Lab 07: Function Generator

【目的】

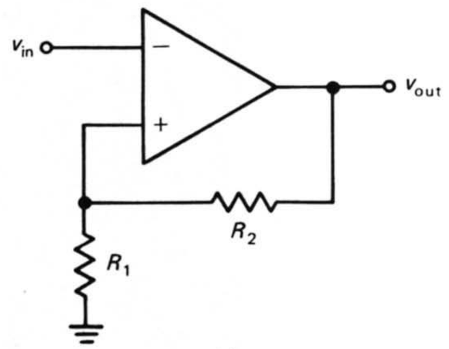
Build circuit to generate square wave and triangle wave using opamp

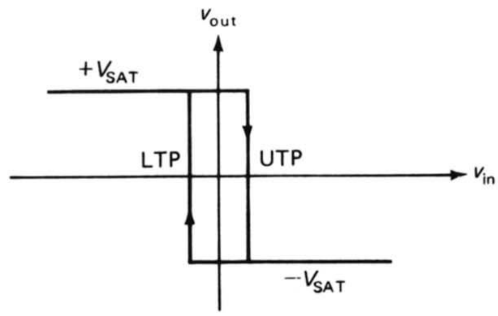
【原理】

Positive feedback and Schmitt trigger

An op amp Schmitt trigger is configures as positive feedback. Because of the positive feedback to non-inverting input, the output is saturated in either the positive or negative direction. The upper trip point (UTP) and lower trip point (LTP) can be found as

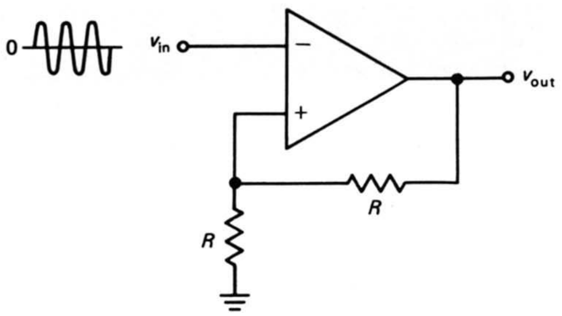
$$UTP = \frac{R_1}{R_1 + R_2} V_{SAT} \qquad LTP = \frac{-R_1}{R_1 + R_2} V_{SAT}$$

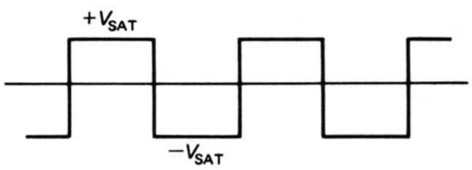




One way to generate square way is to drive a Schmitt trigger with a sine wave whose positive peak is greater than the UTP and negative peak is less than LTP. The shape of input signal is immaterial. Instead of a sine wave, any periodic signal with sufficient amplitude to drive the Schmitt trigger can result in an output square wave.

