EE 2245 Microelectronics Labs

Lab 5: Oscillator Design

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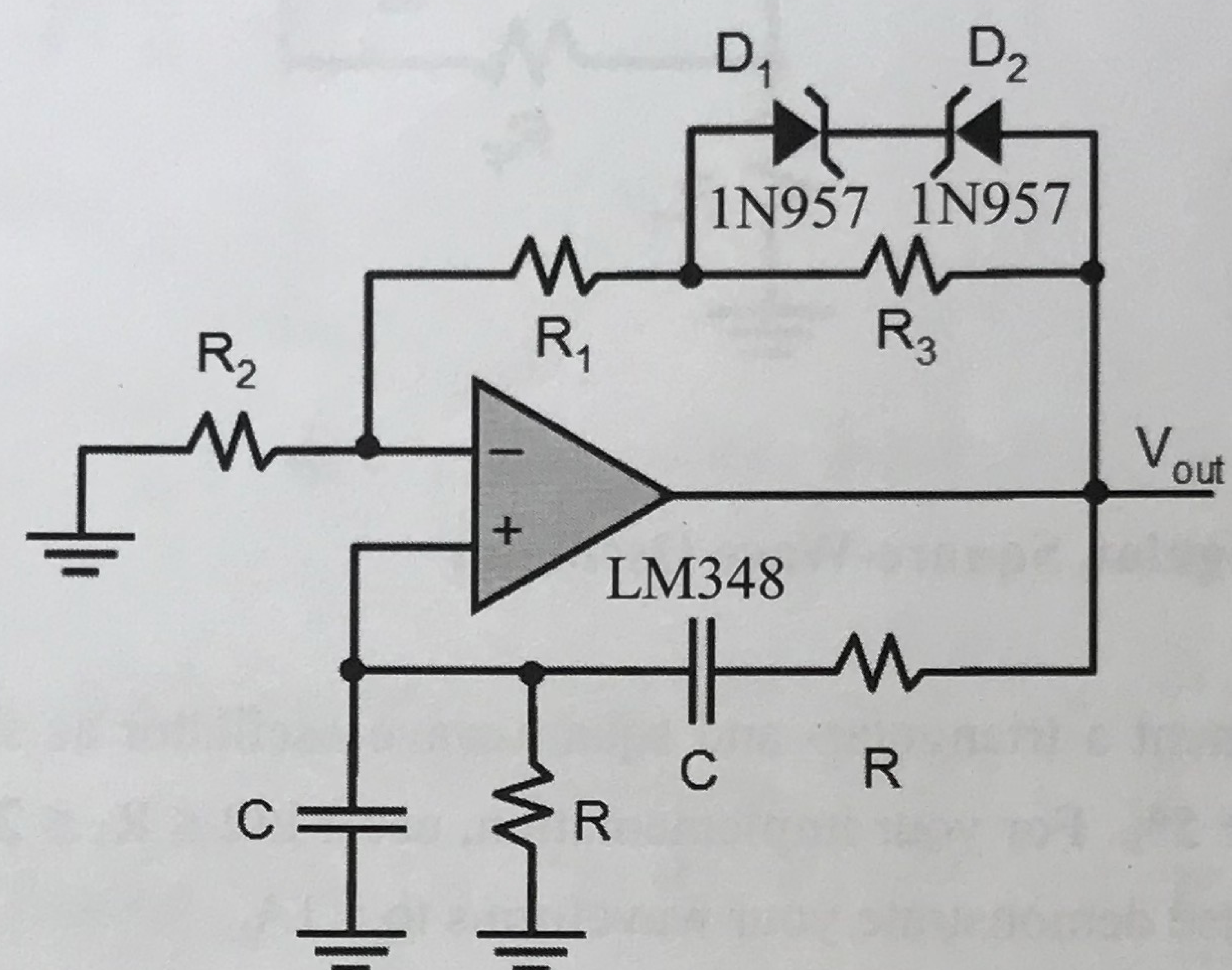
Design Problem I: The Wien-Bridge Oscillator

You are required to implement a Wien-bridge oscillator as shown with an oscillation frequency of 4 kHz and a tolerance of ± 5%. For your implementation, you can only use resistors with values from 1 kΩ to 40 kΩ. Please show your waveform to a TA.



In the report, you need to provide:

(1) Design procedure.
(2) Values of passive elements used in the experiment.
(3) The measured output waveform with some data points indicating the values.
(4) Comments on the experimental result with respect to your calculation.

