CAD circuit simulation project

Ex.3 from 200909 exam

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Ex. 3

Consider an 8bit DAC and a dual OpAmp.

a) Compute the $V_{in}(I_{in})$ relationship dependence on the digital input code D_{in} and the R resistor.

b) Substitute the DAC with an 8bit ADC (i.e. A_{out} becomes A_{in} and D_{in} becomes D_{out}) and write D_{out} as a function of V_{in}.

Solution by hand:

a)

(negative feedback)

- $I_{in} = \dfrac{V_{in} - V^-}{R}$

- $V^+ \longrightarrow$ Superimposition effect

① Vin ON, Aout OFF

$$V_1^- = \dfrac{V_{in}}{2}\left(1 + \dfrac{10k}{10k}\right) = V_{in}$$

② Vin OFF, Aout ON

$$V_2^- = Aout\left(-\dfrac{10k}{10k}\right) = -Aout$$

$\hookrightarrow V^- = V_{in} - Aout = V_{in} - V_{in}\dfrac{D_{in}}{2^8}$

- DAC: $Aout = V_{ref}\dfrac{D_{in}}{2^8} = V_{in}\dfrac{D_{in}}{2^8}$

  $= V_{in}$
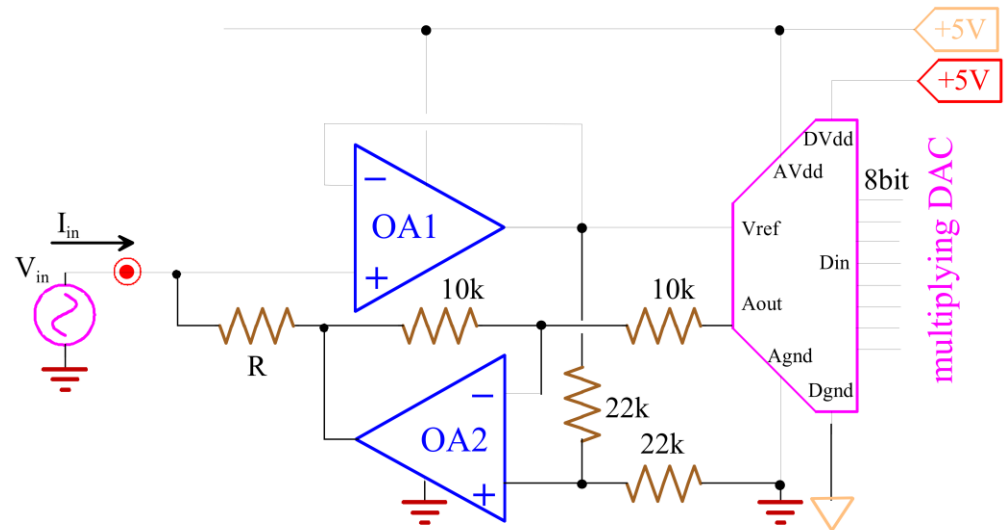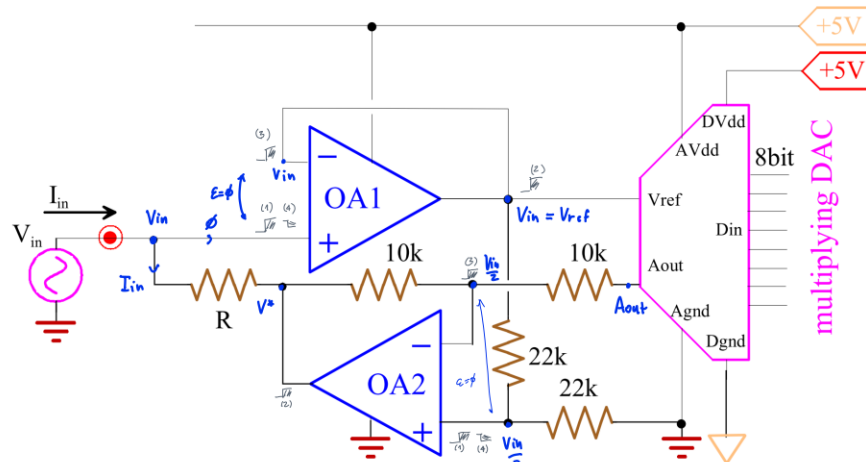
$\Longrightarrow I_{in} = \dfrac{V_{in} - V^-}{R} = \dfrac{V_{in} - V_{in} + V_{in}\dfrac{D_{in}}{2^8}}{R} = \dfrac{V_{in}\, D_{in}}{2^8 \cdot R} = \dfrac{Aout}{R}$

