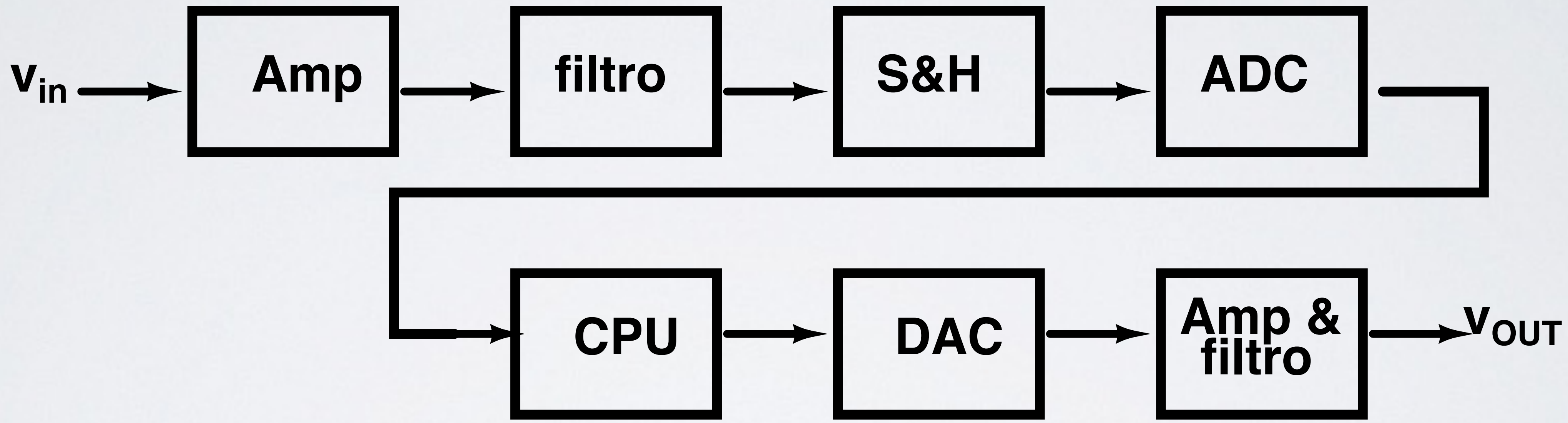
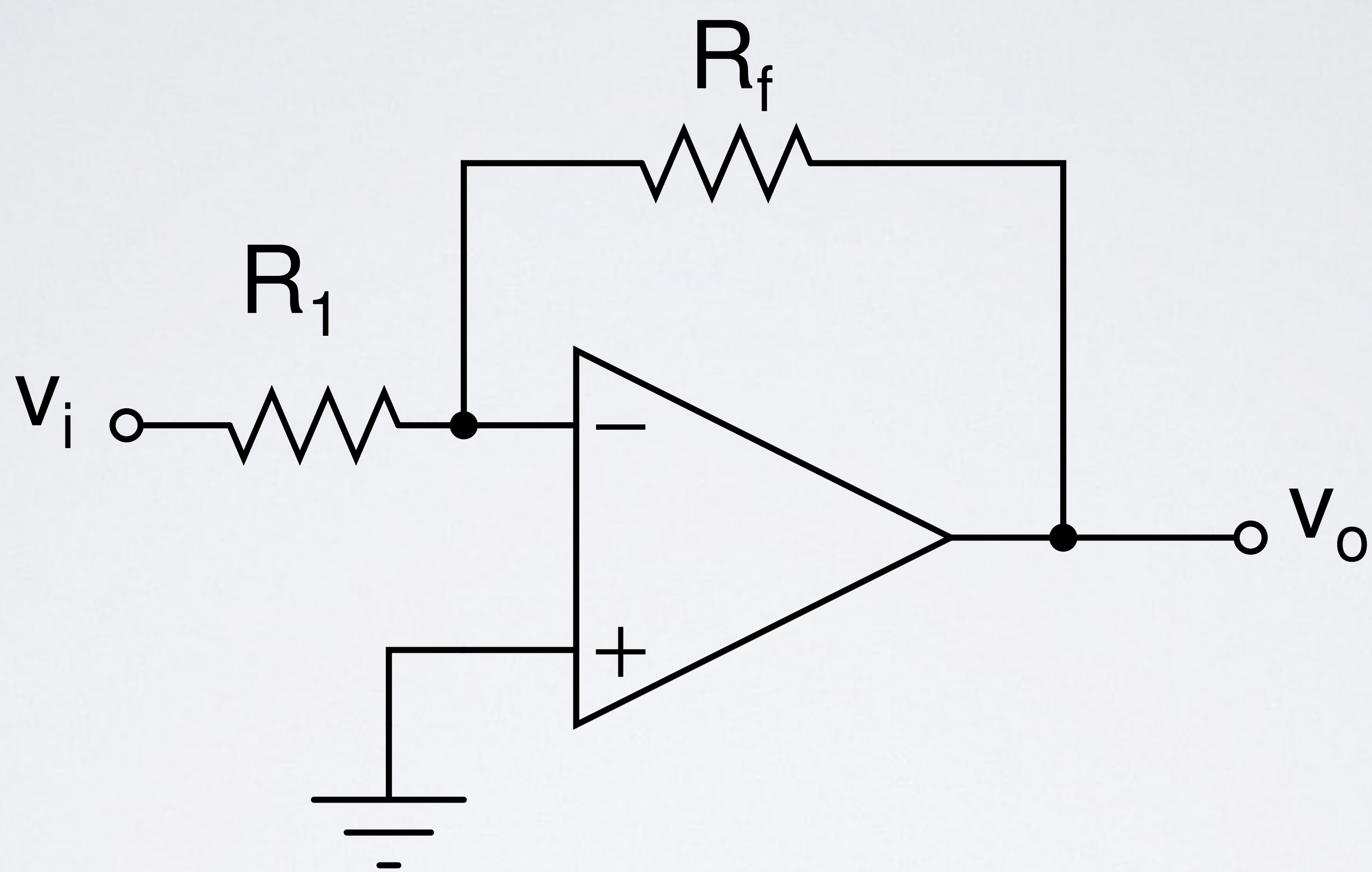
ADC/DAC

