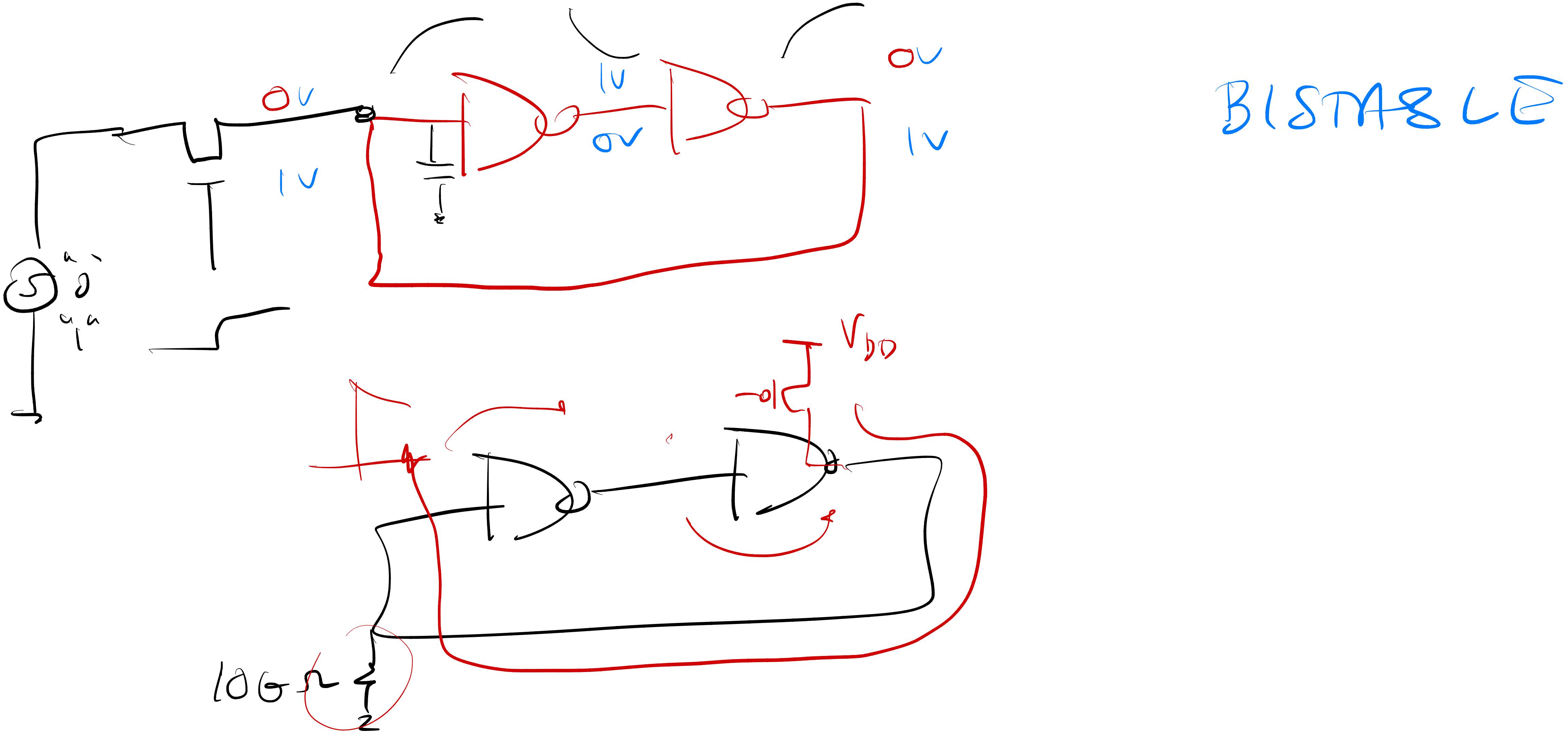
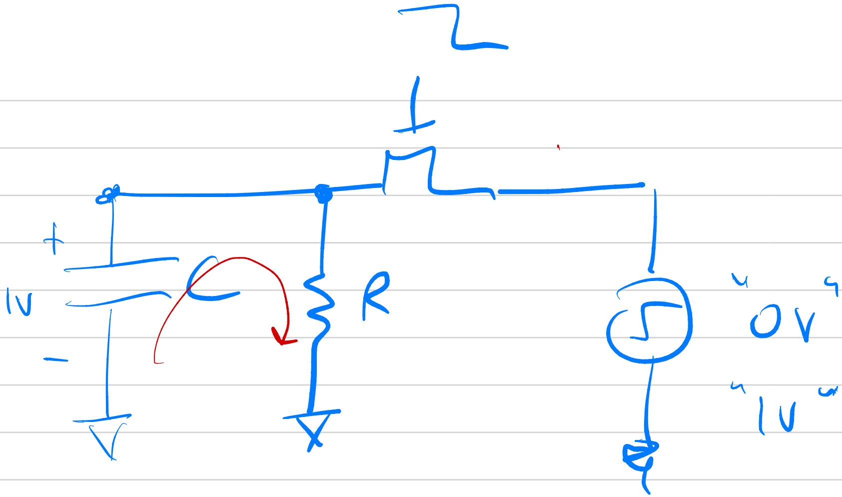
Module 3: CMOS Models and Digital Logic Gates and Applications

EECS 16B

Static RAM (SRAM)