$\hookrightarrow V_{in} = \dfrac{2^8\, R\, I_{in}}{D_{in}}$

OrCAD circuit scheme
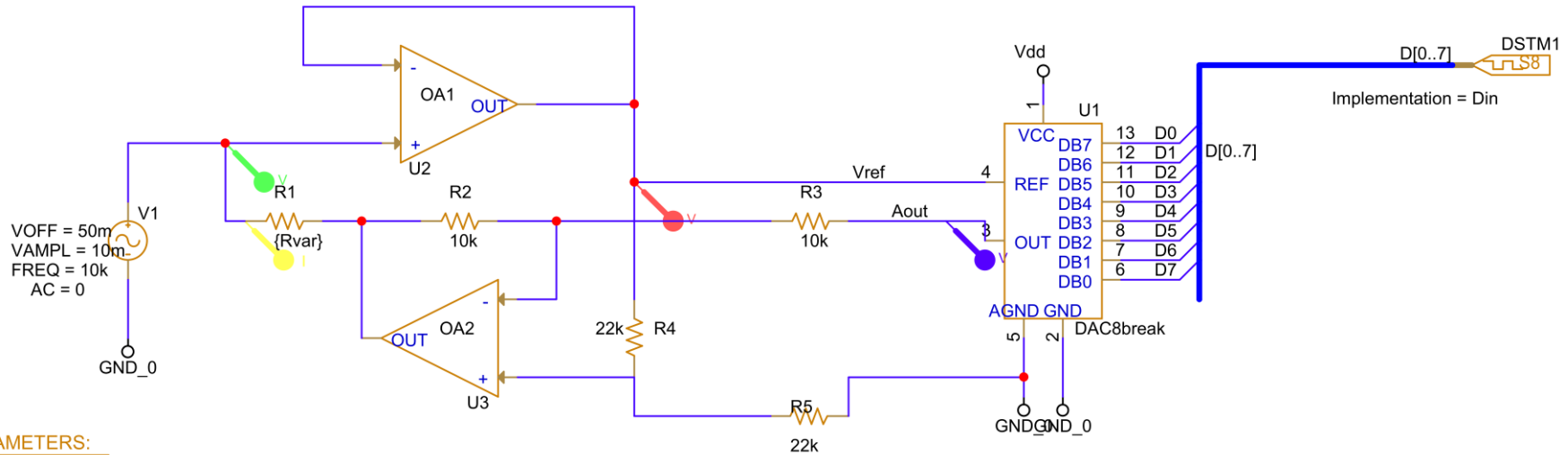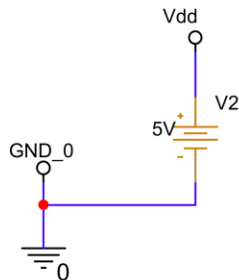