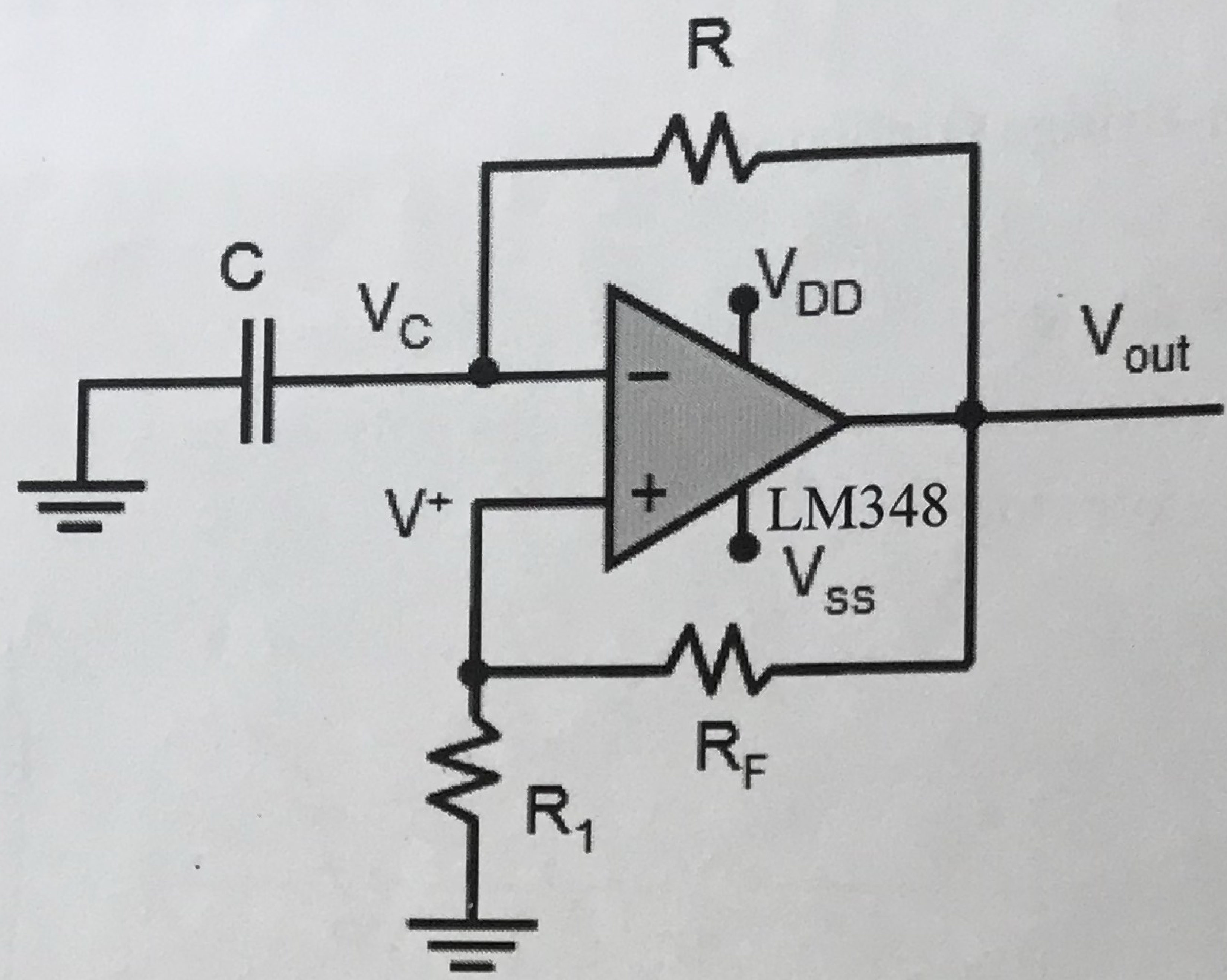
Design Problem II: The Relaxation Oscillator

You are required to implement a relaxation oscillator as shown with an oscillation frequency of 1 kHz and a tolerance of ±5%. **Before you implement the circuit, please show your calculation of the oscillation frequency to a TA (or me).** For your implementation, you can only use resistors with values from 1 kΩ to 10 kΩ. Please show your waveform to a TA.

In the report, you need to provide:

(1) Design procedure.

(2) Values of passive elements used in the experiment.
(3) The measured waveforms of V_{out} and V_c with some data points indicating the values.
(4) Comments on the experimental result with respect to your calculation.