INEL 4207 Digital Electronics

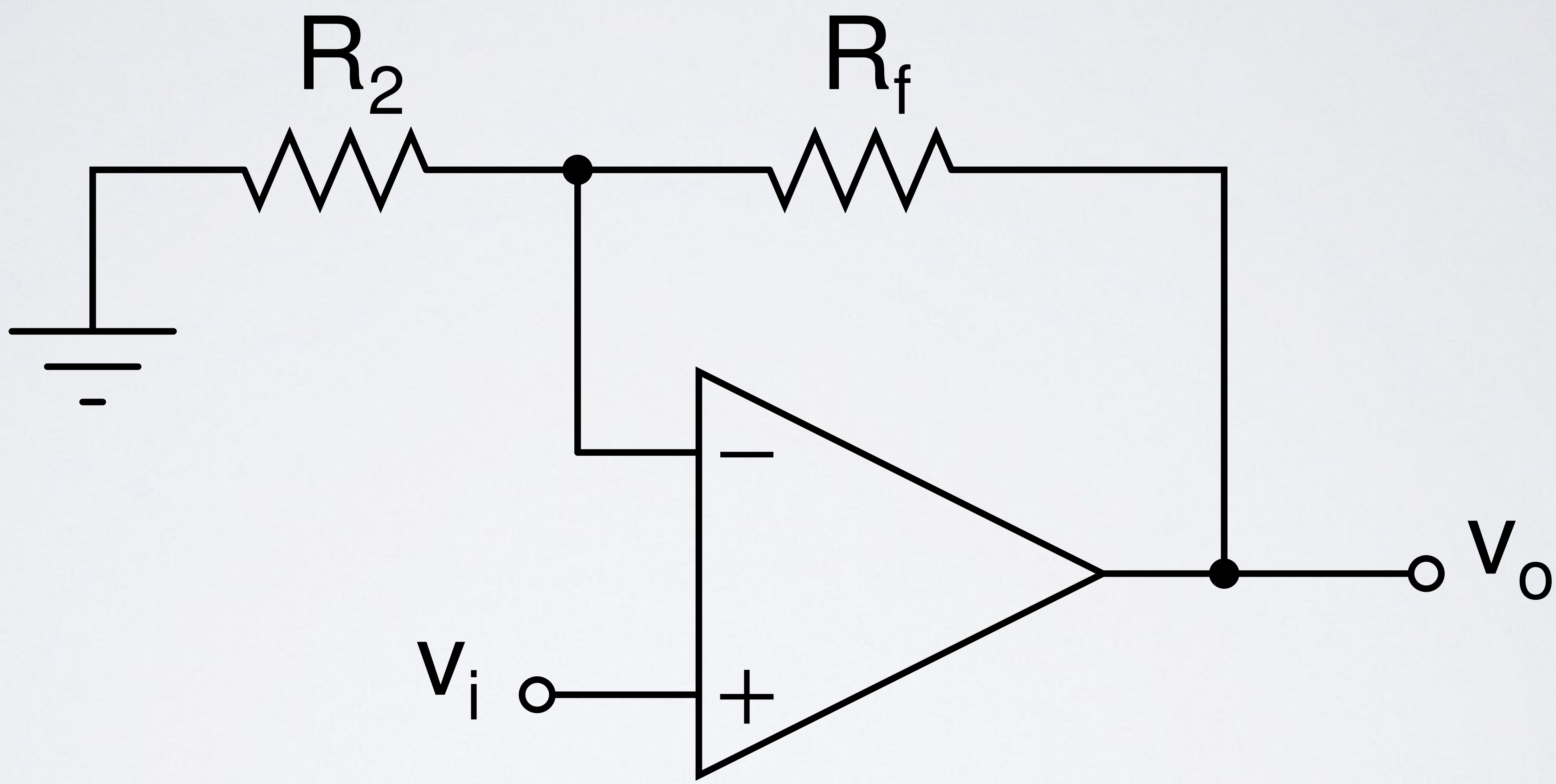
MIXED-SIGNAL SYSTEM



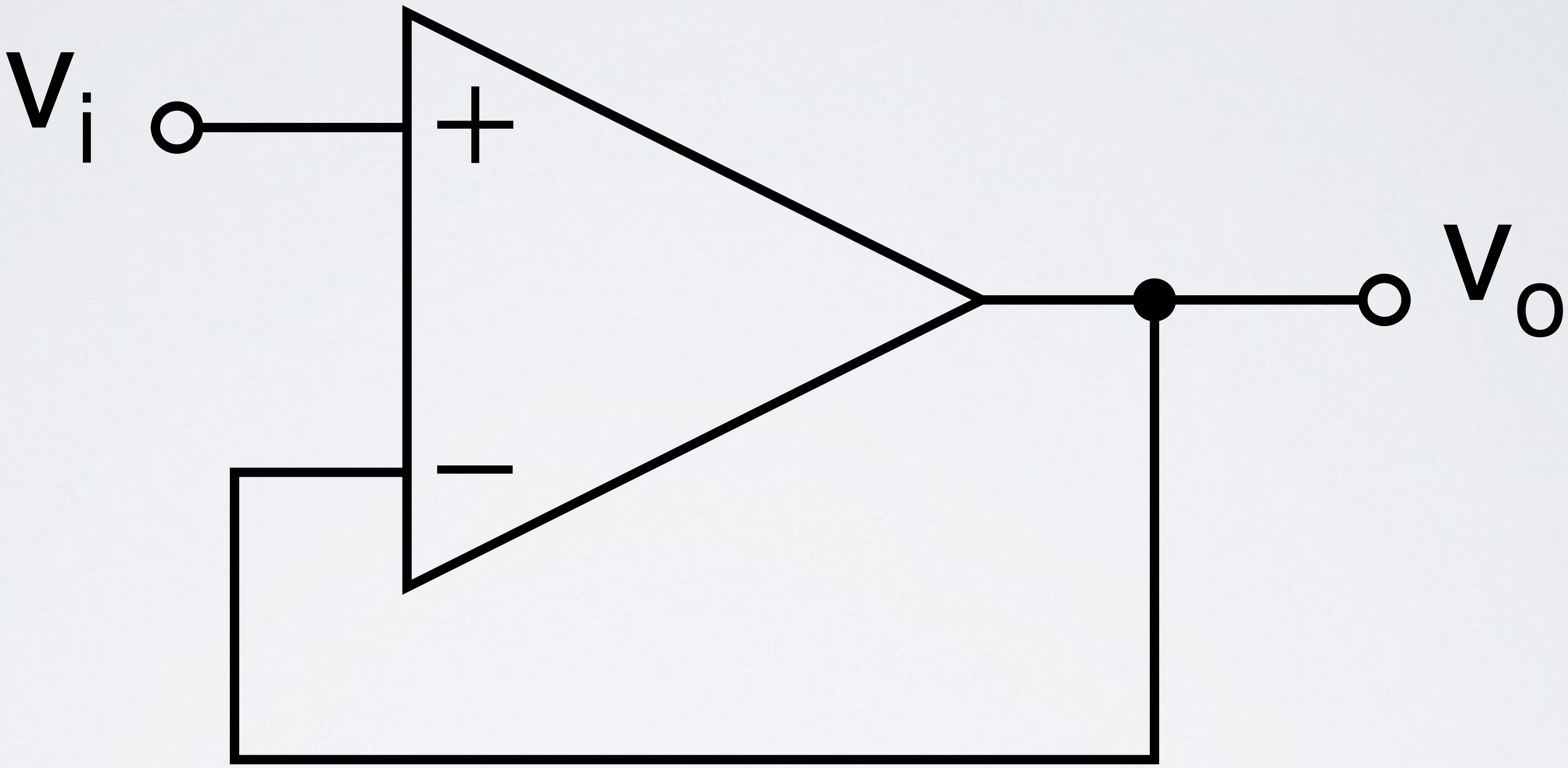
INVERTING AMPLIFIER



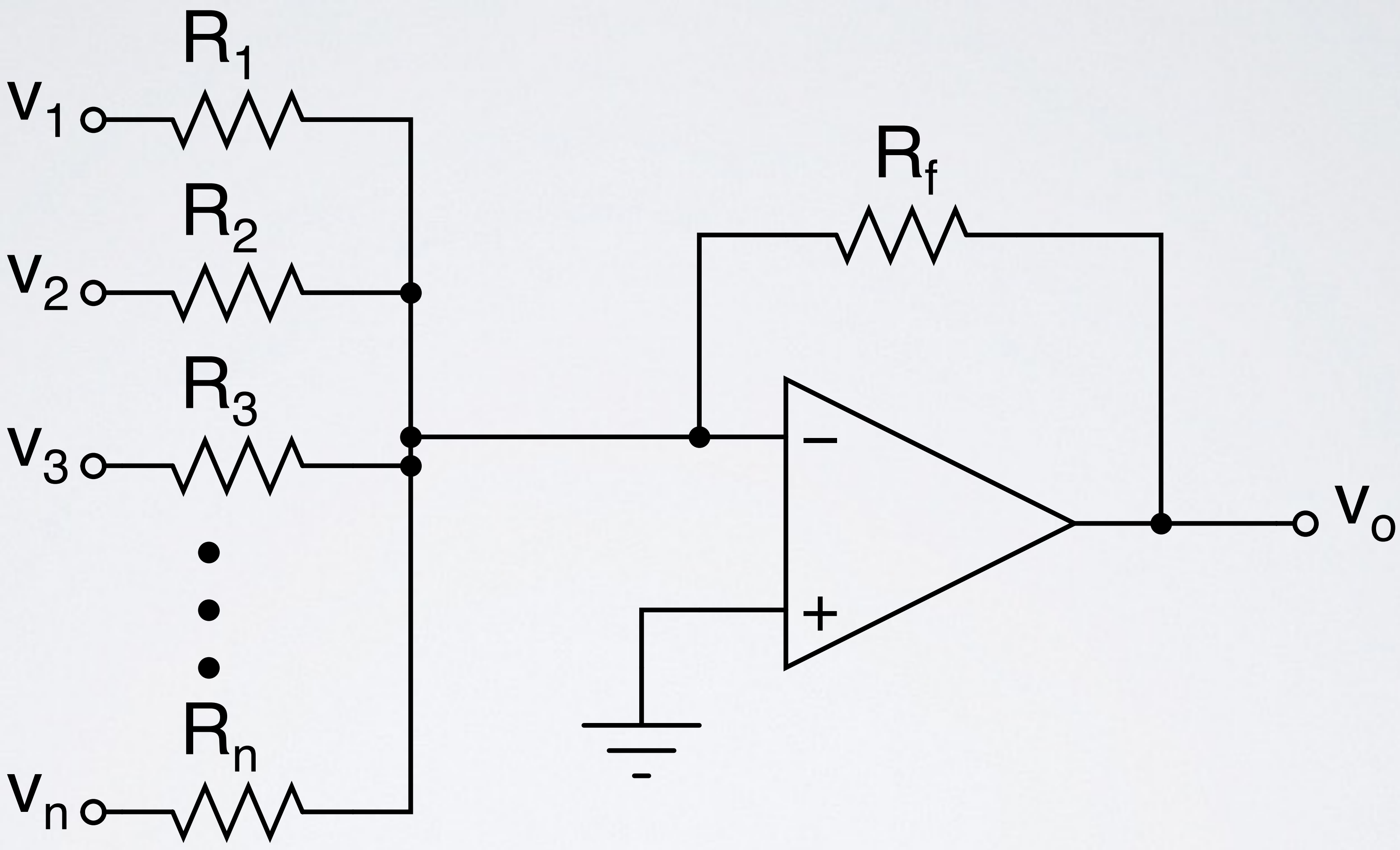
