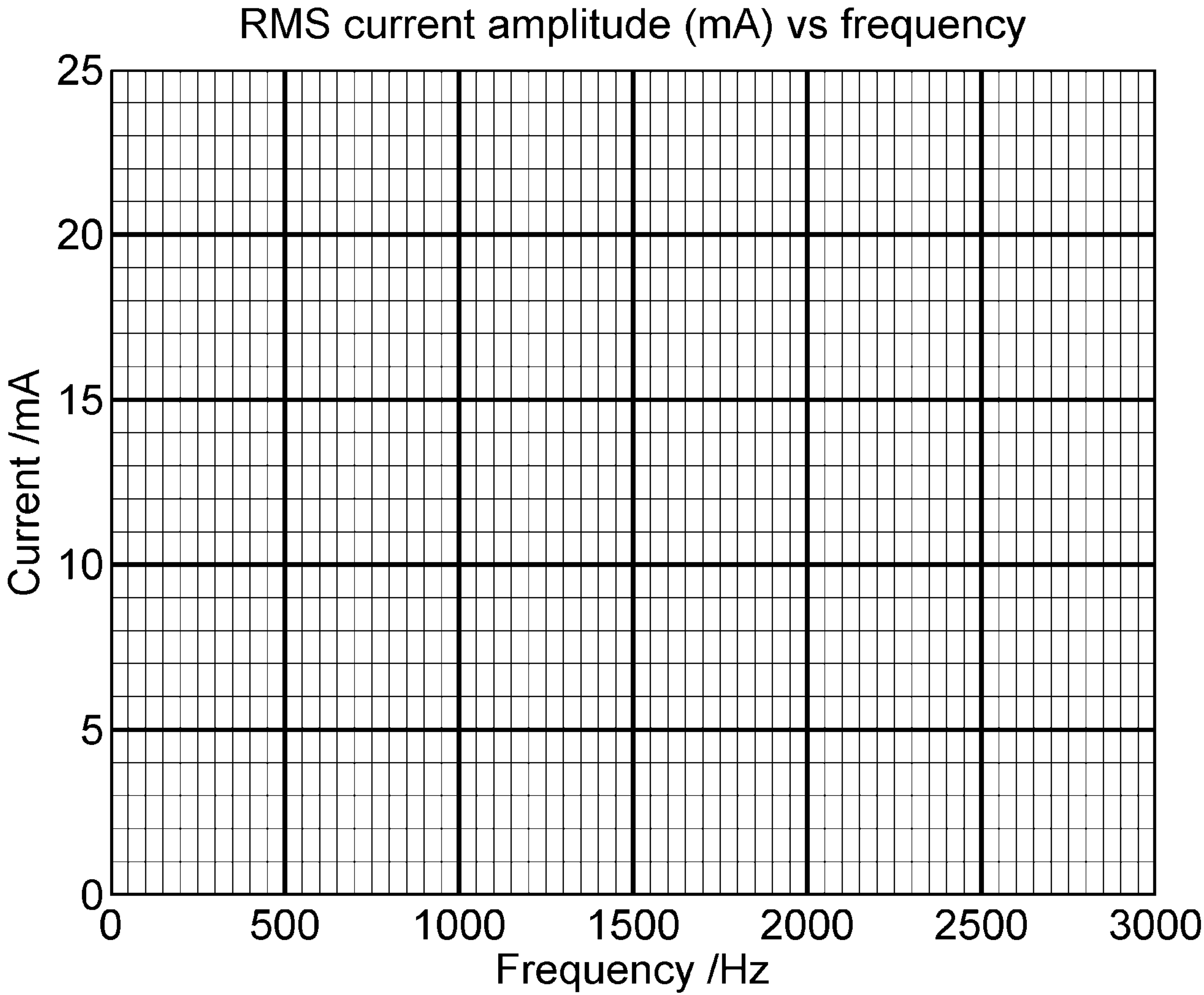
1.0μF
2.2μF
4.7μF

Plot each graph using a different colour, and don't forget to clearly label each trace with the corresponding capacitance.

Aim to plot the curves for 1.0mF and 4.7μF capacitors.

If you have sufficient time, do the 2.2μF also.