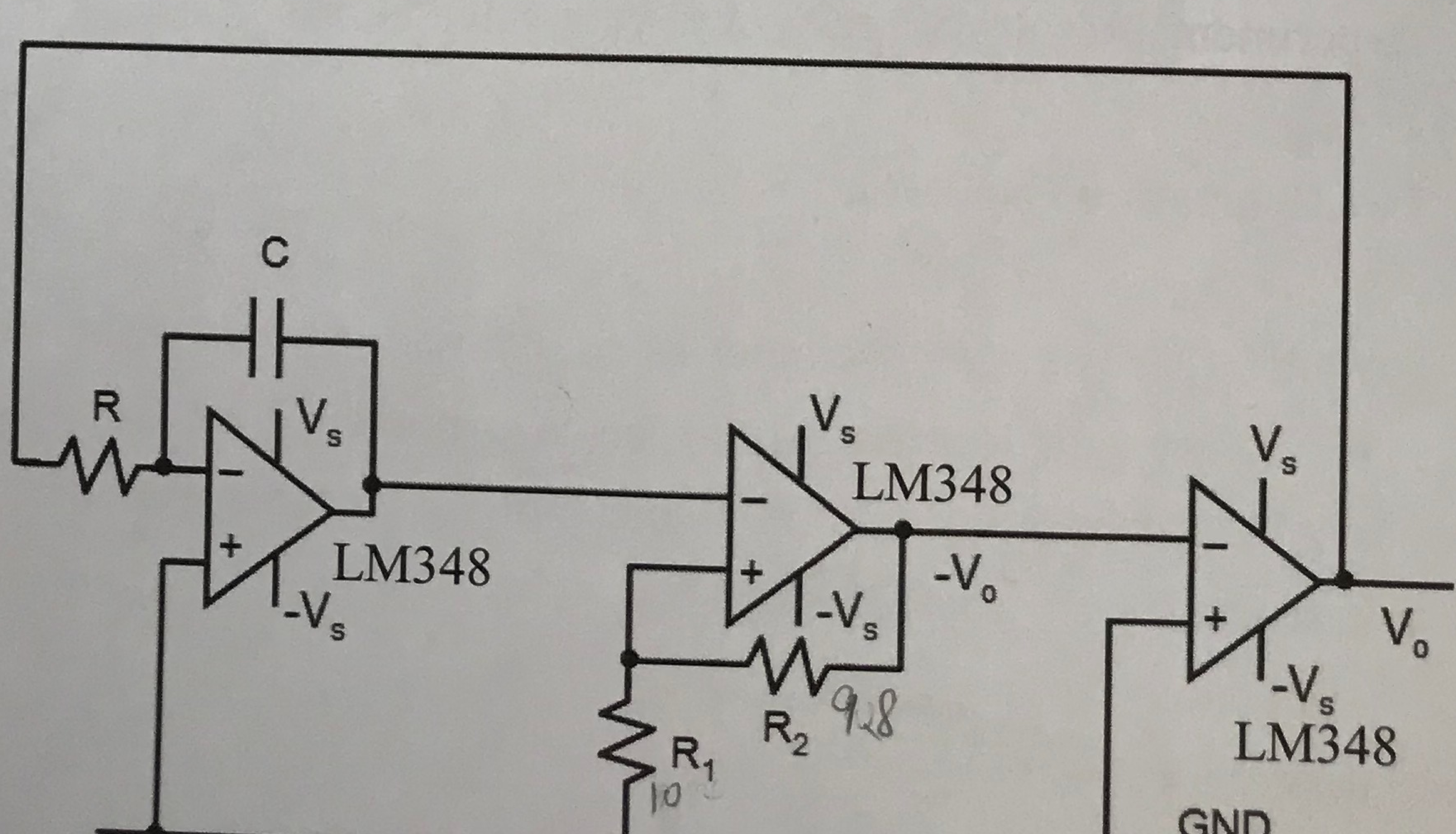


Design Problem III: Triangular, Square-Wave Oscillator

You are required to implement a triangular- and square-wave oscillator as shown with a frequency of 800 Hz and a tolerance of ± 5%. For your implementation, use 1 kΩ ≤ R_1 ≤ 20 kΩ, 1 kΩ ≤ R_2 ≤ 20 kΩ, and 1 kΩ ≤ R ≤ 30 kΩ. Please demonstrate your waveforms to a TA.

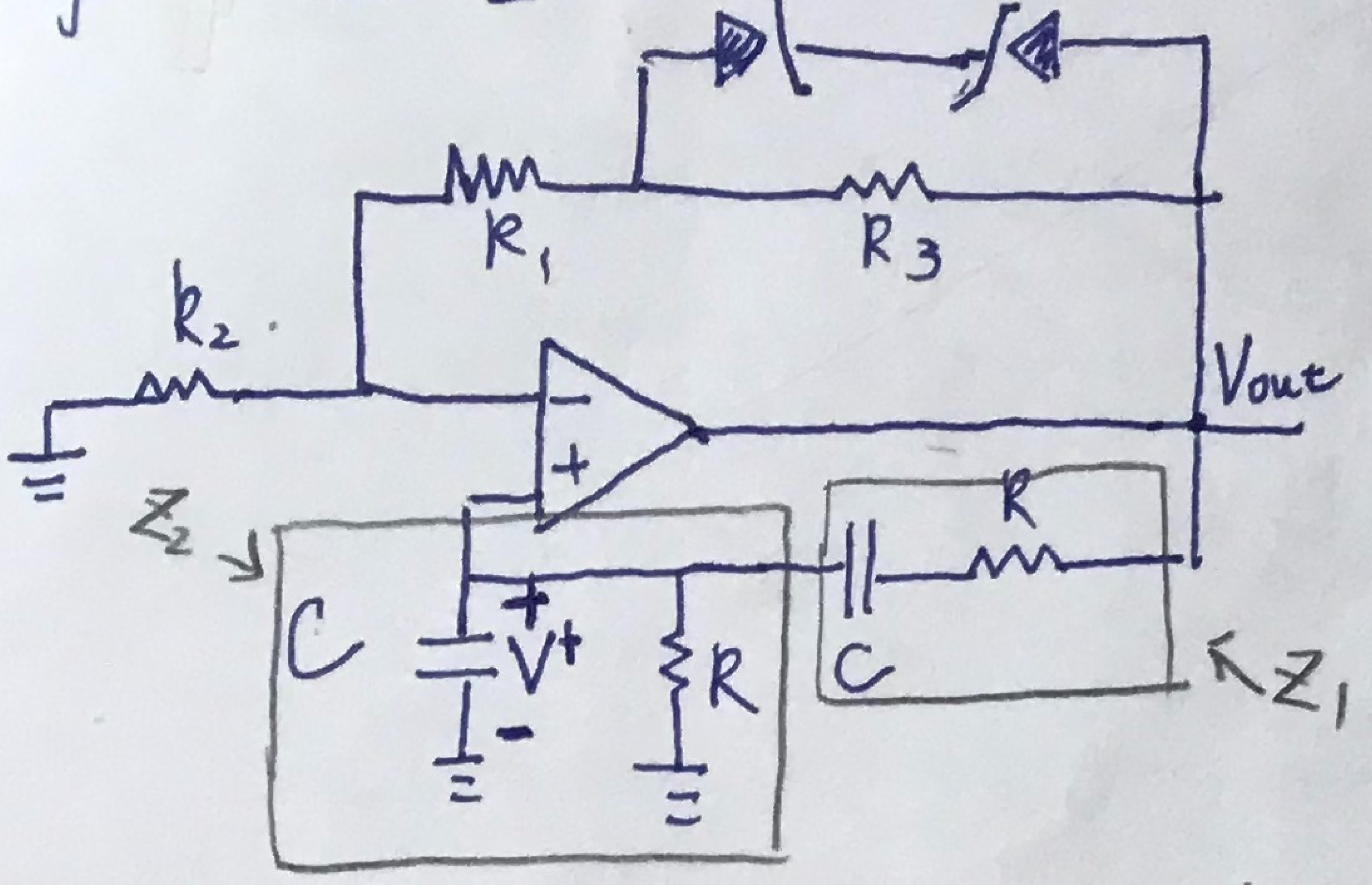
In the report, you need to provide:

(1) Design procedure.
(2) Values of passive elements used in the experiment.
(3) The measured square and triangular waveforms with some data points indicating the values.
(4) Comments on the experimental result with respect to your calculation.