NON-INVERTING AMPLIFIER



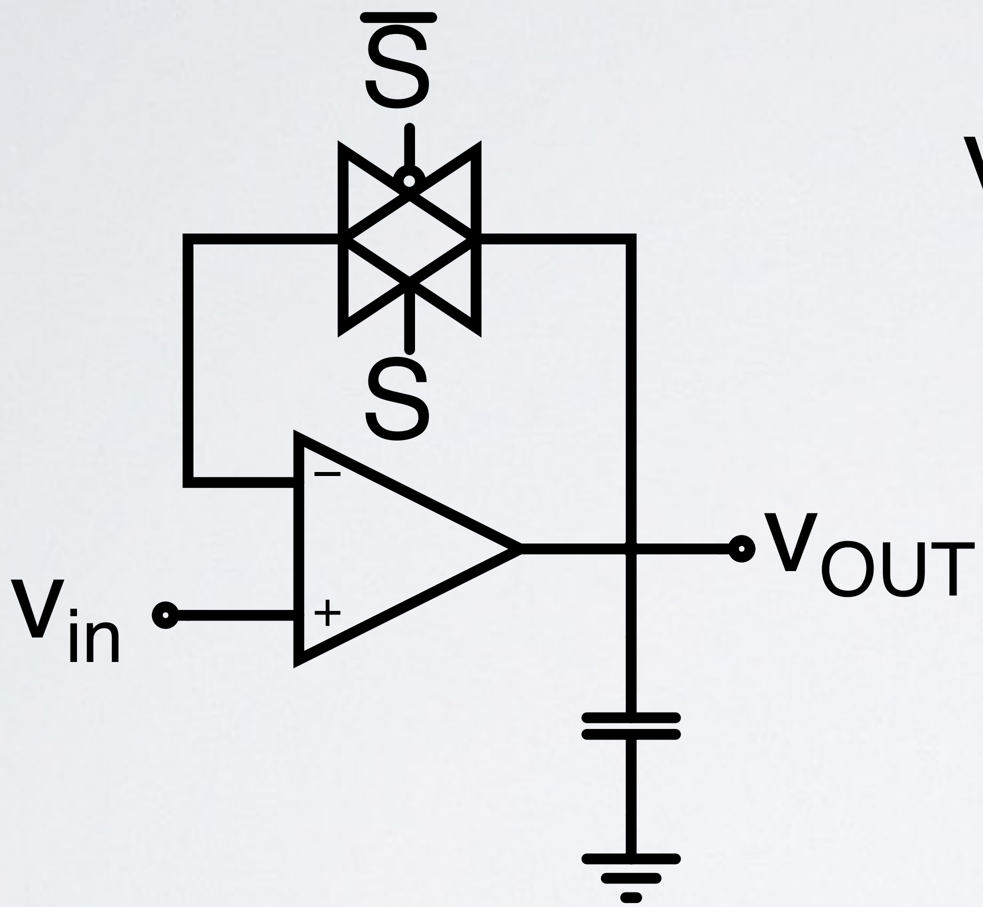
BUFFER AMPLIFIER

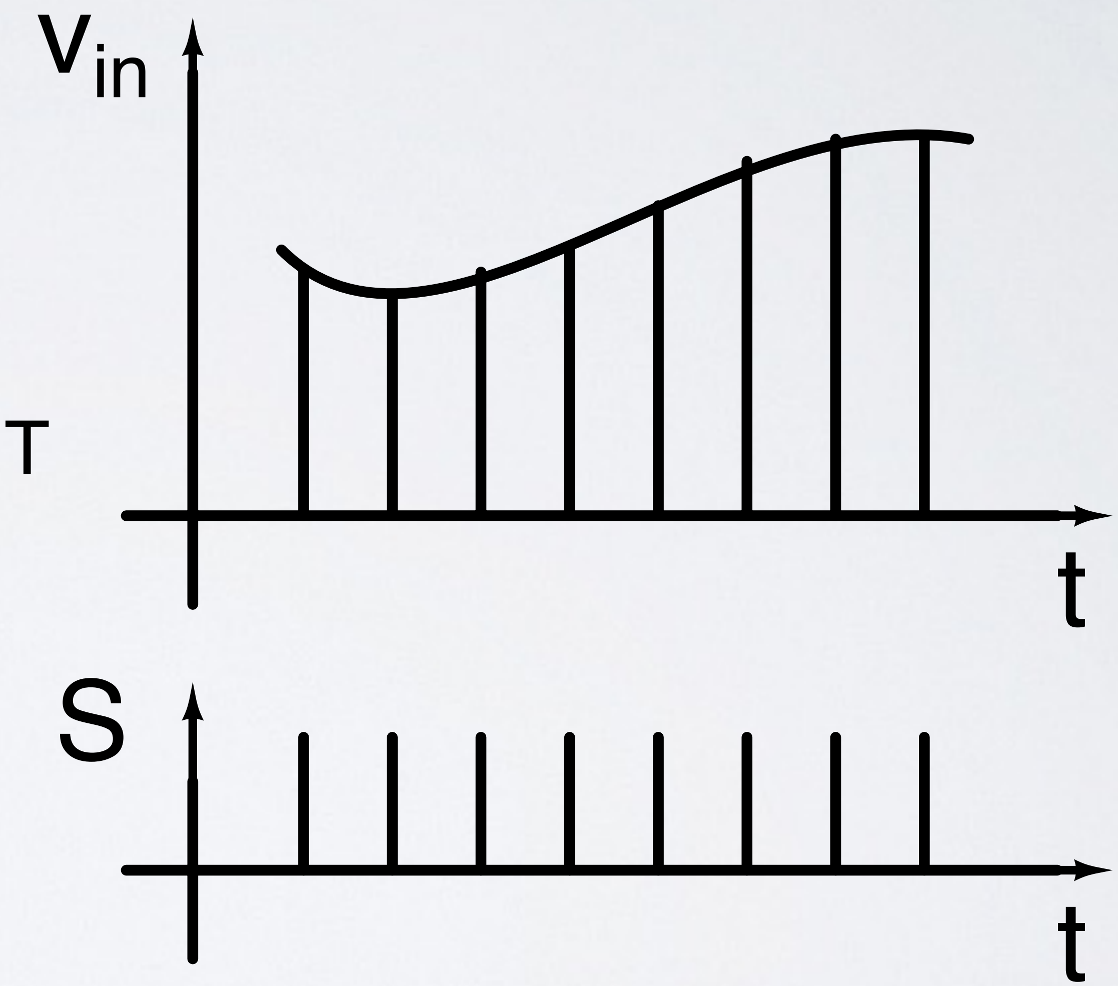


SUMMING AMPLIFIER

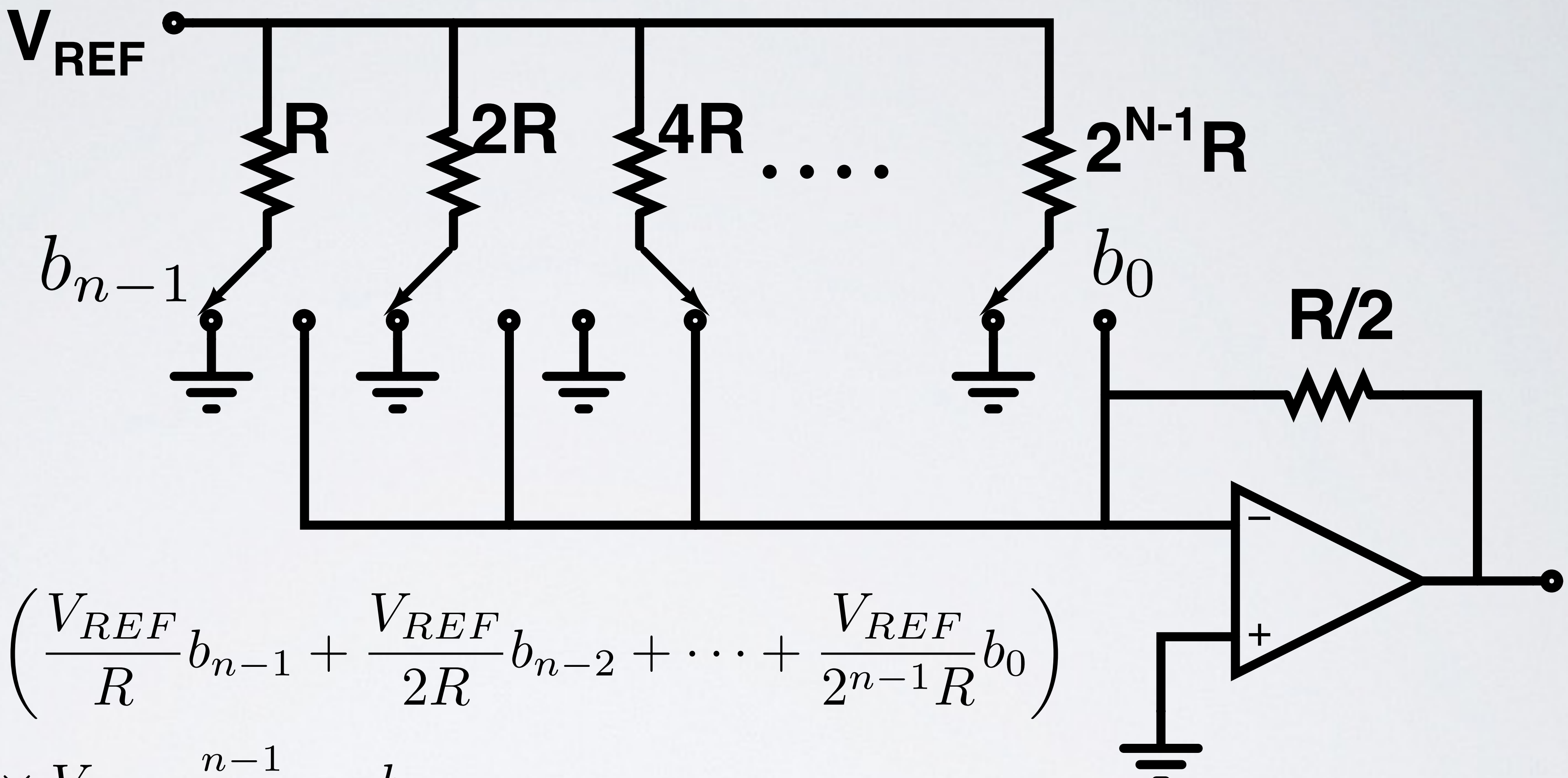