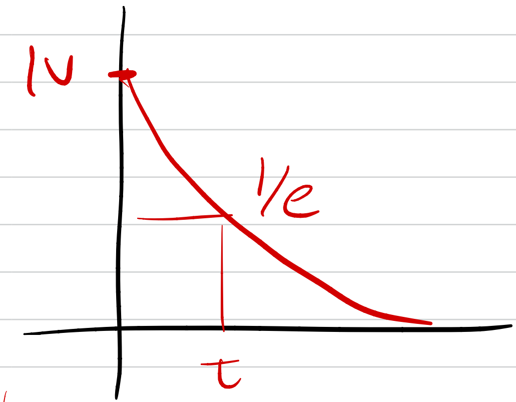
DRAM



$$\tau = RC$$

$$= R \cdot 10fF$$

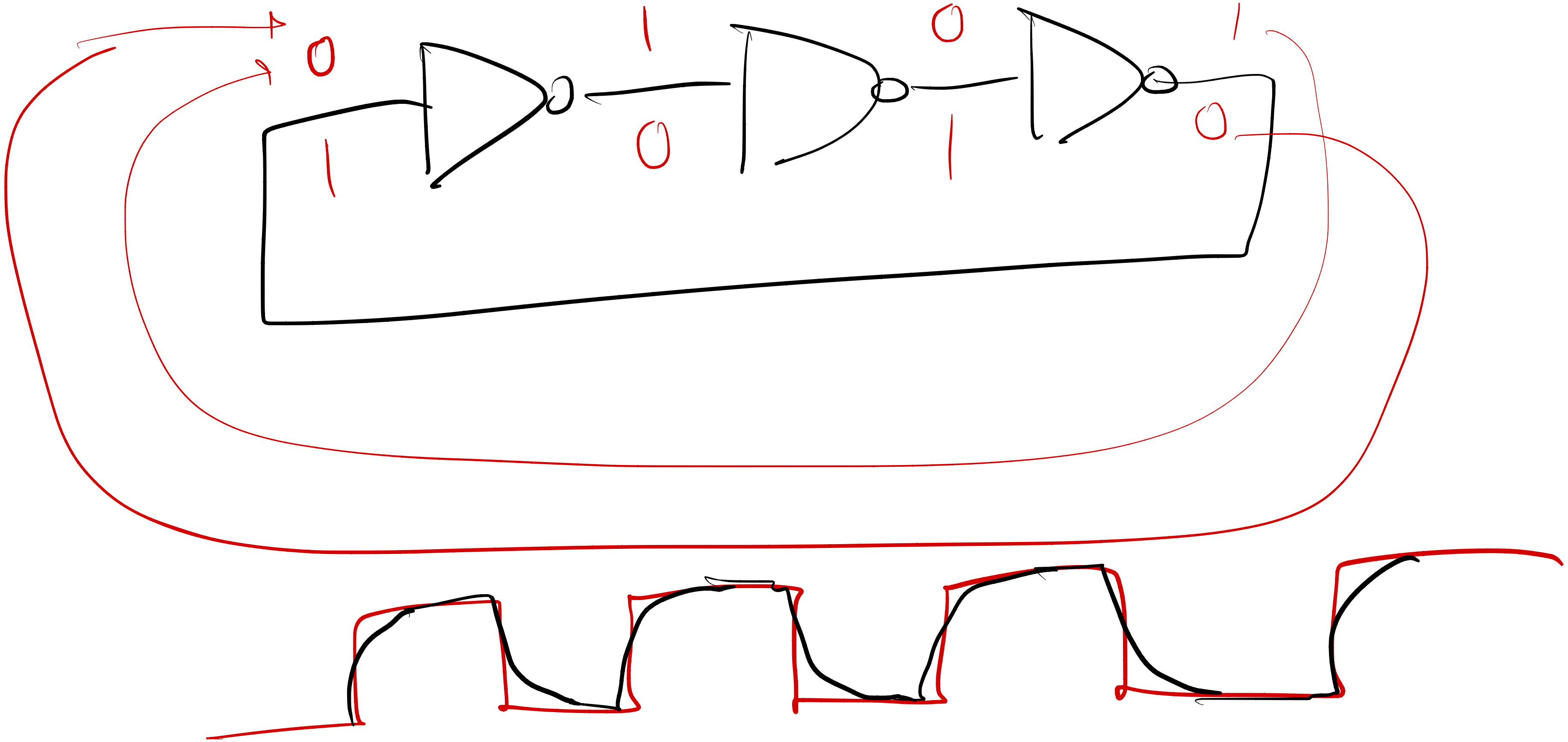
$$= R \cdot 10 \times 10^{-15}$$

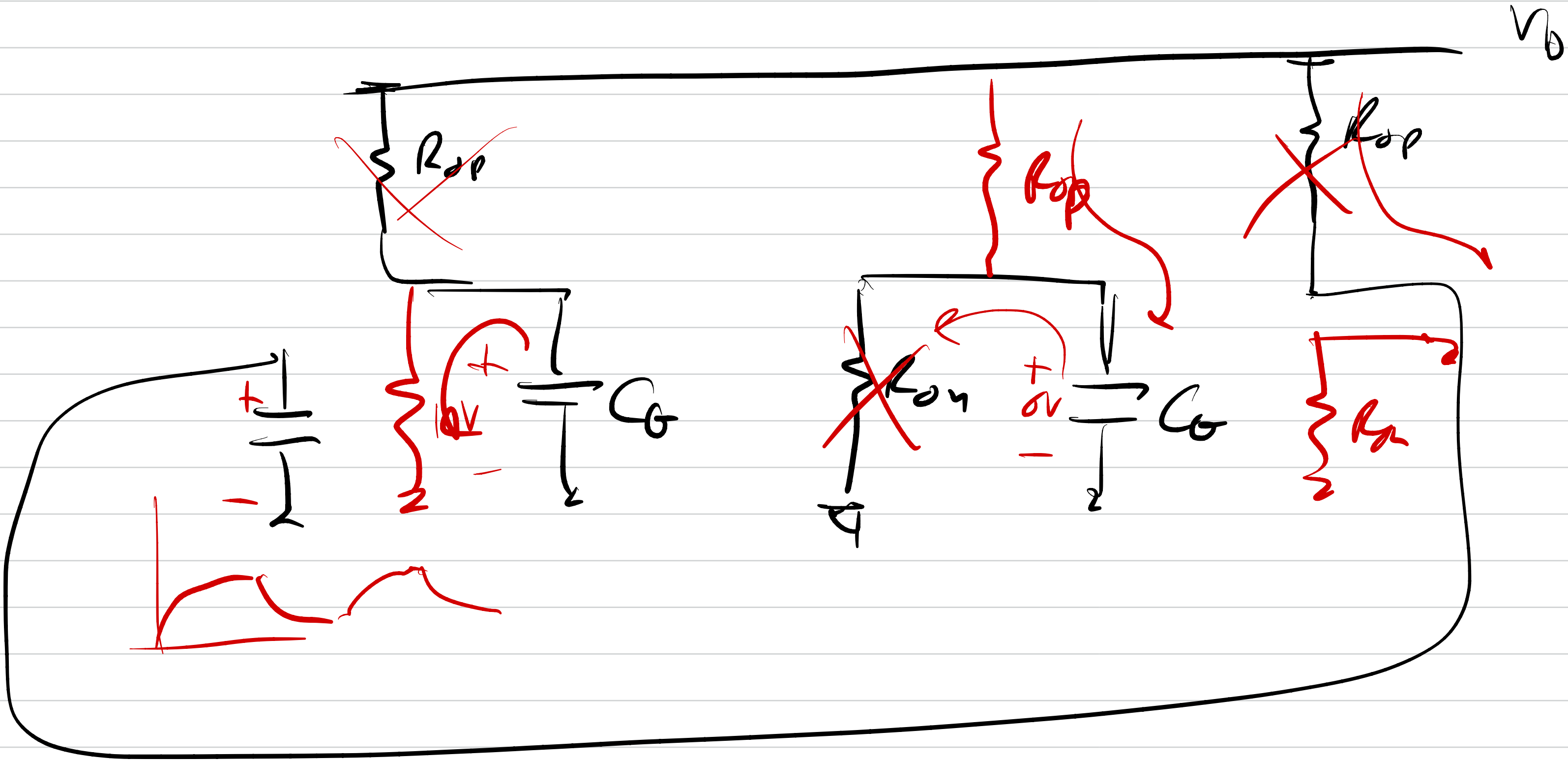


$$R = 100G\Omega = 10^{2} \times 10^{9} = 10^{11}$$

$$\tau = 10^{11} \times 10 \times 10^{-15} = 10^{-3}$$