Design Problem I

(1)

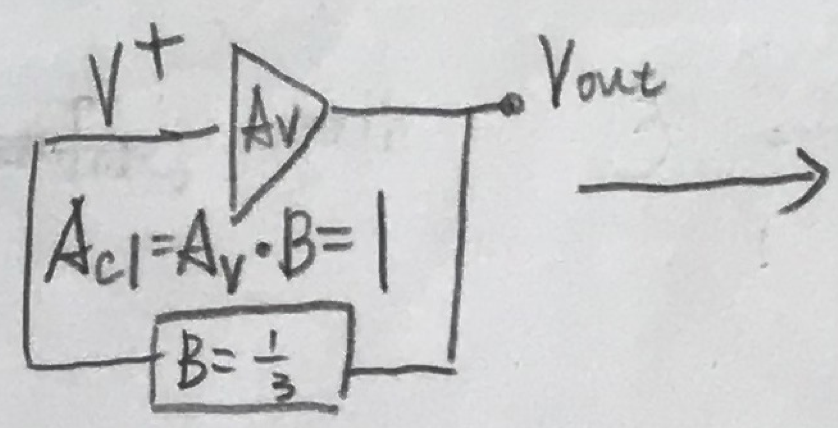


$$\frac{V^+(s)}{V_{out}(s)} = \frac{Z_2}{Z_1+Z_2} = \frac{R /\!/ \frac{1}{sC}}{(R+\frac{1}{sC}) + R /\!/ \frac{1}{sC}}$$

$$= \frac{sRC}{R^2C^2s^2 + 3RCs + 1}$$

$s=j\omega$ 代入

$$\frac{V^+(j\omega)}{V_{out}(j\omega)} = \frac{j\omega RC}{(1-\omega^2R^2C^2) + j\omega 3RC},$$ and the phase shift between V^+ & Vout must be zero to produce oscillation. ∴ $1-\omega^2R^2C^2=0 \Rightarrow \omega = \frac{1}{RC}$ (↳ resonant frequency) $\Rightarrow \frac{V^+(j\omega)}{V_{out}(j\omega)} = \frac{j\omega RC}{j\omega 3RC} = \frac{1}{3}$



⟶ Therefor $A_V = 3 = 1 + \frac{R_1}{R_2}$ ∴ $R_1 = 2R_2$

(2)

To get $f = 4\ kHz = \frac{1}{2\pi RC}$, and $R_1 = 2R_2$

	R_1	R_2	R_3	R		C	
calculated value	20kΩ	10kΩ	1kΩ	20kΩ	20kΩ	2nF	2nF
measured value	20.074kΩ	9.91kΩ	1.002kΩ	20.85 kΩ	19.96 kΩ	1.96 nF	2.02nF

(3) waveform 附在最後一頁

(4)

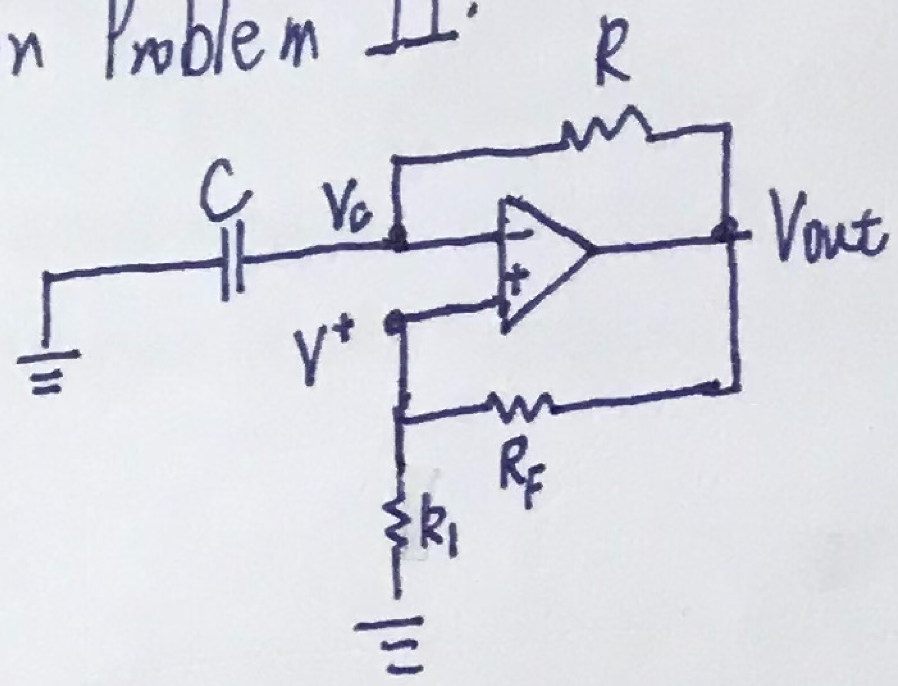
由於R_1取的比理論值大一點，∴A_V太大造成 Vout 大過於 VDD 造成波峰會有平的部分