SAMPLE AND HOLD



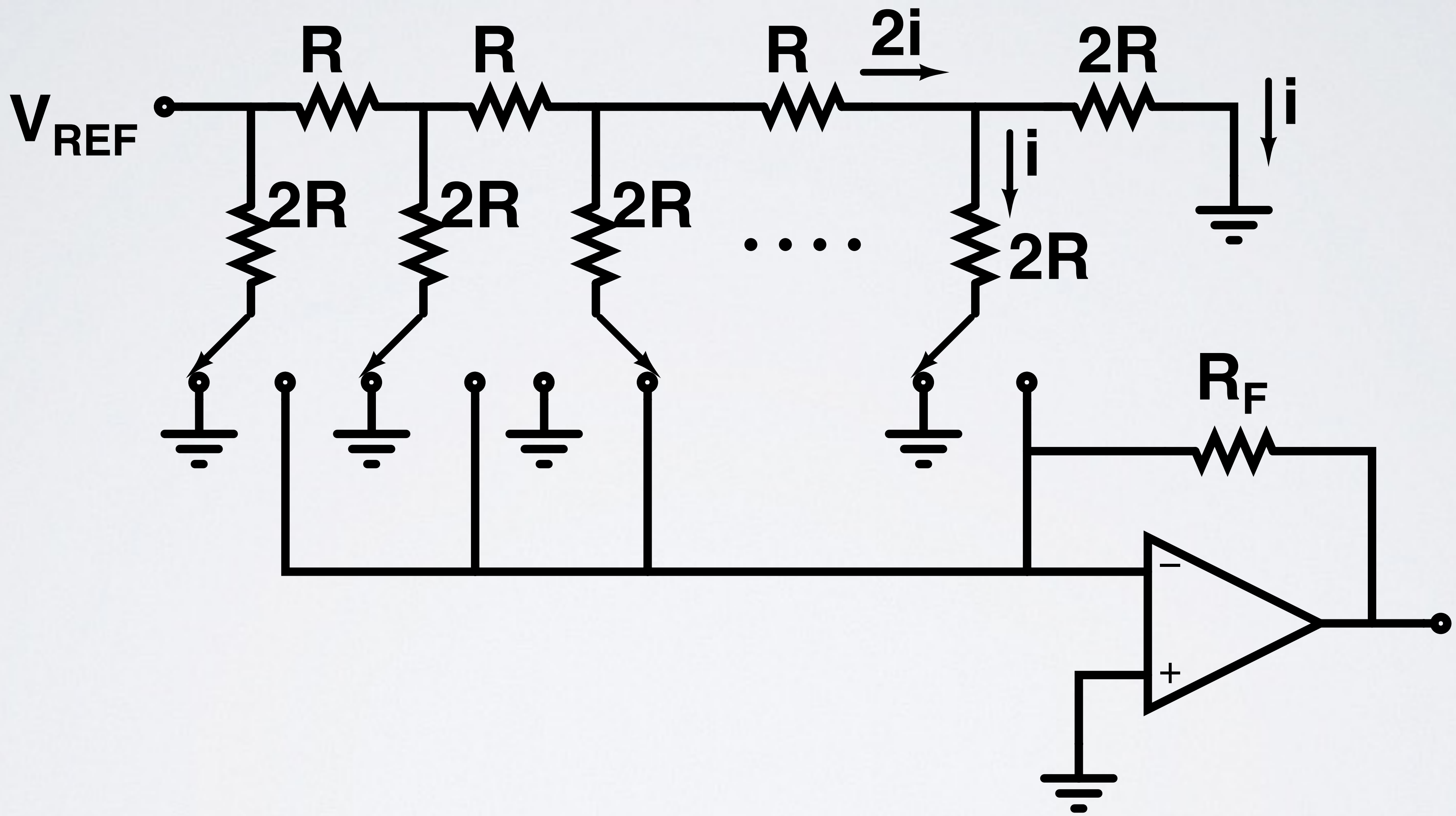


DAC

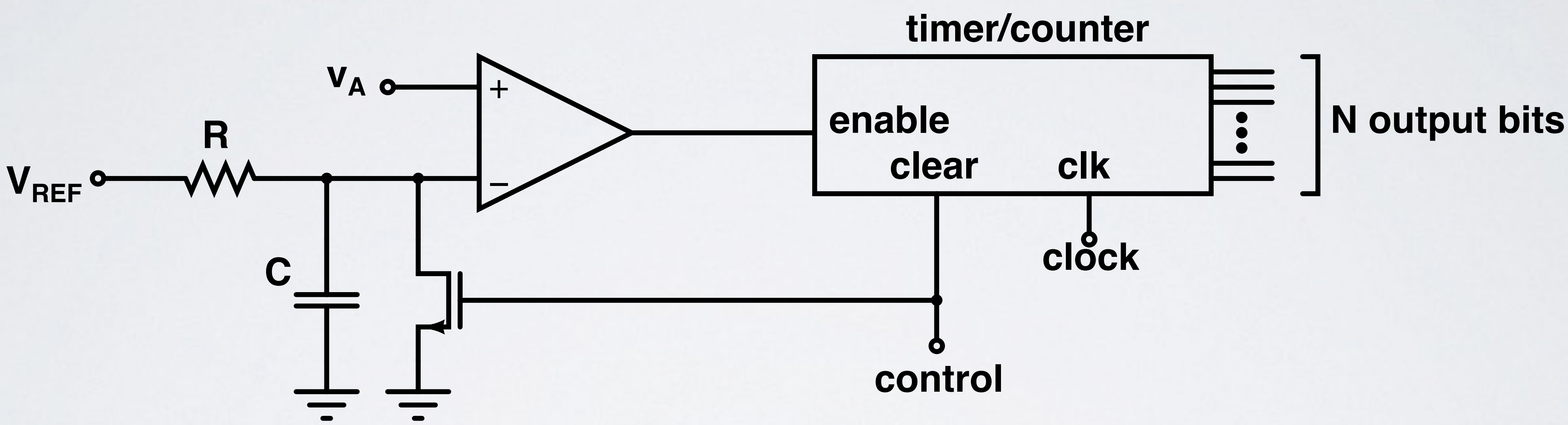


$$
\begin{aligned}
v_{OUT} &= -\frac{R}{2}\left(\frac{V_{REF}}{R}b_{n-1} + \frac{V_{REF}}{2R}b_{n-2} + \cdots + \frac{V_{REF}}{2^{n-1}R}b_0\right) \\
&= -\frac{R \times V_{REF}}{2}\sum_{i=0}^{n-1}\frac{b_i}{2^{n-i-1}R} \\
&= -V_{REF}\sum_{i=0}^{n-1}\frac{b_i}{2^{n-i}}
\end{aligned}
$$