$$UTP = \frac{1}{2} V_{SAT} \qquad LTP = \frac{-1}{2} V_{SAT}$$

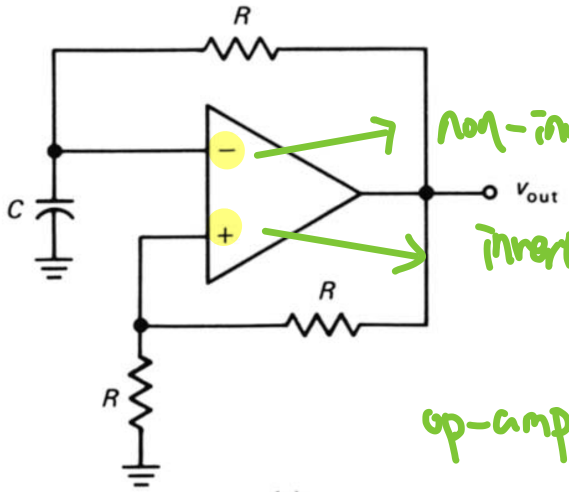




Relaxation Oscillator

Relaxation oscillator is a circuit whose output frequency depends on the charging and discharging of a capacitor. Instead of being externally driven by any function generator, the circuit supplies its own input voltage by way of the RC circuit. Assume the output is positively saturated at first. The non-inverting input is $V_+ = V_{SAT}/2$. On the other hand, the inverting input start to charging exponentially from 0 V. As long as the capacitor voltage is less than the UTP, the output remains at positive saturation. As capacitor voltage (V_-) goes slightly more than UTP, the output voltage switch to negative saturation. The non-inverting input also switch to $V_+ = -V_{SAT}/2$. The inverting input start to discharging exponentially. The switch happen again when capacitor voltage (V_-) become slightly lower than LTP. The output is square wave and input is an exponential wave. A mathematical analysis shows the frequency of the output square wave is

$$f = \frac{0.455}{RC}$$

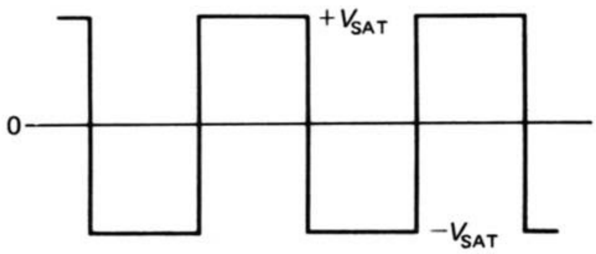


non-inverting input

inverting input

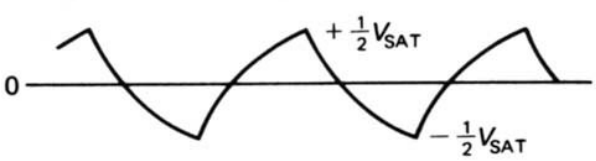
op-amp $\begin{cases} V_+ > V_- : & \text{output} = V_{SAT} \\ V_- > V_+ : & \text{output} = -V_{SAT} \end{cases}$

(a)



output

(b)



input

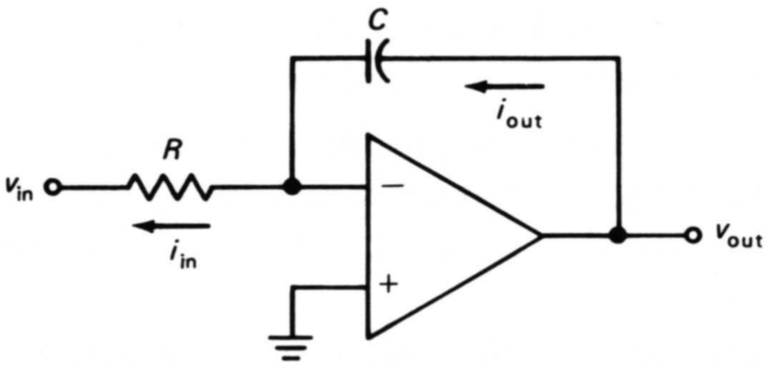
(c)

Op Amp Integrator

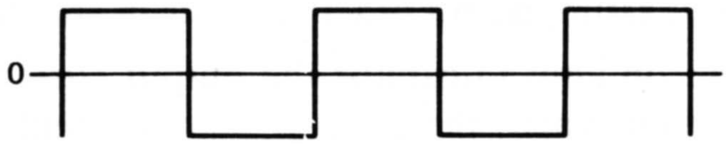
$$i_{out} = i_{out} = \frac{-v_{in}}{R} \qquad v_{out} = \frac{Q}{C} = \frac{i_{out}t}{C} = \frac{-v_{in}}{CR}t$$

When square wave drive an op amp integrator, the output is a triangular wave.