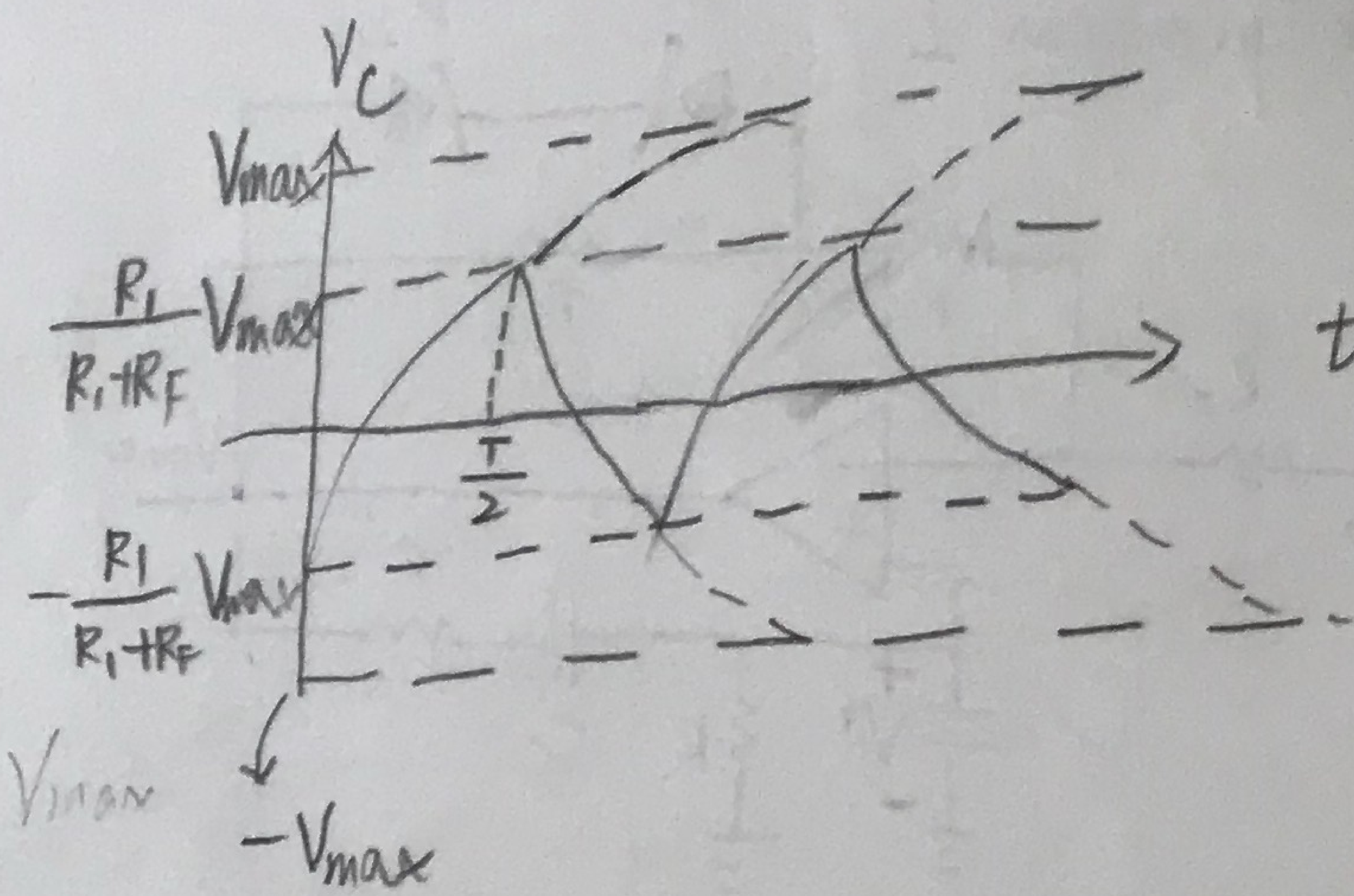
measured frequency = 3.925kHz

Error rate = $\frac{3.925-4}{4} = -1.875\%$

The error rate is pretty small!

Design Problem II:





(1) $\frac{V_{out}-V_c}{R} = C\frac{dV_c}{dt}$,

$\Rightarrow \frac{dt}{RC} = \frac{dV_c}{V_{out}-V_c}$

$\Rightarrow \frac{-t}{RC}\Big|_{t=0}^{t} = -\ln(V_{out}-V_c)\Big|_{V_c(0)}^{V_c(t)}$

$\Rightarrow \frac{-t}{RC} = \ln\left(\frac{V_{out}-V_c(t)}{V_{out}-V_c(0)}\right)$

$\Rightarrow e^{-\frac{t}{RC}} = \frac{V_{out}-V_c(t)}{V_{out}+\frac{R_1}{R_1+R_F}V_{out}}$

$V_c(\frac{T}{2}) = \frac{R_1}{R_1+R_F}V_{max}$, $V_{max} = V_{out}$

$\Rightarrow e^{-\frac{T}{2RC}} = \frac{V_{out}-\frac{R_1}{R_1+R_F}V_{out}}{V_{out}+\frac{R_1}{R_1+R_F}V_{out}} = \frac{R_F}{2R_1+R_F}$

$\Rightarrow \frac{-T}{2RC} = \ln\left(\frac{R_F}{2R_1+R_F}\right) \Rightarrow T = -2RC\cdot\ln\left(\frac{R_F}{2R_1+R_F}\right)$

$\Rightarrow f_0 = \frac{1}{T} = \frac{1}{2RC\ln(1+\frac{2R_1}{R_F})} = 1\,kHz$

Assume $R_1 = R_F = 2k\Omega$

$\Rightarrow f_0 = \frac{1}{2RC\ln(3)} = 1kHz \Rightarrow RC = 4.5512\times10^{-4}$

(2)

	R	C	R_1	R_F
selected value	4551.2Ω	100nF	2kΩ	2kΩ
measured value	4.67kΩ	102.5nF	1.98kΩ	1.99kΩ