Ring Oscillator



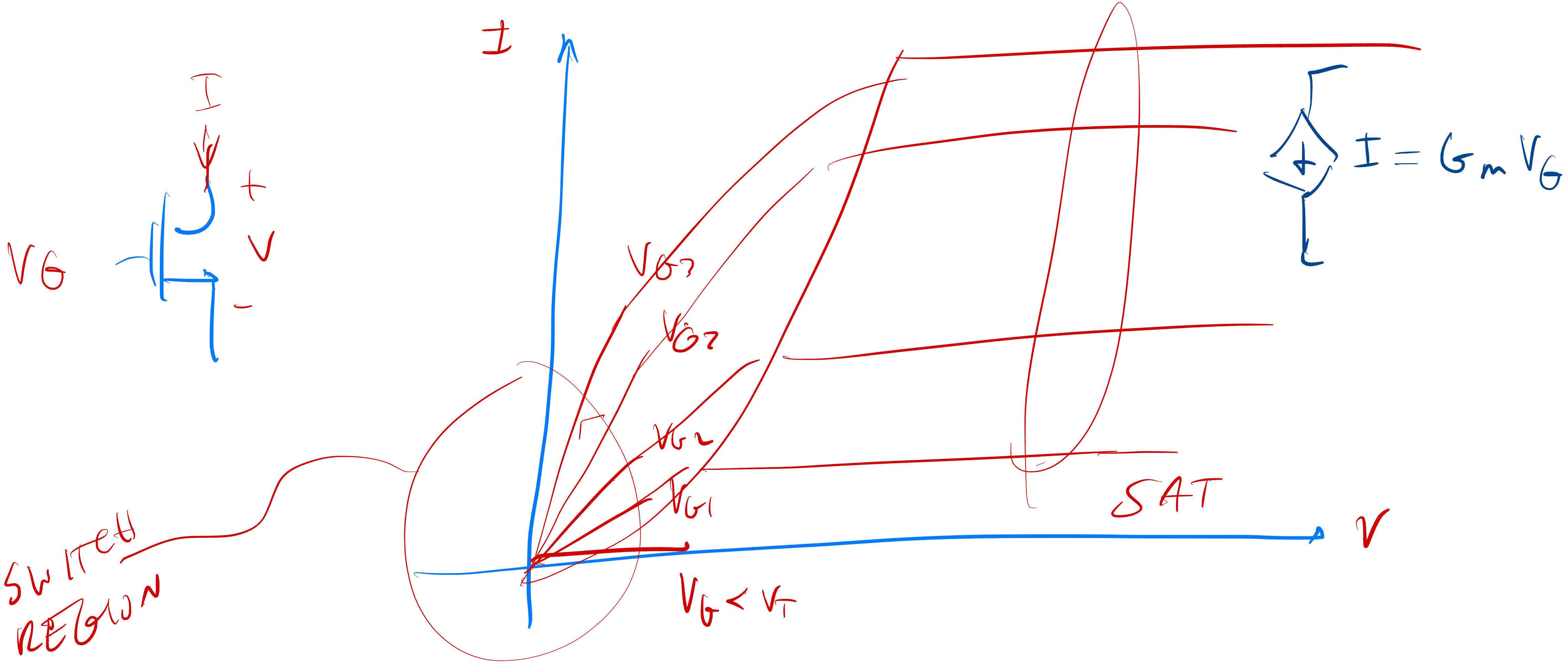


VDD
Rdp
Rop
Rop
Ron
CG
Ron
CG
Rn
0V
0V

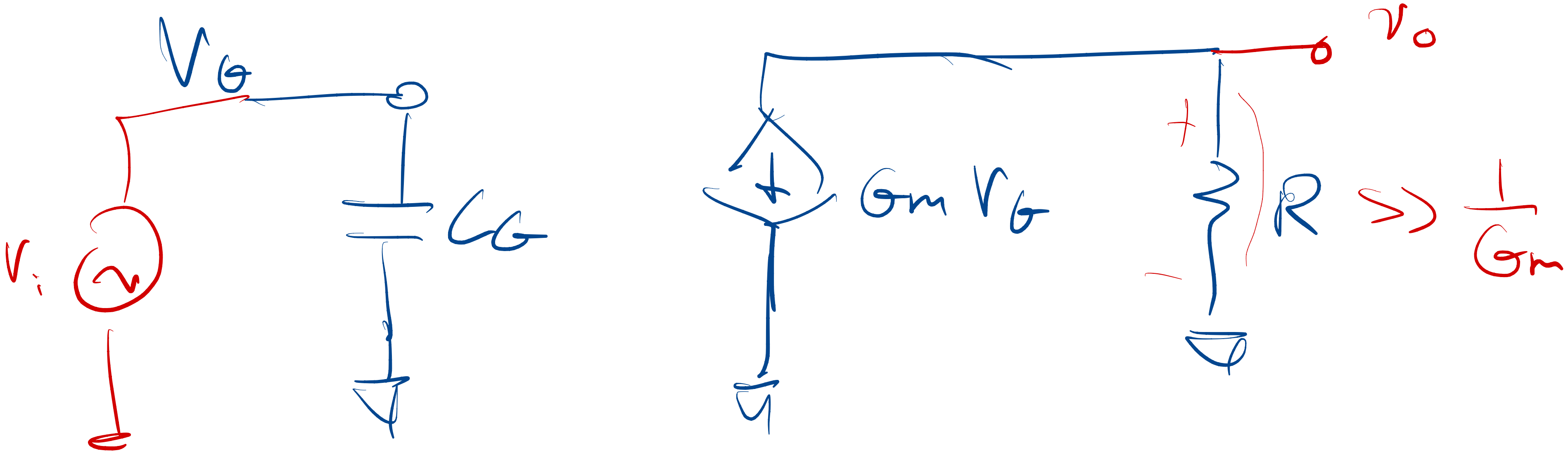
Differential Equations for Inverter

HW & DISC

I-V Curve Again



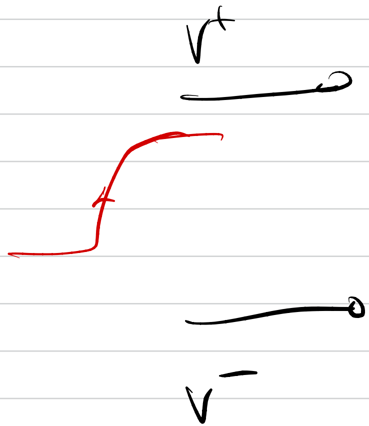
~~Op-~~Amp Model with RC

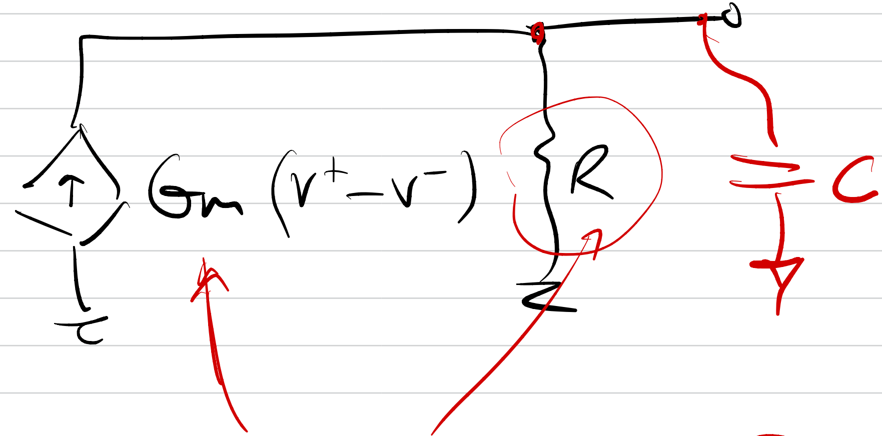