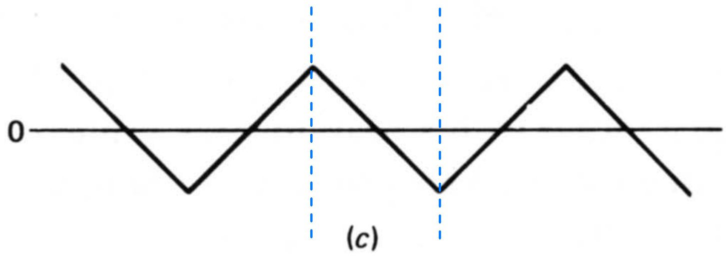
$$v_{out(p-p)} = \frac{v_{in(max)}}{CR}\frac{T}{2} = \frac{v_{in(max)}}{2fCR} = \frac{v_{in(p-p)}}{4fCR}$$



(a)



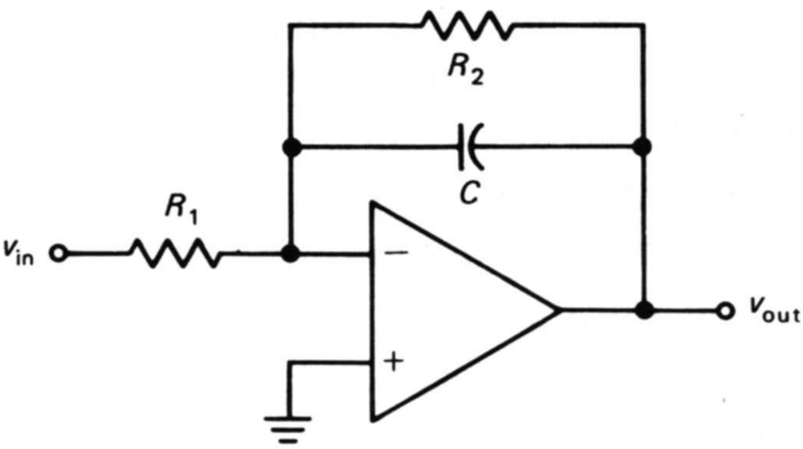
(b)



(c)

Because a capacitor appears open at zero frequency, the input offset may saturate op amp. To avoid this, a resistor is usually shunted across the capacitor. Typically, this resistance R_2 is 5 ot 10 times larger than the input resistance R_1. This shunt resistance has virtually no effect on the output, provided the input frequency is much greater than $1/2\pi R_2 C$

$$f \gg \frac{1}{2\pi R_2 C}$$



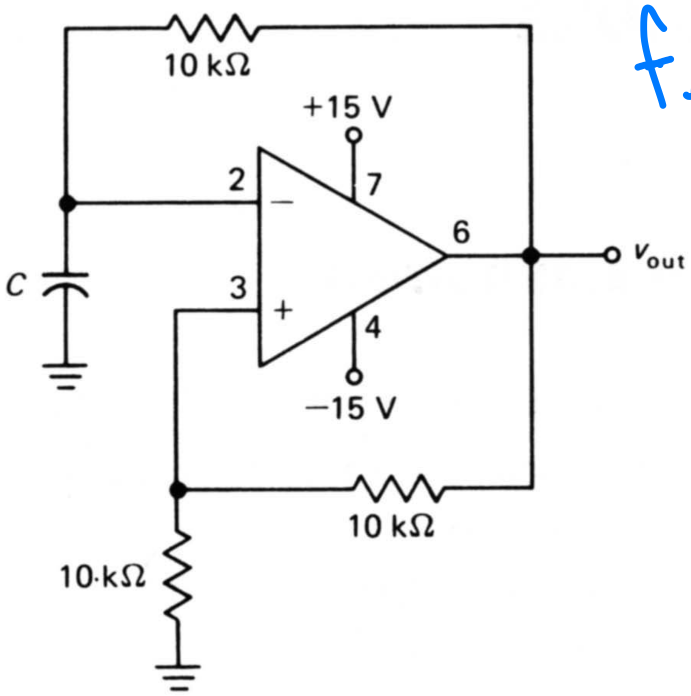
【儀器】

示波器、電源供應器、電阻(10KΩx3, 12KΩ, 100KΩ)、電容(0.022uF (223) x2, 0.047uF (473), 0.1 uF)、OPAMP (ua741C x2)