(3) wavefore 附在最後一頁

(4) V_c measured frequency = 988.1 Hz

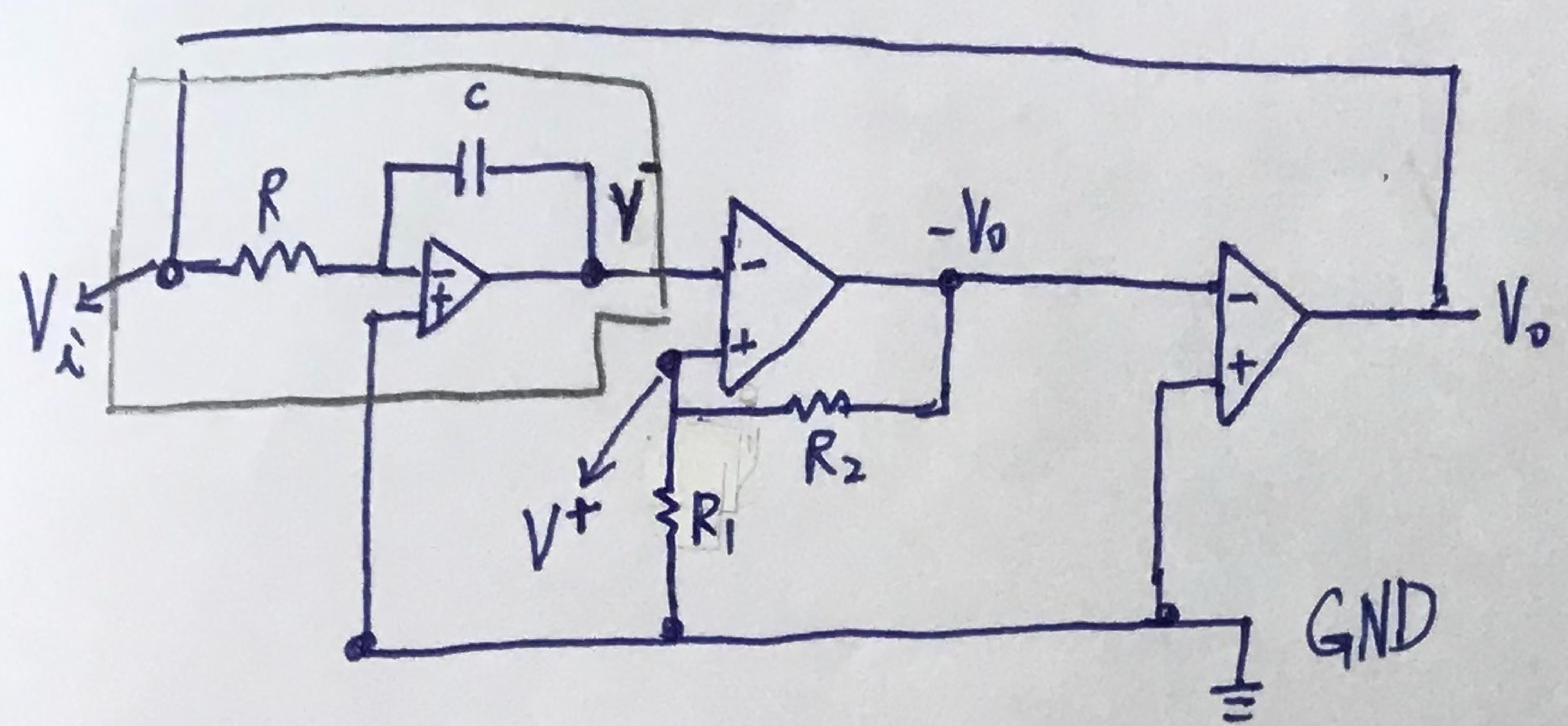
Error rate = $\frac{988.1-1000}{1000} = -1.19\%$

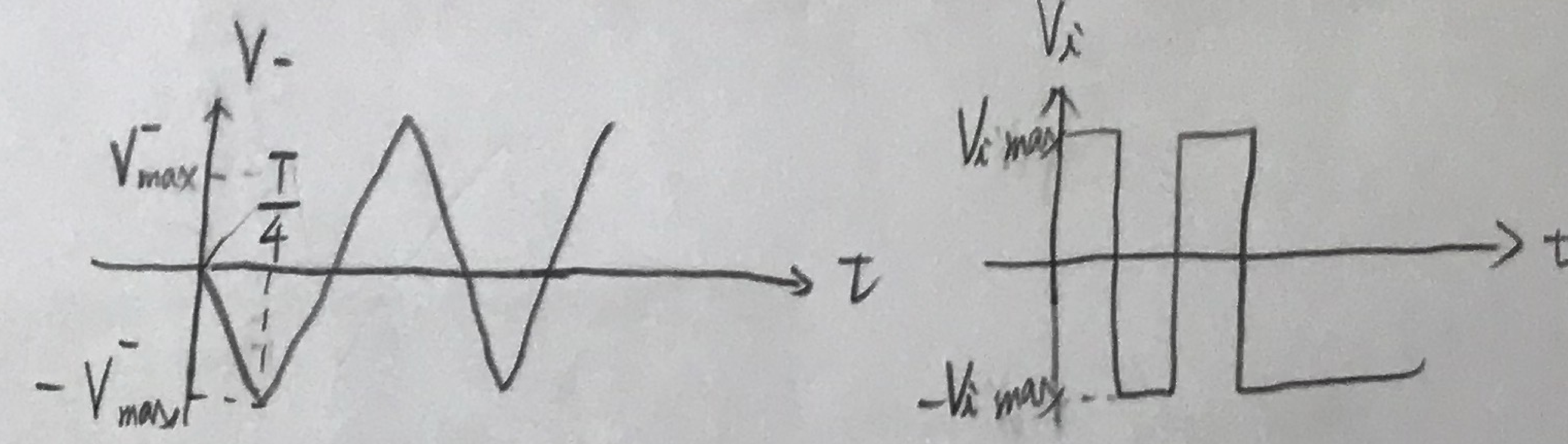
V_{out}: measured frequency = 989.4 Hz

Error rate = $\frac{989.4-1000}{1000} = -1.06\%$

誤差可能來自導線、儀器微量的寄生電阻

Design Problem III





$$V^-_{max} = \frac{-1}{RC} V_{i,max} \frac{T}{4}$$

1)

$$\frac{V^-(S)}{V_i(S)} = -\frac{1}{sRC}$$

$$\Rightarrow V^-(t) = \int_0^t \frac{-1}{RC} V_i (dt)$$

$$= \frac{-1}{RC} V_i t$$

Schmitt Trigger: 令 $R_1 = R_2 \Rightarrow V^+ = \frac{-1}{2} V_0$ $\Rightarrow V^-$ 振幅 $= \left|\frac{1}{2} V_{i,max}\right|$ 才能比較

振幅 $= \left|\frac{1}{2} V_{i,max}\right|$

$$\therefore \frac{T}{4} \times \frac{1}{RC} V_{i,max} = \frac{1}{2} V_{i,max} \Rightarrow RC = \frac{T}{2} \Rightarrow T = 2RC = \frac{1}{800} \Rightarrow RC = 6.25 \times 10^{-4}$$

2)

	selected	measured
R_1	10kΩ	9.84kΩ
R_2	10kΩ	10.05kΩ
R	6.25kΩ	6.26kΩ
C	0.1μF	60nF

(3)

waveform 附在最後一頁

(4)