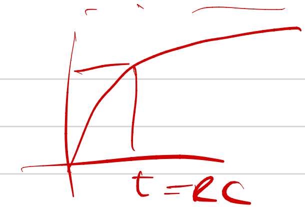
$$v_o = (-G_m V_G) \cdot R = -G_m R \, V_i$$

$$A_v = -G_m R \gg 1$$

16A / 16B





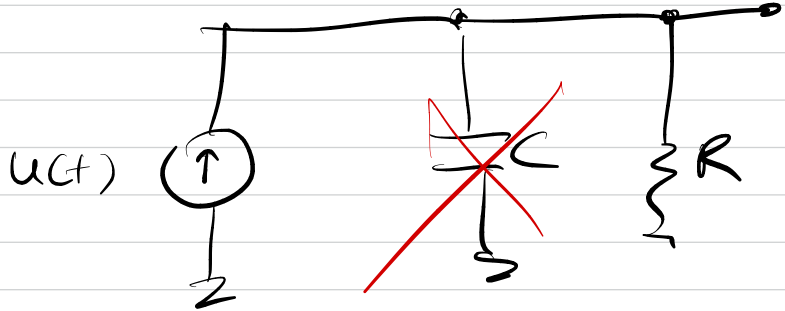


$$RC\frac{dV}{dt} + \frac{V}{\cancel{R}} = RG_m(V^+ - V^-) = \begin{cases} 1V & \text{typo} \\ \text{or} & \text{zero} \end{cases}$$

Input (constant)