【步驟】

Relaxation Oscillator

1. Calculate theoretical frequency of V_{out} for capacitors listed in the table.
2. Connect the circuit using C=0.022 uF
3. Draw the wave form of V_{out} (pin6). Measure and record the peak-to-peak value and frequency (f_{meas}) in table.
4. Draw the wave form of V_{in} (pin2). Measure and record the peak-to-peak value in table.
5. Change capacitors (0.047 uF and 0.1 uF) and repeat step 3 and 4.



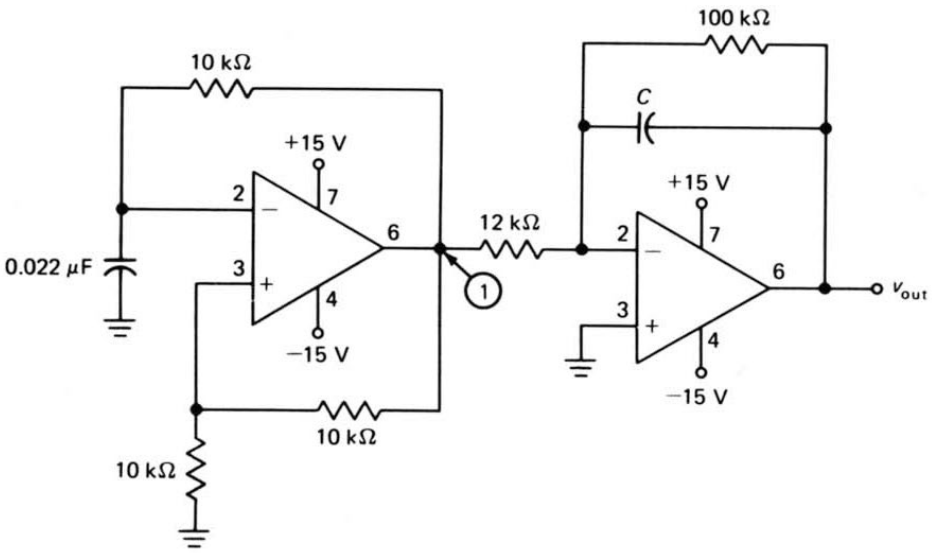
$$f_{th} = \frac{0.455}{(0.022\times10^{-6})\times(10\times10^{3})}$$

$$= \frac{45500}{22}$$

$$= 2068$$

Op Amp integrator

1. Connect the circuit using C=0.022 uF. Note use 0.022 uF in relaxation oscillator now.
2. Measure and record the peak-to-peak voltage and draw the waveform at TP1 and V_{out}.
3. Change Capacitor (0.047 uF and 0.1 uF) and repeat step 2.



【問題與討論】

Relaxation oscillator

1. Dose the measured frequency differ from the calculated frequency? If yes, give one reason why?
2. Why is the input voltage approximately half the output voltage?

Op integrator

3. What is the approximate frequency driving the integrator (output of the relaxation oscillator)?
4. Explain why the integrator output decrease when capacitor increases?

【補充】紀錄表格

Relaxation oscillator

C	**f_{calc}**	**V_{out} (PIN6)**	**fmeas**	**V_{in} (PIN2)**
0.022	2068	12.5	2083	6.5
0.047	968	12.5	882	6.5
0.1	445	12.5	417	6.5

Op integrator (波型與振幅)

C	**TP1 V_{p-p} (pin 6 of 1st OP)**	**$V_{out, p-p}$**
0.022		12
0.047	24	4.4
0.1		2.2