Given schematics
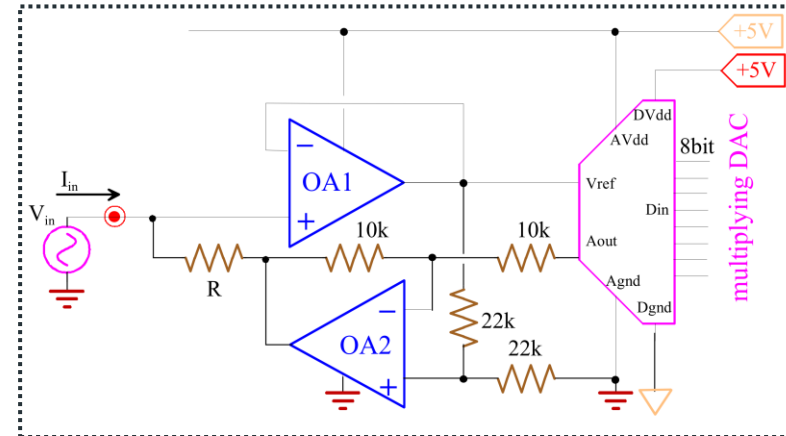
Digital Input stimulus
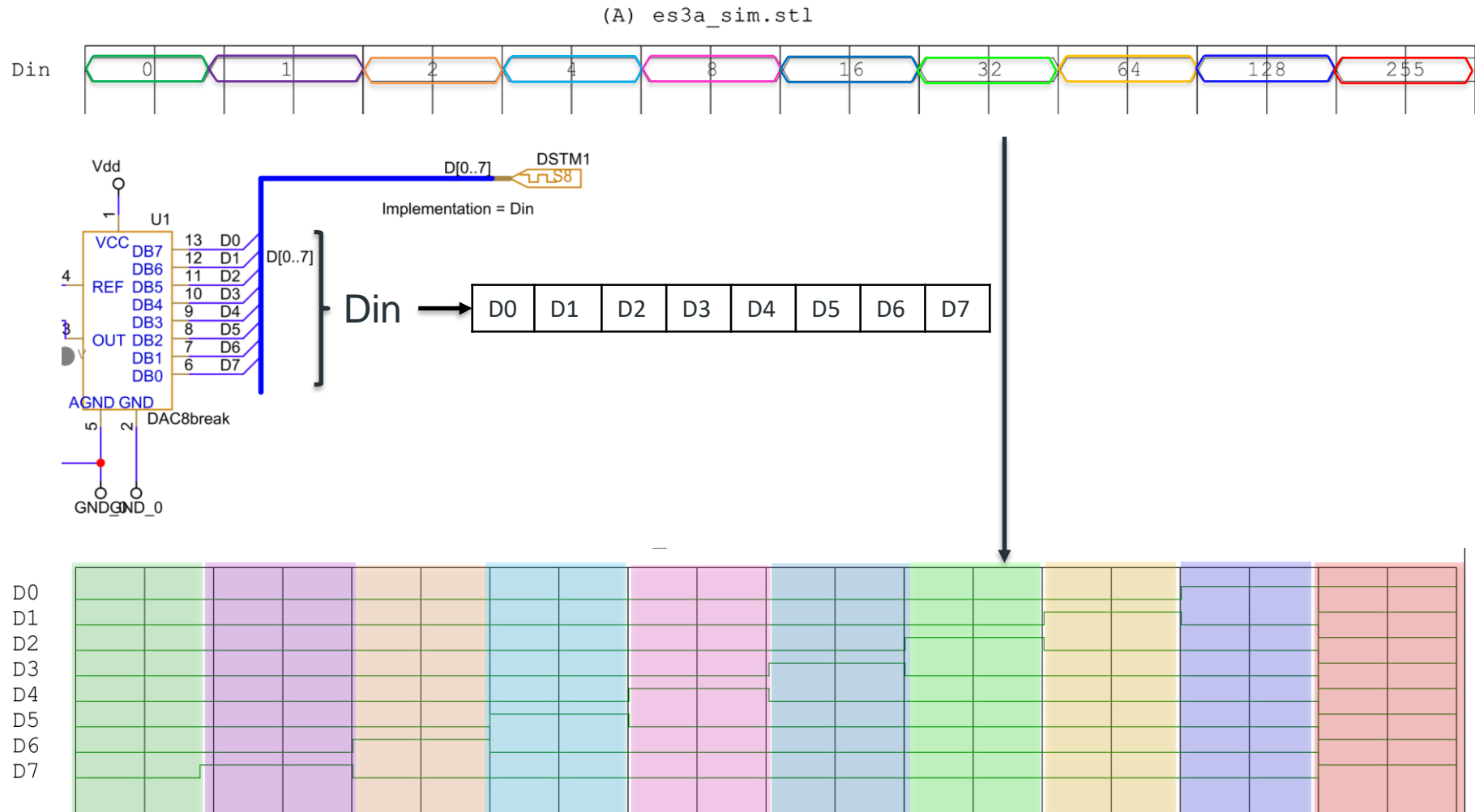
ES3a
Simulation Results