Capacitor voltage gain |Vc/Vin| vs frequency
Gain |Vc/Vin|
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
500
1000
1500
2000
2500
3000
Frequency /Hz

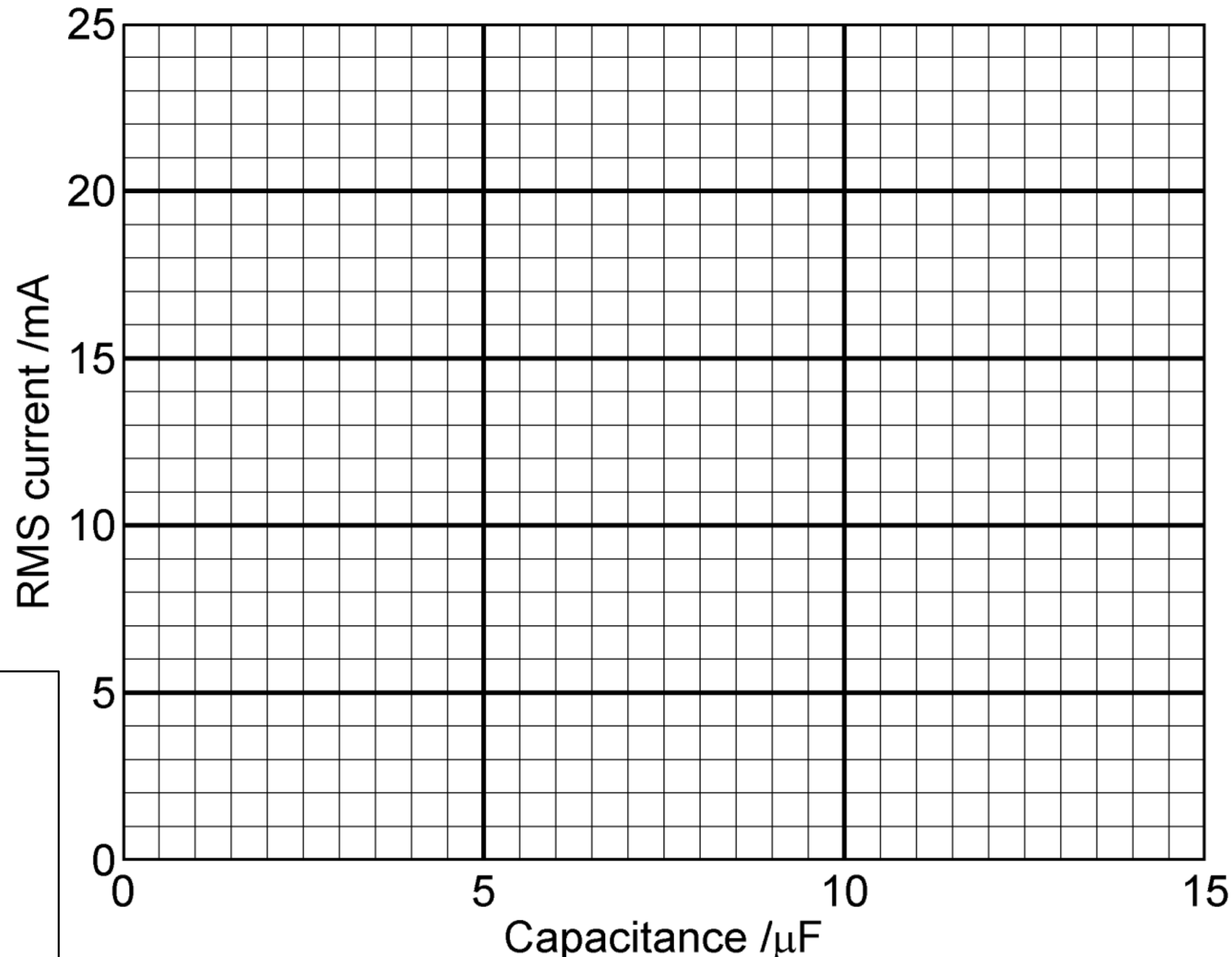

RMS current amplitude (mA) vs frequency
Current /mA
25
20
15
10
5
0
0
500
1000
1500
2000
2500
3000
Frequency /Hz

TASK5: Comment on the shapes of the graphs you have just plotted. Refine your commentary in **TASK3** following the graphs. **BE QUANTITATIVE**.

Task 6. Set the frequency to 200Hz and keep the the signal generator at 3.0V (sine wave) and the resistor at 100Ω.
Record the RMS current over the full range of capacitances. Plot the data using the axes below. Comment on the relationship in the text box below the axes.
Calculate the characteristic frequencies to help your conclusion.

Capacitance /μF	**RMS current /mA**	**Characteristic frequency /Hz**
0.22		
0.47		
1.00		
2.20		
4.70		
6.80		
10.00		
15.00		

RMS current vs capacitance. f= Hz. $|V_{in}|$=3V, R = 100Ω.



Characteristic frequency: $$f_c = \frac{1}{2\pi RC}$$

EXTENSION: Set the capacitance to be 15μF, and change the signal generator output to be (i) a **square wave** and then (ii) a '**sawtooth**' (triangle) wave.
Set the frequency to be 3,000Hz in each case and change the time-base to see the waveforms clearly. Report your observations and draw appropriate sketches of the oscilloscope traces. Why do you think an RC circuit can be thought of as an 'analogue calculus machine?'