Measured frequency = 821 Hz

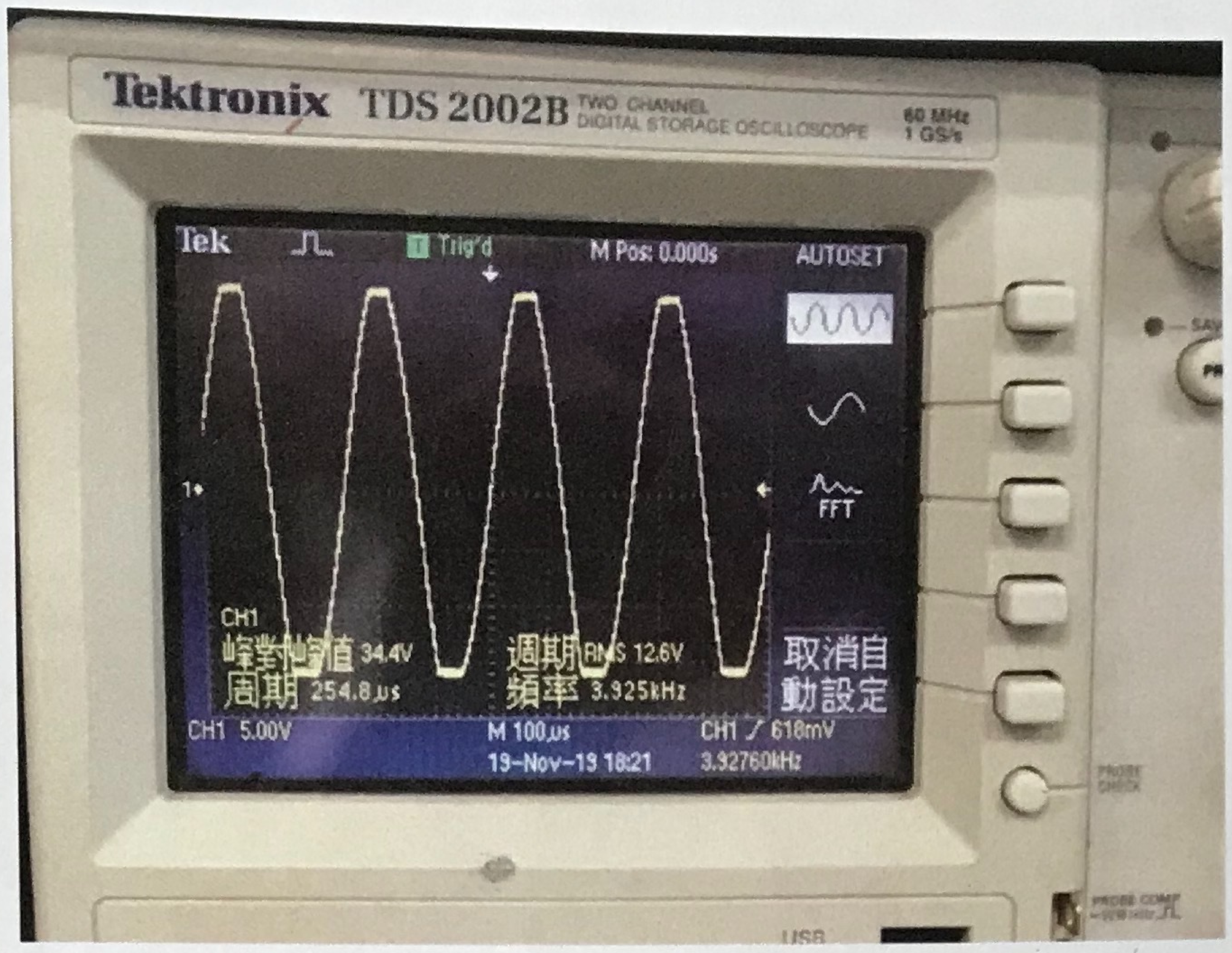
Error rate = $\frac{821-800}{800}$ = 2.625%

Note that the value of measured C is much less than its calculated value.

I think it's because the value of measured R is larger than its calculate value, RC = constant and there is some parasitic resistance in wire.