(**simulation: es3a_sim**) with R(R1)=1kΩ
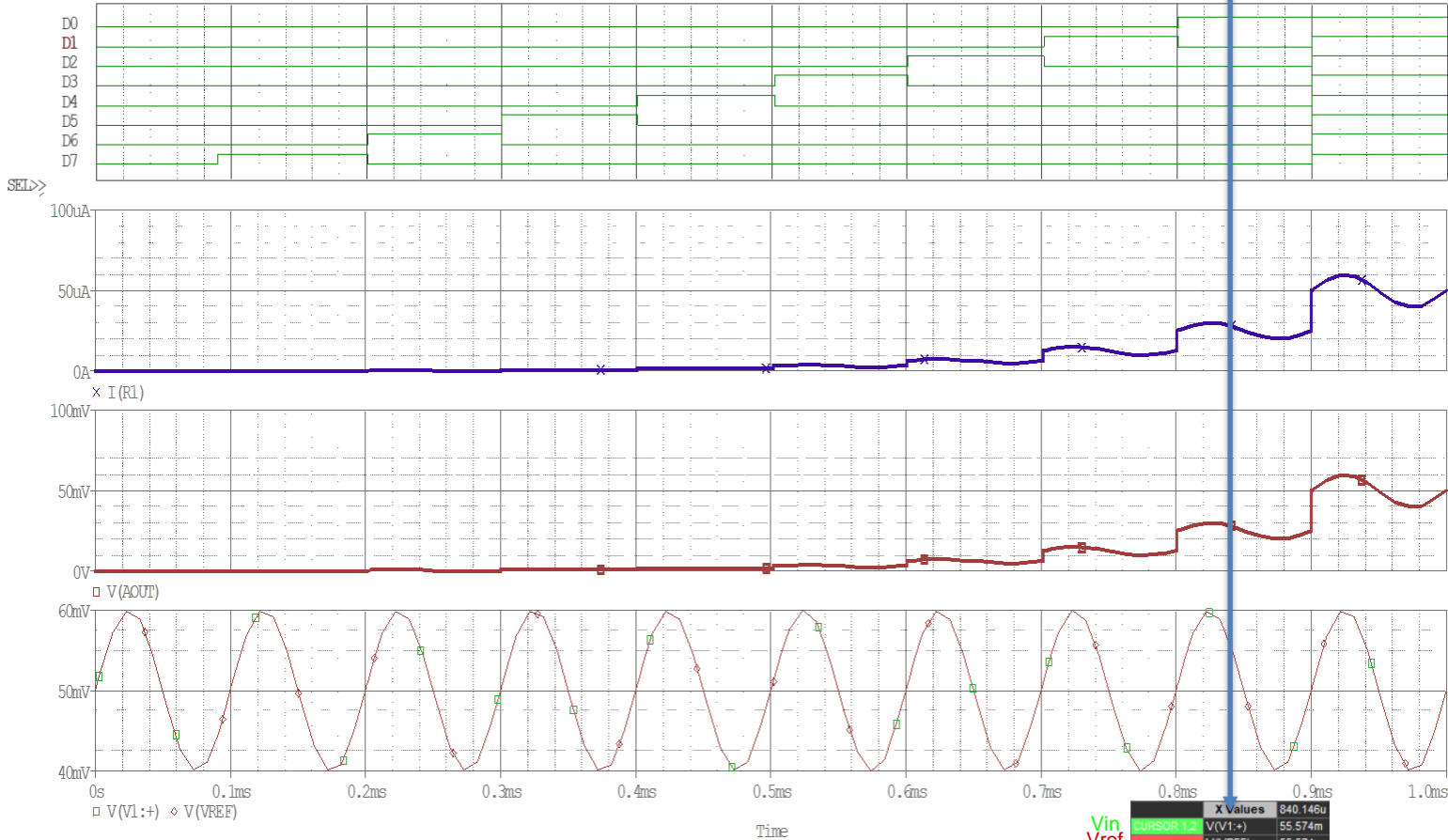
Din

Iin

Aout

Vin = Vref

$$\cdot \; DAC: \quad Aout = V_{ref} \frac{D_{in}}{2^8} = V_{in} \frac{D_{in}}{2^8}$$
$$\uparrow = V_{in}$$

	X Values	840.146u
Vin CURSOR 1,2	V(V1:+)	55.574m
Vref	V(VREF)	55.574m
Aout	V(AOUT)	27.787m
Iin	I(R1)	27.787u

$$= \frac{V_{ref} D_{in}}{2^8} = \frac{V_{in} D_{in}}{2^8} = \frac{V_{in} 2^7}{2^8} = \frac{V_{in}}{2} = \frac{55.574m}{2} = 27.787m$$