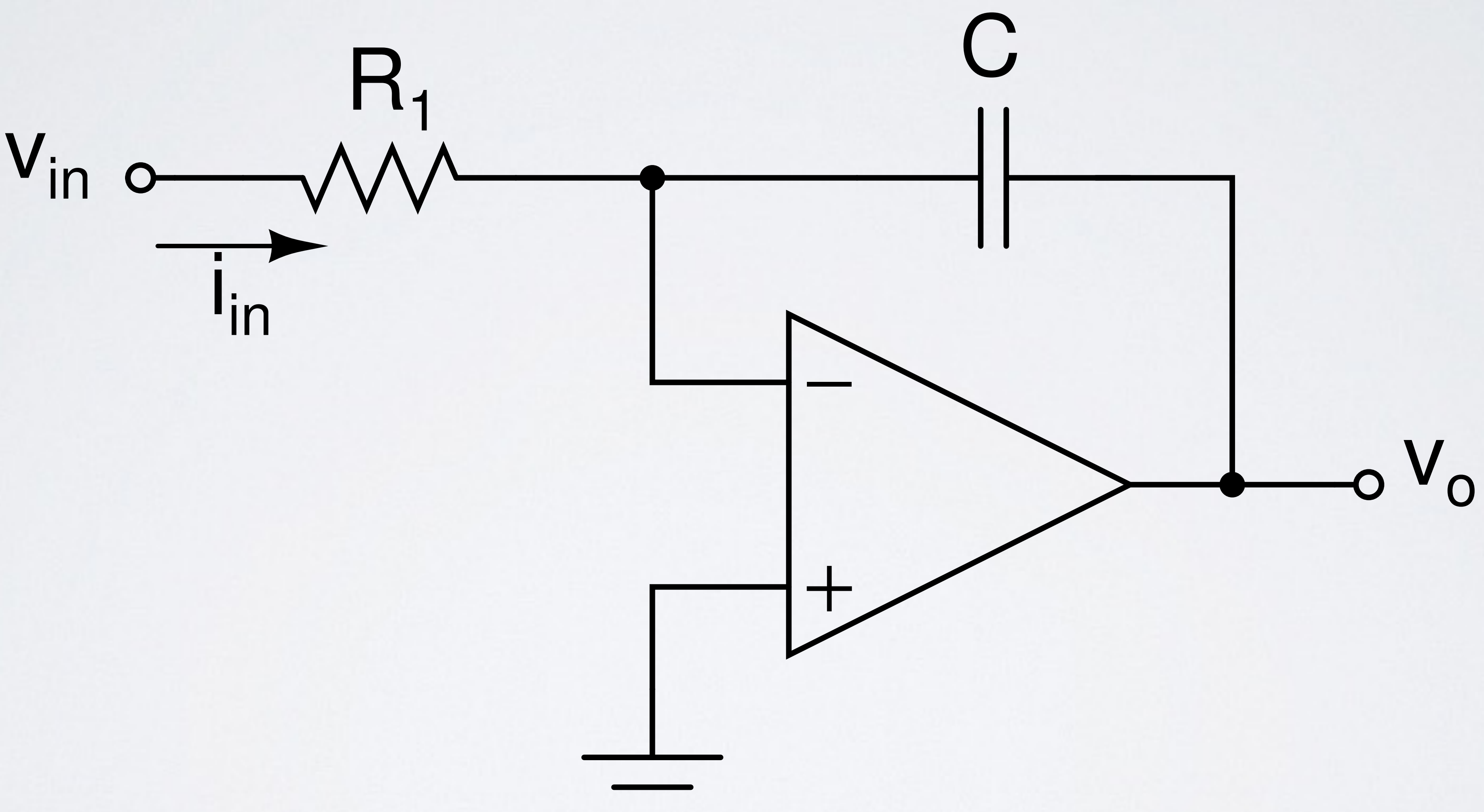
DAC



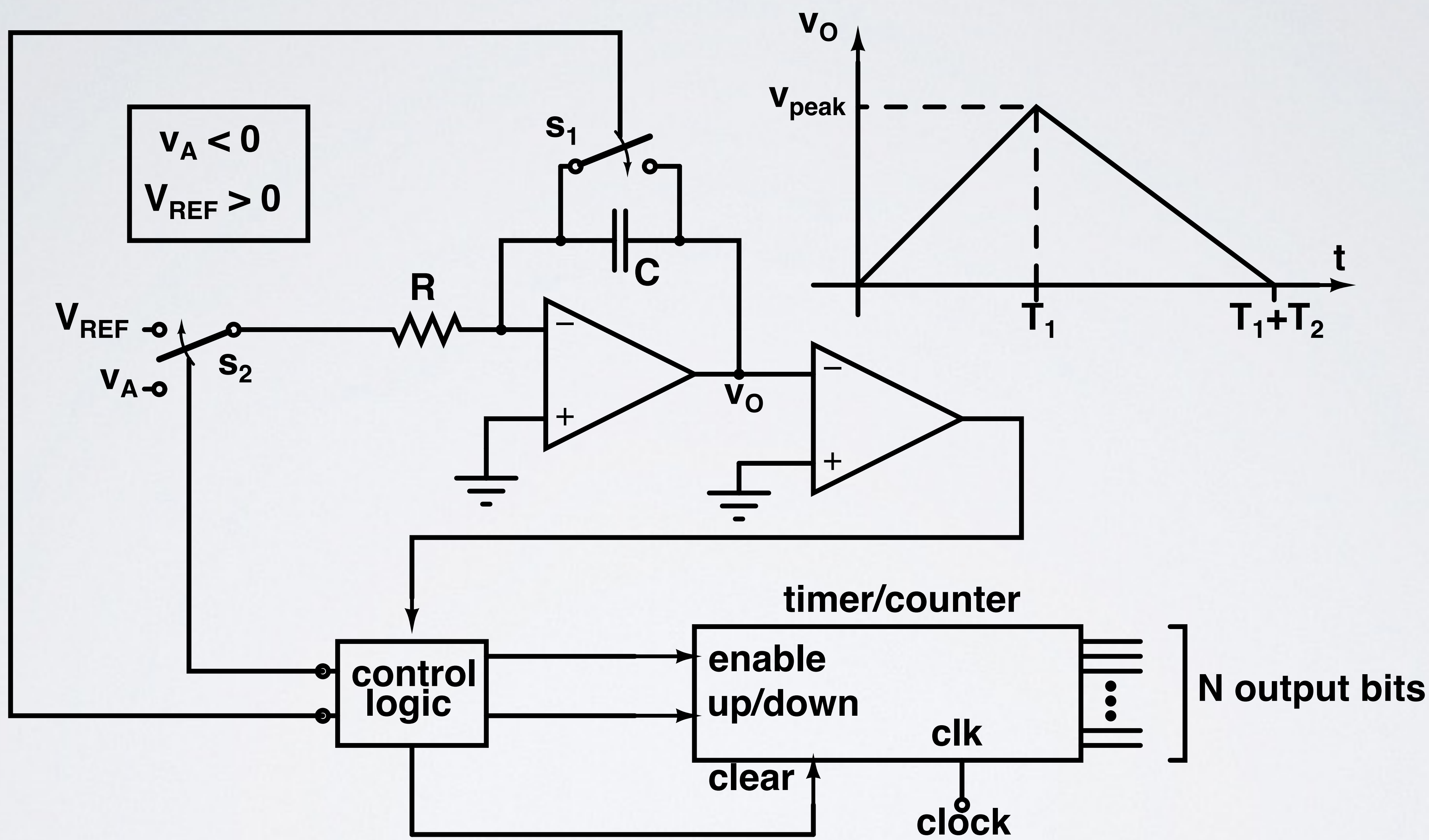
SIMPLE ADC


timer/counter
v_A
+
−
R
V_{REF}
C
enable
clear
clk
clock
control
N output bits

INTEGRATOR

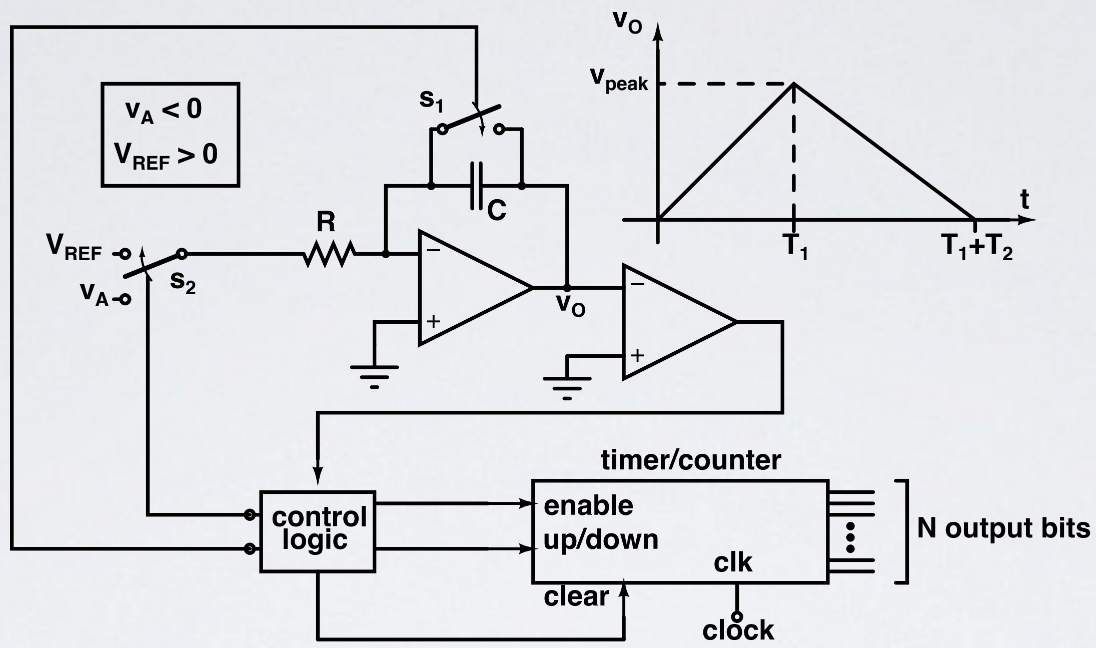


DOUBLE-SLOPE ADC



At t=0 capacitor C is discharged and s_2 is connected to v_A. At t=T_1 s_2 is switched to V

1. A 12-bit dual-slope ADC of the type illustrated below



At t=0 capacitor C is discharged and s_2 is connected to v_A. At t=T_1 s_2 is switched to V_{REF}.

utilises a 1-MHz clock and has $V_{ref} = 10V$. Its analog input is in the range 0 to $-10V$. The fixed interval T_1 is the time taken for the counter to accumulate a count 2^N.