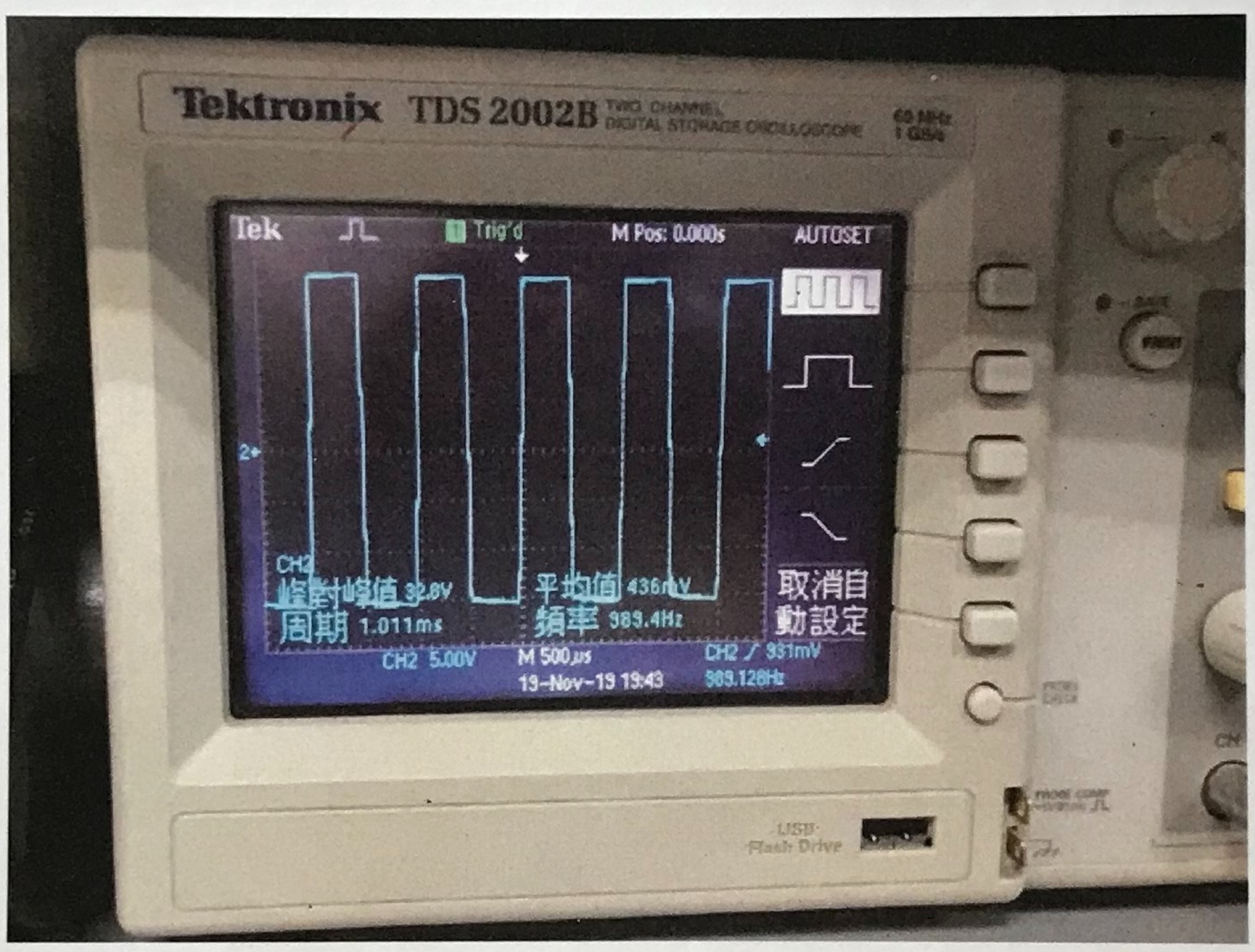
Also, parasitic resistance may cause error on measured frequency.

Design Problem 1



Design Problem 2

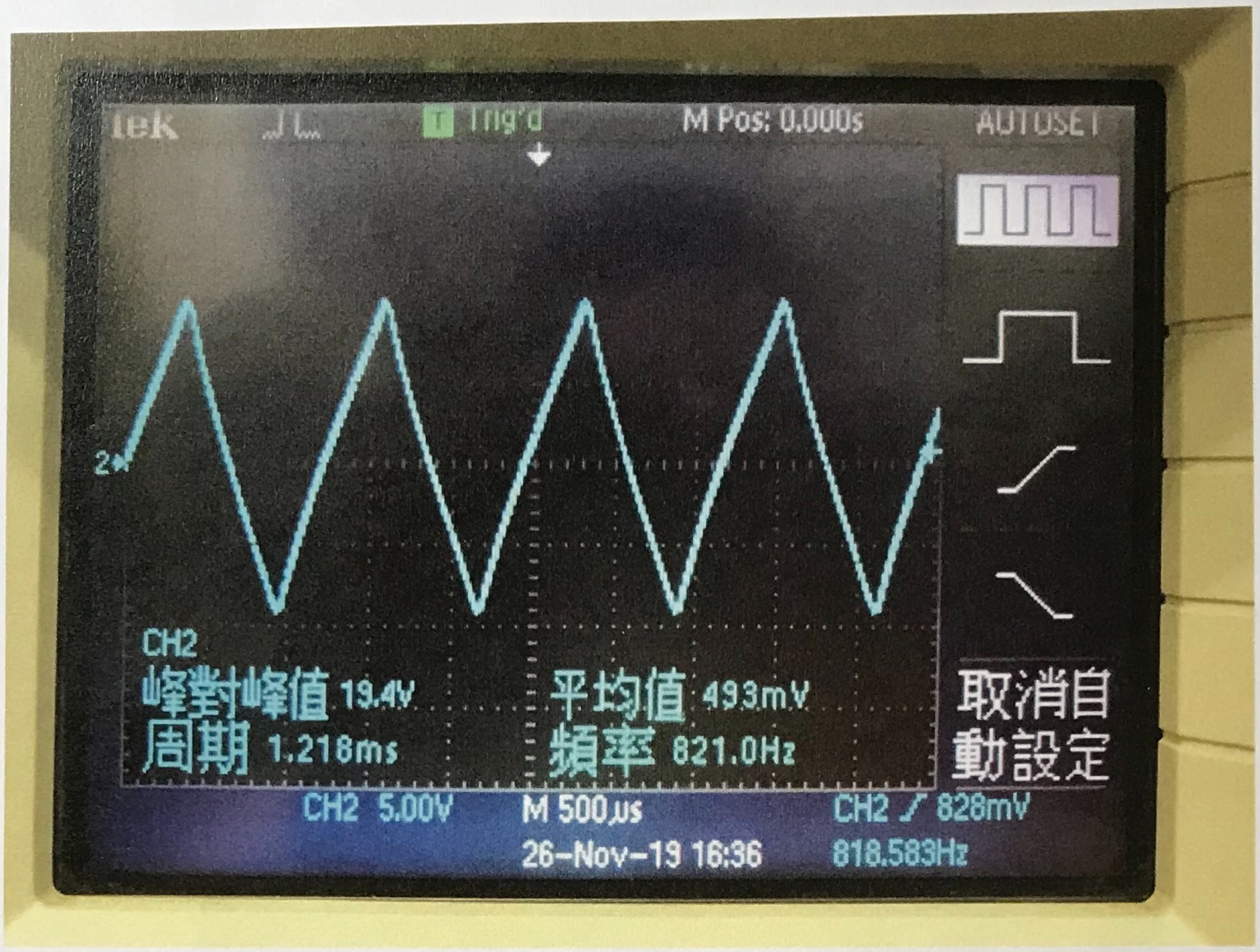
V_{out}



V_C

Design Problem 3

Integrator output



Blue curve is V_0 and yellow line is $-V_0$