$$\boxed{\tau \frac{dV}{dt} + V = u(t)}$$

Solution By Inspection



$v(0) = 0V$

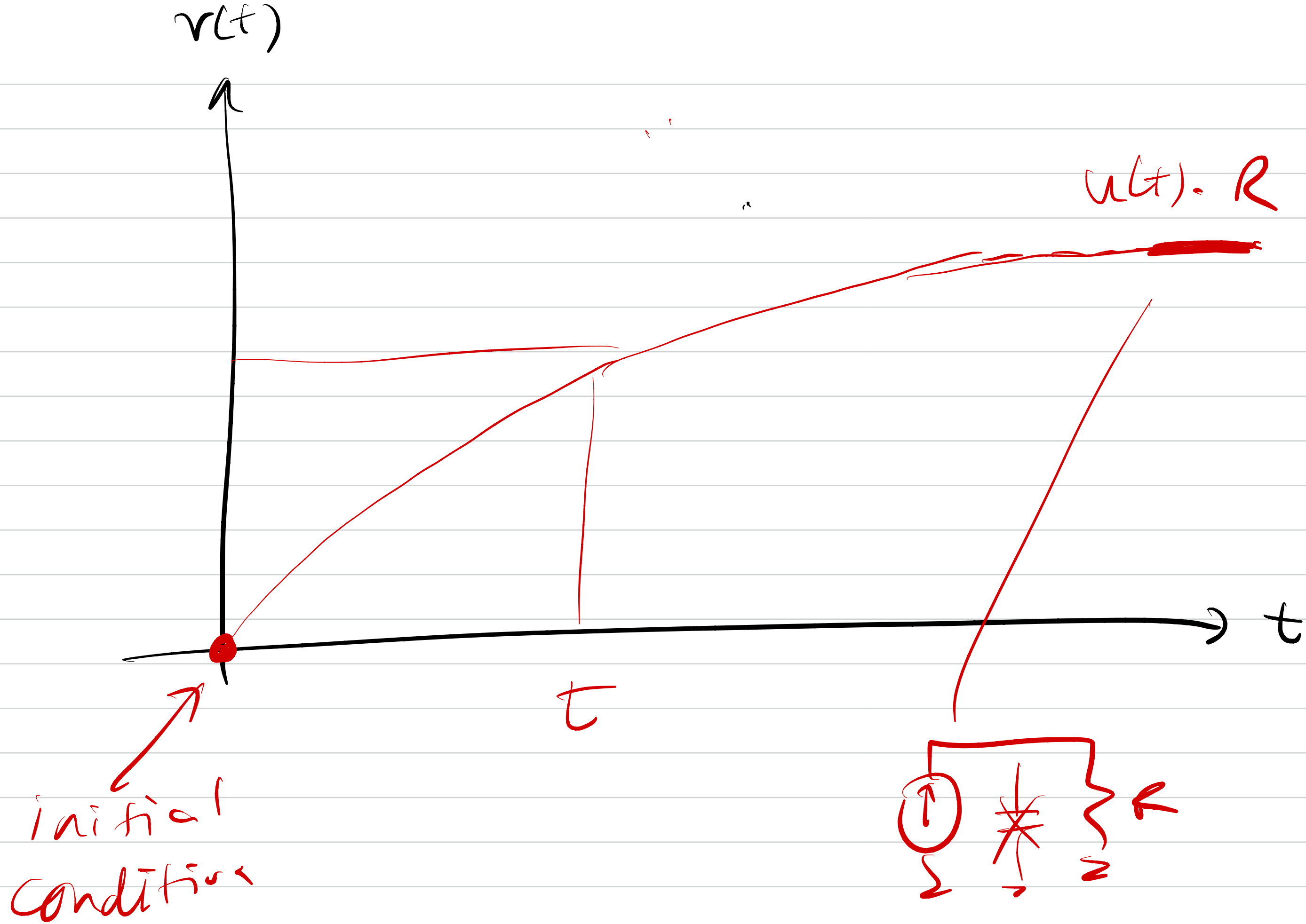
Capacitors are open circuit

predict Steady-state Solution

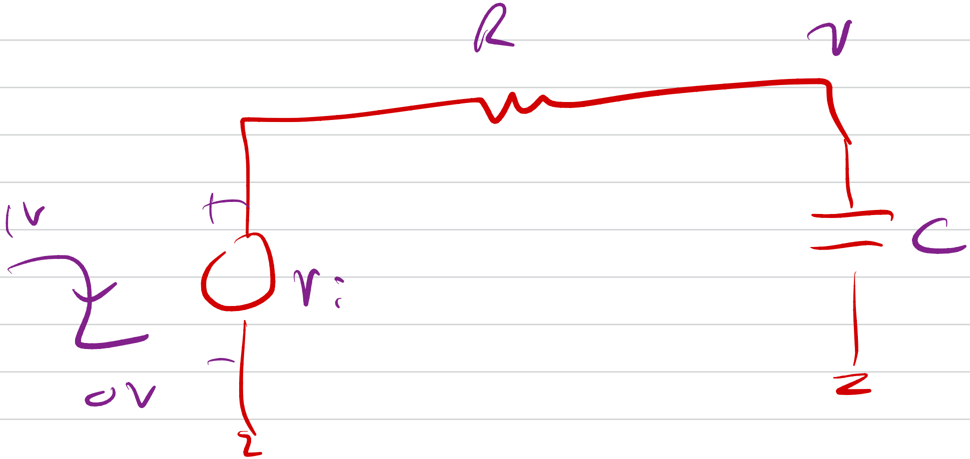
$$\tau \frac{dv}{dt} + v = u(t)$$

$v \sim$ constant

$$\frac{dv}{dt} = 0$$

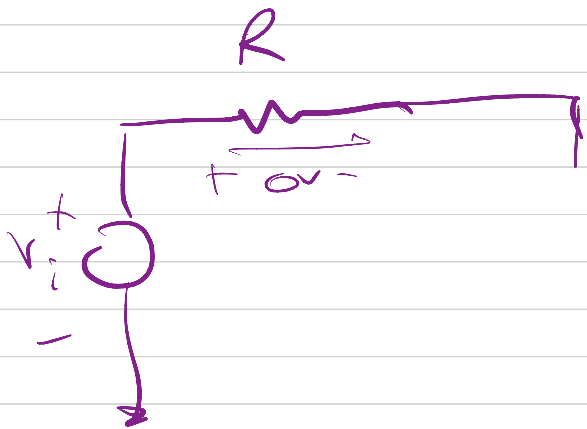


v(t)
u(t)·R
t
t
initial condition



$v(0) = 1V$

$v(\infty) = ?$



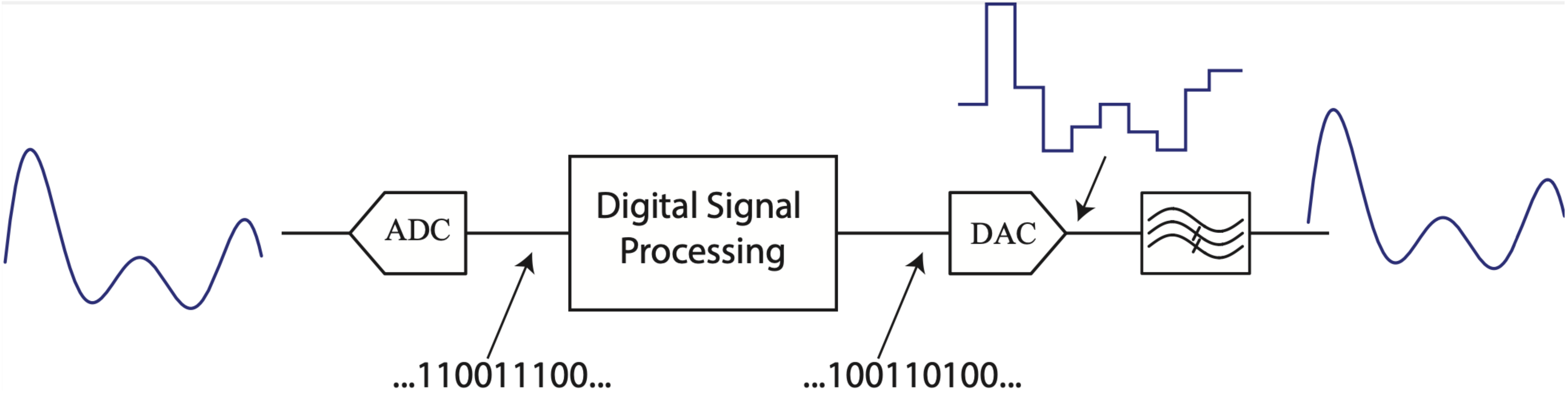