a) (10 points) What is the time required to convert an input voltage equal to the full-scale value?

b) (10 points) If the peak voltage reach at the output of the integrator is $10V$, what is the integrator time constant?

c) (10 points) If through ageing, R increases by 2 % and C decreases by 1 %, what does V_{peak} become?

67

10

$$T_c = \frac{1}{f_{clk}} = 1\mu s$$

$$T_1 = 2^{12}\, T_c = \underline{\underline{4.096\,ms}}$$

$$T = T_1 + T_2 = T_1\left(1 + \frac{V_A}{V_{ref}}\right)$$

$$= 2T_1 = \underline{\underline{8.19\,ms}}$$

$$V_{peak} = 10 = \frac{V_A}{\tau}\, T_1$$

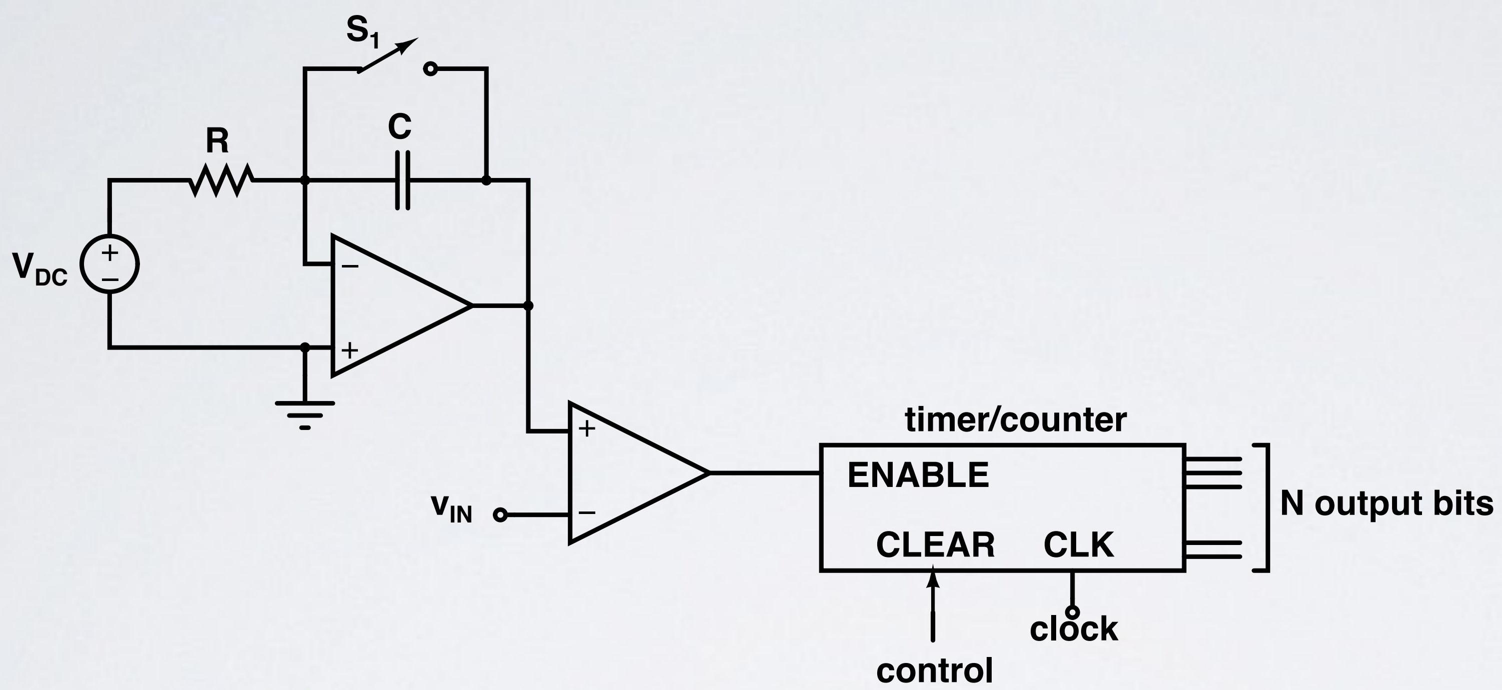
$$\Rightarrow \tau = \frac{V_A}{V_{peak}}\, T_1 = \underline{\underline{4.096\,ms}}$$

$\Delta\tau = -1\%$ and causes a -1% change in Vpeak

$$\Rightarrow V_{peak} = \underline{\underline{9.9\,V}}$$

No. Final count does not depend on τ

1. The following diagram



sketches an ADC. Prior to $t = 0$, capacitor C is discharged and the counter is erased by the control signal. At $t = 0$, s_1 opens and the counter is allowed to count. The analog input voltage, v_{IN}, is in the range of $0V$ to $5V$. If $V_{DC} = -10V$,

$a)$ (20 points) Find R and C so that the maximum conversion time equals $0.1ms$.

$b)$ (10 points) If a 10 MHz clock (1 MHz = 1024 kHz) is used, what is the number of bits of resolution?

a) (20 points) Find R and C so that the maximum conversion time equals $0.1ms$.

ANSWER: The capacitor charges with a constant current $i = {}^{V_{DC}}\!/_{R}$, so for the opamp,

$$\frac{dv_{O1}}{dt} = \frac{10V}{RC}$$

A conversion will be done when $v_{O1} = v_{IN}$, so when $v_{IN} = 5V$,

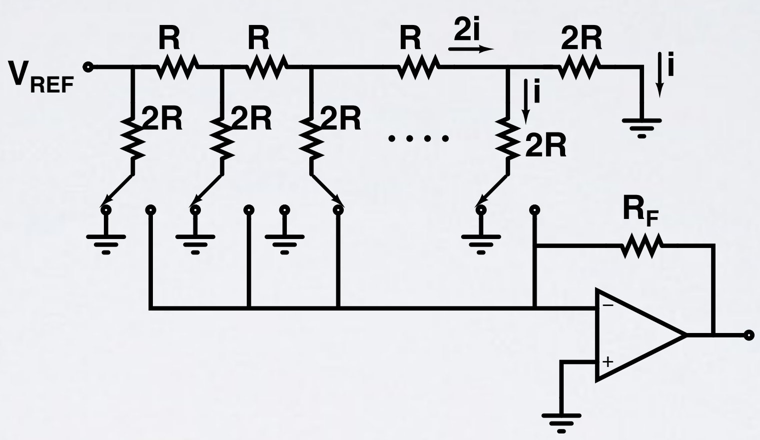
$$\frac{5V}{0.1ms} = \frac{10V}{RC} \Rightarrow RC = 0.2ms$$

Any appropriate values will work. For example, select $R = 10k\Omega$ and $C = 20nF$.

b) (10 points) If a 10 MHz clock (1 MHz = 1024 kHz) is used, what is the number of bits of resolution?

ANSWER: There will be $10.24 \times 10^6 \times 0.1 \times 10^{-3} = 1.024 \times 10^7 \times 10^{-4} = 1024$ clock pulses per conversion, for a resolution of 10 bits ($2^{10} = 1024$).

3. The following sketch shows a $R - 2R$ digital-to-analog converter (DAC).

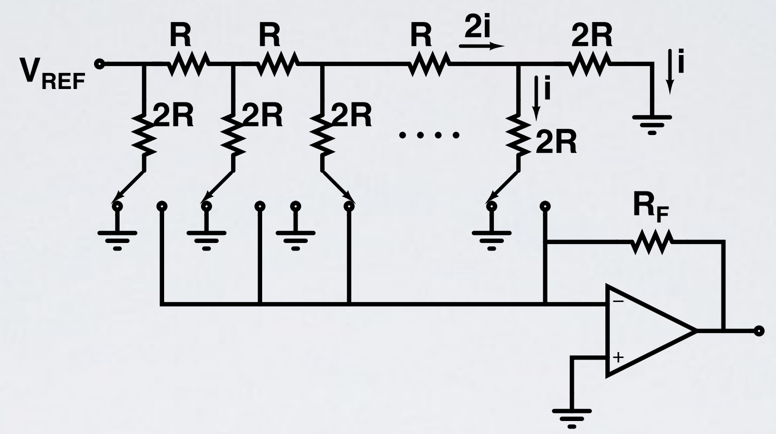


If the circuit uses 10 bits, $R = 1k\Omega$ and $V_{REF} = -5V$,

(a) (20 points) find the value of R_F that should be used to have an output voltage range from $0V$ to $10V$.

(b) (20 points) for the value of R_F found in part (a), what is the output voltage for a binary input equal to 0100011101?

3. The following sketch shows a $R-2R$ digital-to-analog converter (DAC).



If the circuit uses 10 bits, $R = 1k\Omega$ and $V_{REF} = -5V$,

(a) (20 points) find the value of R_F (to within 0.1%) that should be used to have an output voltage range from $0V$ to $10V$.

ANSWER: The maximum current, which flows through R_F when all input bits are logic-1, can be expressed as

$$i_{max} = \frac{5V}{1k\Omega}\left(\frac{2^{10}-1}{2^{10}}\right) = 4995.12\mu A$$

so

$$10V = 4995.12\mu A \times R_F \Rightarrow \boxed{R_F = 10V/4995.12\mu A = 2002\Omega}$$

(b) (20 points) for the value of R_F found in part (a), what is the output voltage for a binary input equal to 0100011101?

ANSWER:

$$v_{out} = 2002\Omega \times 2.5mA\left(2^{-10} + 2^{-8} + 2^{-7} + 2^{-6} + 2^{-2}\right) = \boxed{1.393V}$$