$v(\infty) = v_i = 0V$


V(t)
1V
τ
t

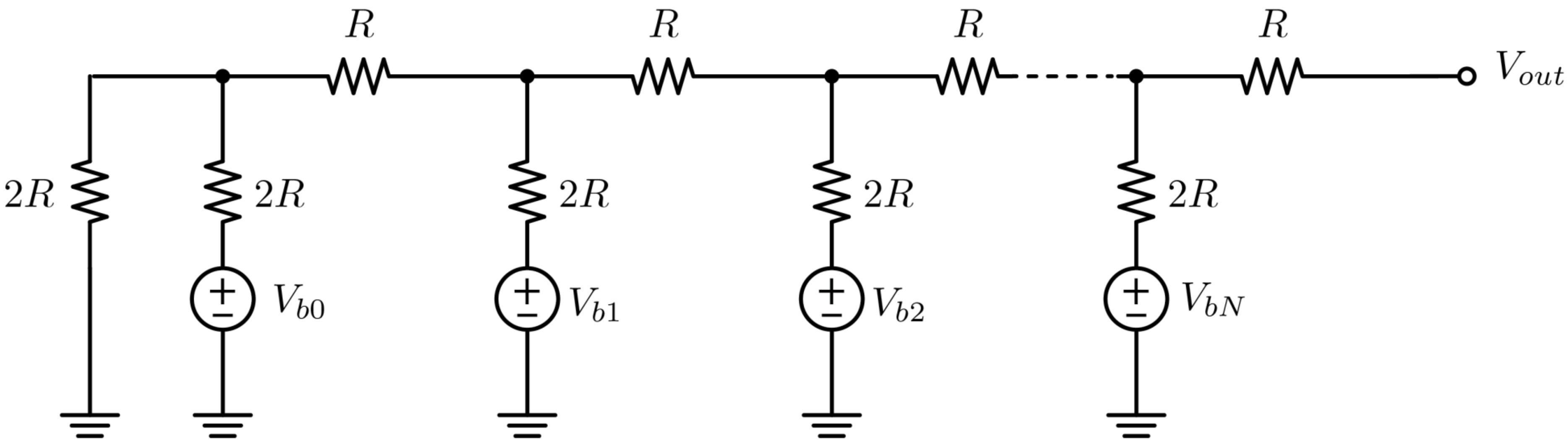
Amplifier Settling Time

Applications

ADCs and DACs



R-2R Ladder Digital-to-Analog Converter

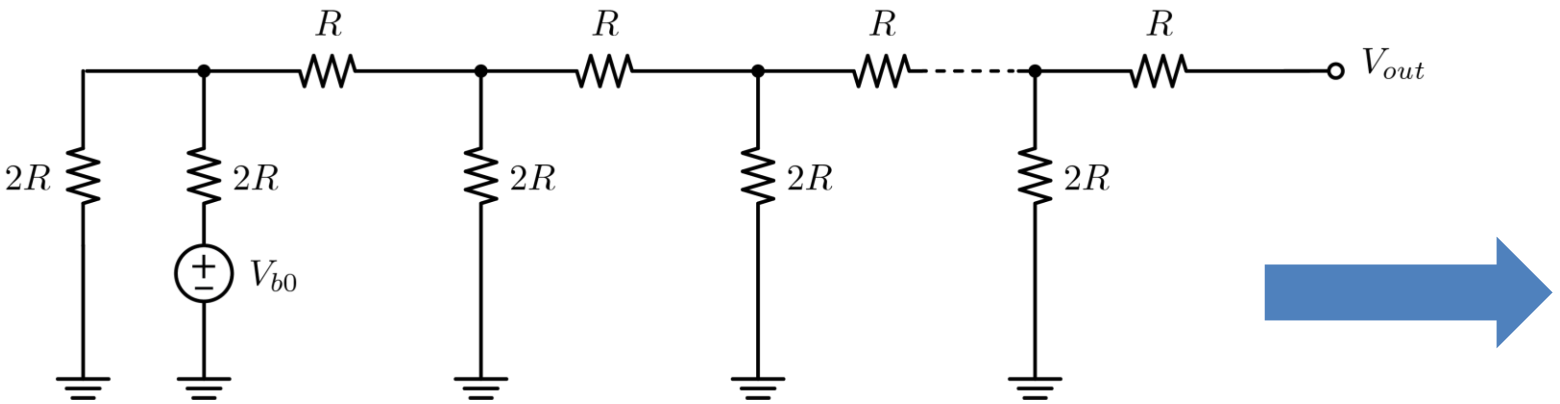


How to set all these “digital” voltages?

Remember Superposition and Equivalence?

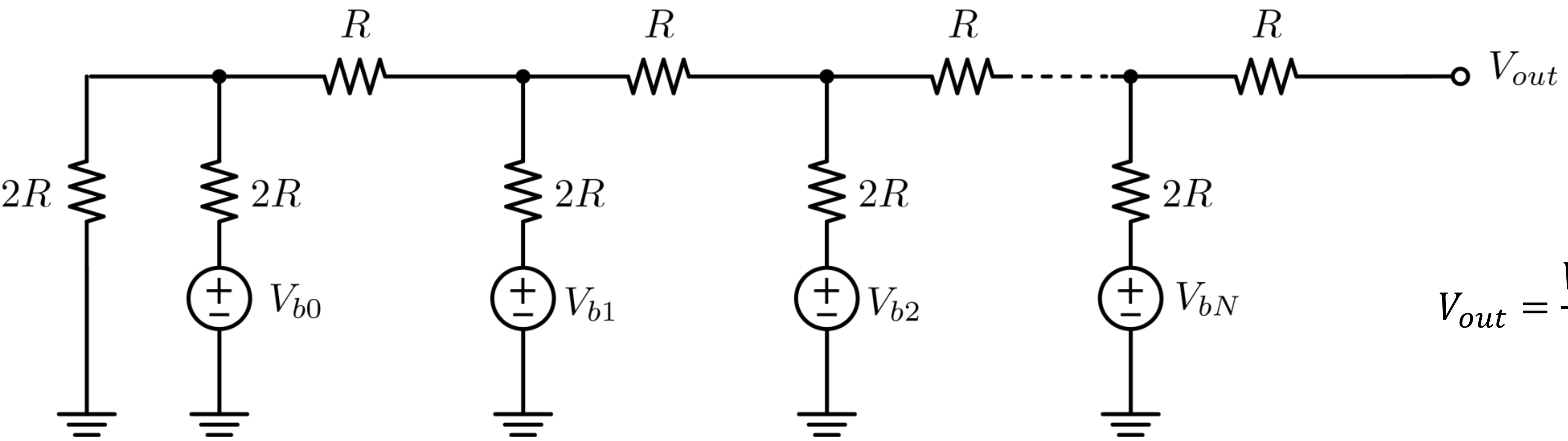
R-2R Ladder Digital-to-Analog Converter

Use superposition: Start with first voltage source:



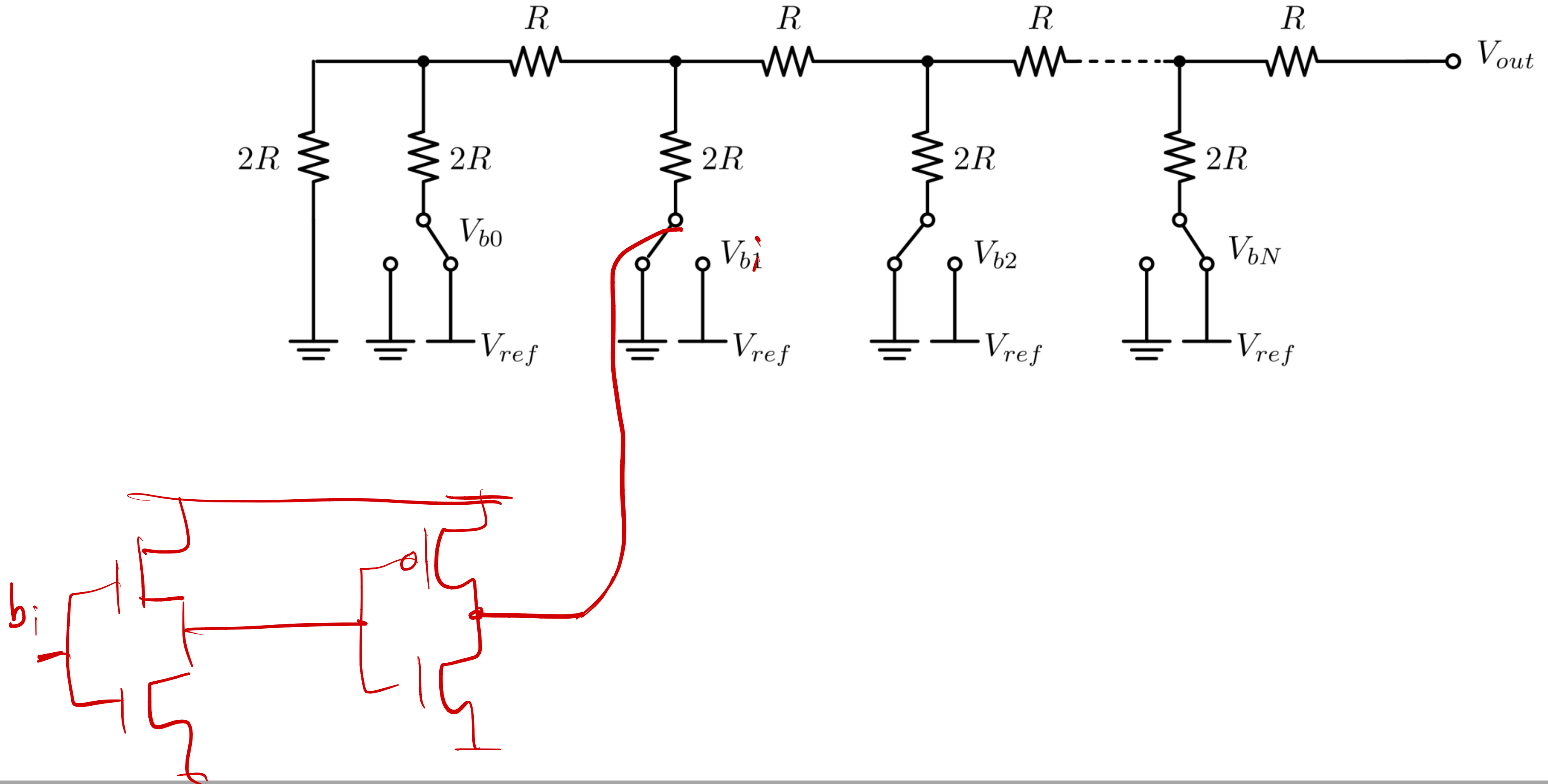
R-2R Ladder Digital-to-Analog Converter

Adding all contributions from the sources



$$V_{out} = \frac{V_{b0}}{2^N} + \frac{V_{b1}}{2^{N-1}} + \cdots + \frac{V_{bN}}{2}$$

Switches

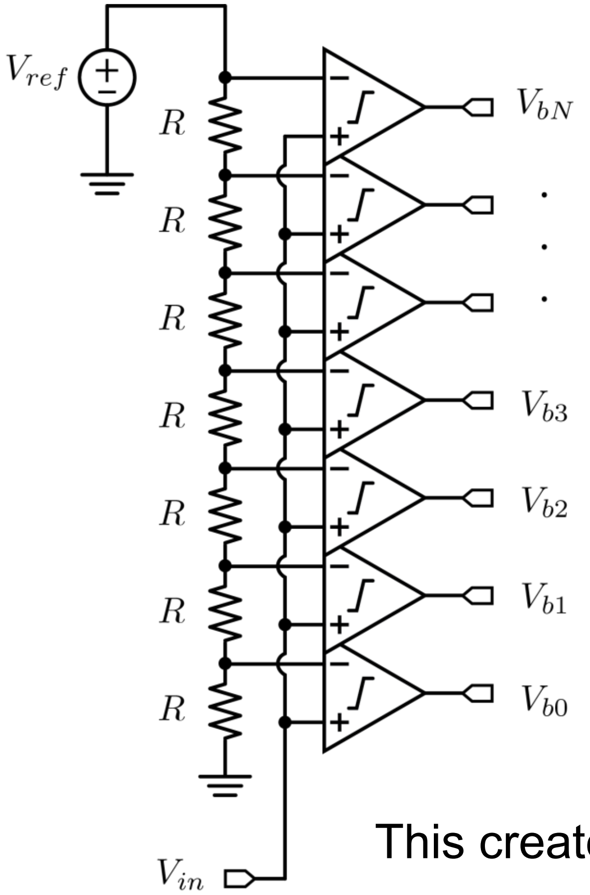


CMOS Gates

How fast can we “convert”?

- If there were no capacitors, we could do it instantly !

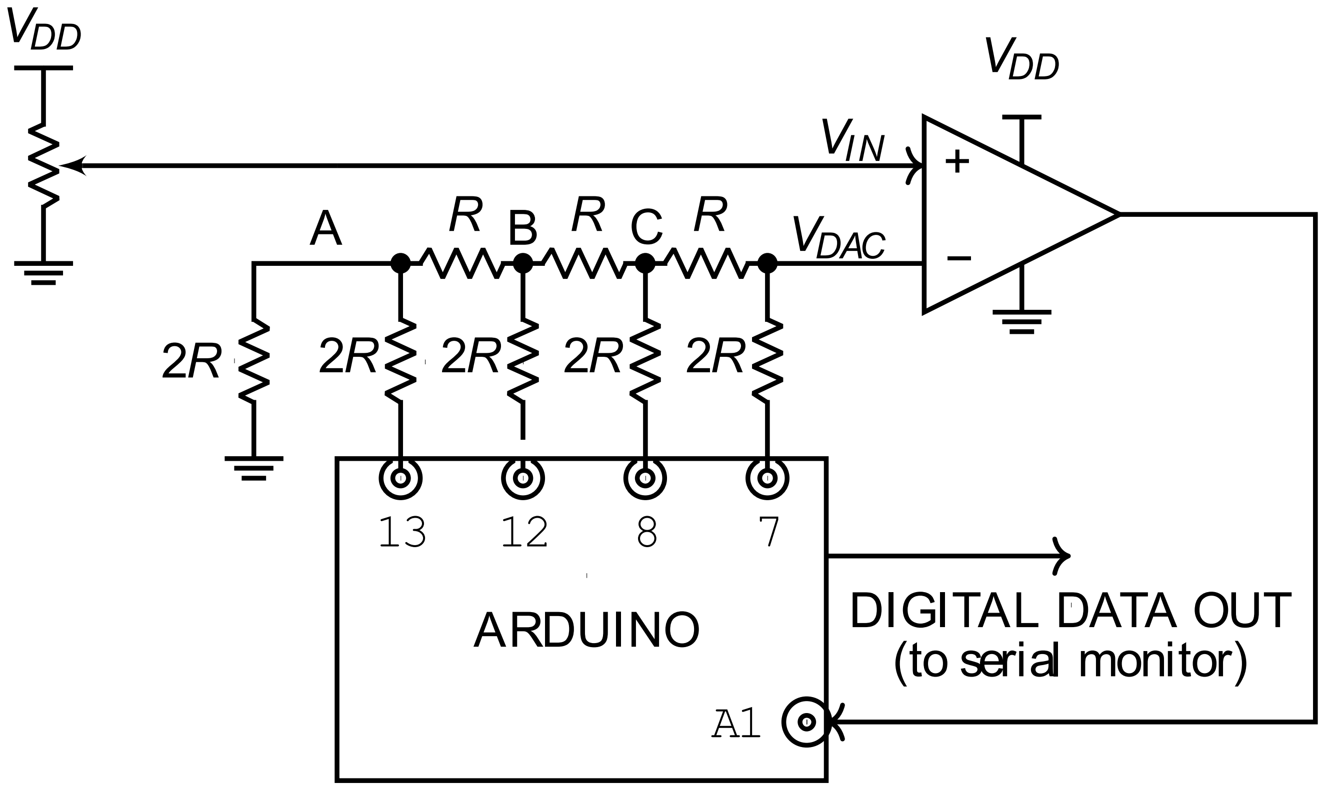
Analog to Digital Conversion



- Very fast massively parallel architecture
- Requires 2^N comparators (specialized op-amps)
- Op-amps have input capacitance
- Power consumption is high for fast operation

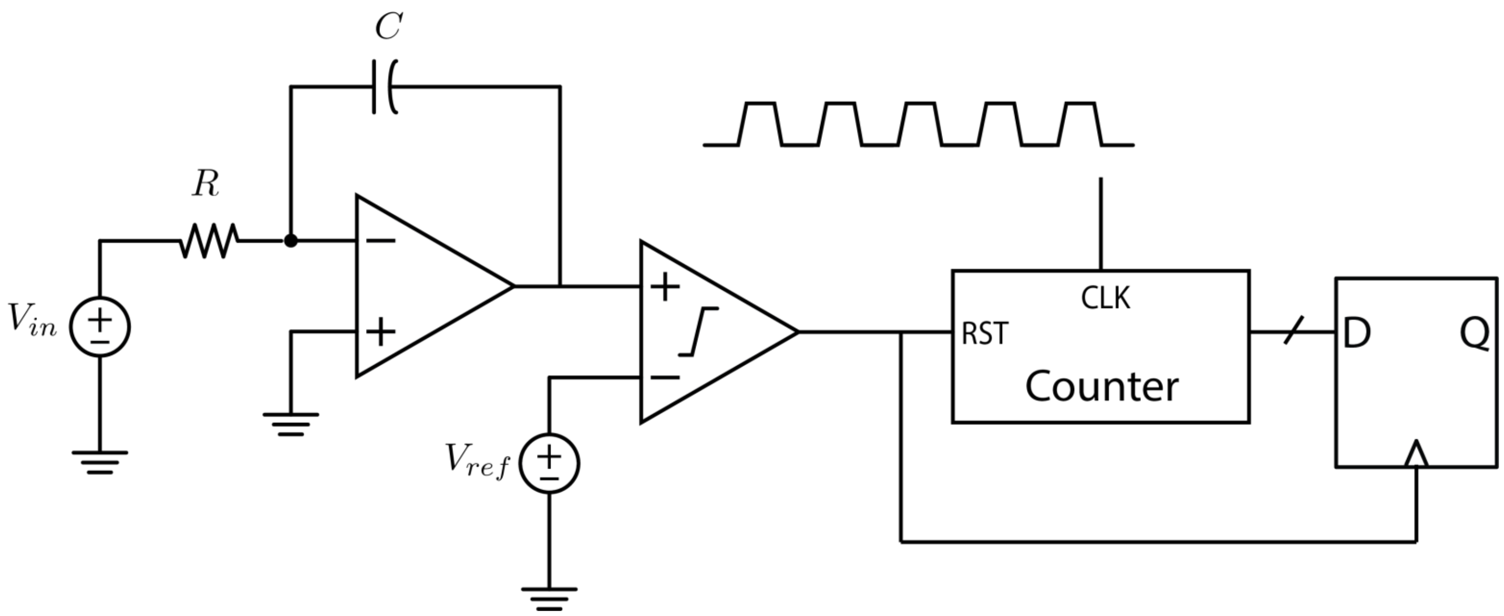
This creates a "Thermometer" digital code. Need to convert to binary for most applications:

Lab 2: SAR (Successive Approximation Resistor) ADC



- Use a DAC to guess signal and find best digital representation
- Can do this in log(N) steps ("guessing game")

RC Integrator Idea



- RC + op-amp creates a ramp with slope proportional to input
- Count how long it takes to reach a reference value
- Counter is digital representation