Din = 2^7 = 128

ES3a
Simulation Results

(**simulation: es3a_sim**) with R(R1)=1kΩ

Iin

$$I_{in} = \frac{V_{in} - V^+}{R} = \frac{V_{in} - V_{in} + \overline{V_{in} \frac{D_{in}}{2^8}}}{R} = \frac{V_{in} D_{in}}{2^8 \cdot R} = \frac{A_{out}}{R}$$

Aout

Vin , Vref

ES3a
Simulation Results

(**simulation: es3a_sim**) with R(R1)=5kΩ

$$I_{in} = \frac{V_{in} - V^+}{R} = \frac{V_{in} - V_{in} + \overline{V_{in} \frac{D_{in}}{2^8}}}{R} = \frac{V_{in} D_{in}}{2^8 \cdot R} = \frac{A_{out}}{R}$$

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Simulation Results

(**simulation: es3a_sweep**) with R(R1)=Rvar=[1kΩ÷10kΩ], Din=1 constant, Vin=Vref=50mV (constant bias)
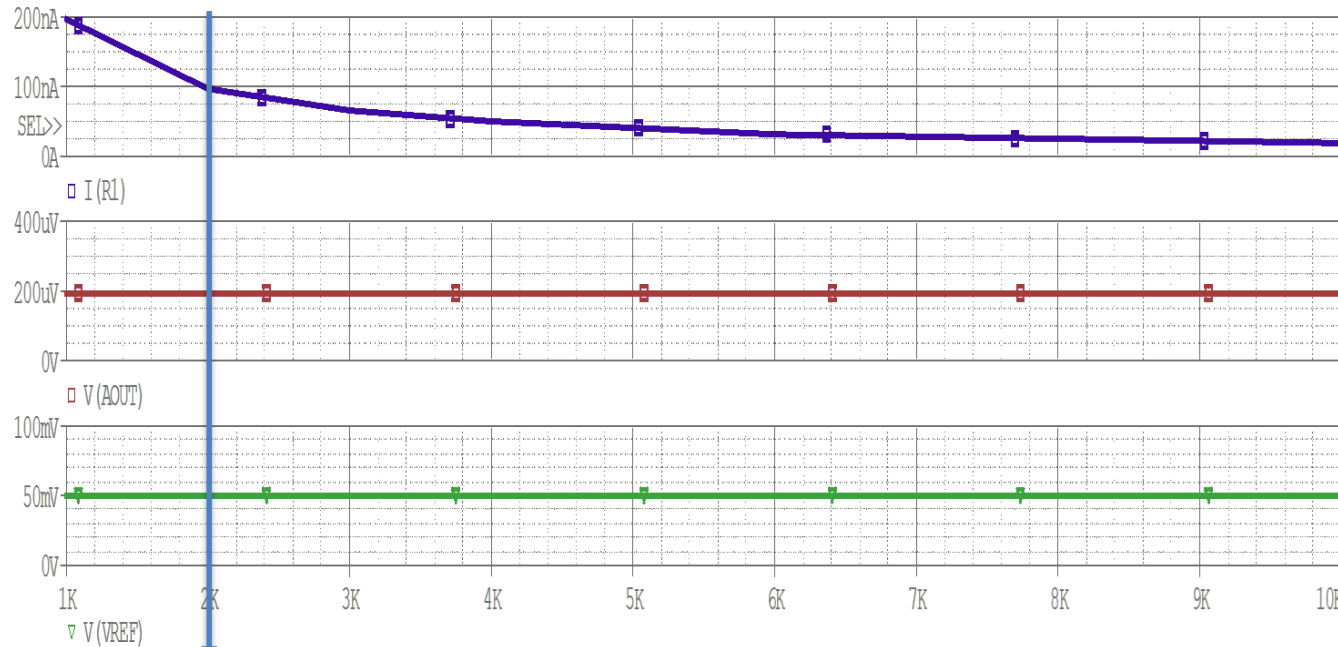
Iin

$$\text{Aout} = \frac{V_{ref}D_{in}}{2^8} = \frac{V_{ref} \cdot 1}{256}$$
$$= \frac{50mV \cdot 1}{256} = 195.312\mu V$$

Vref

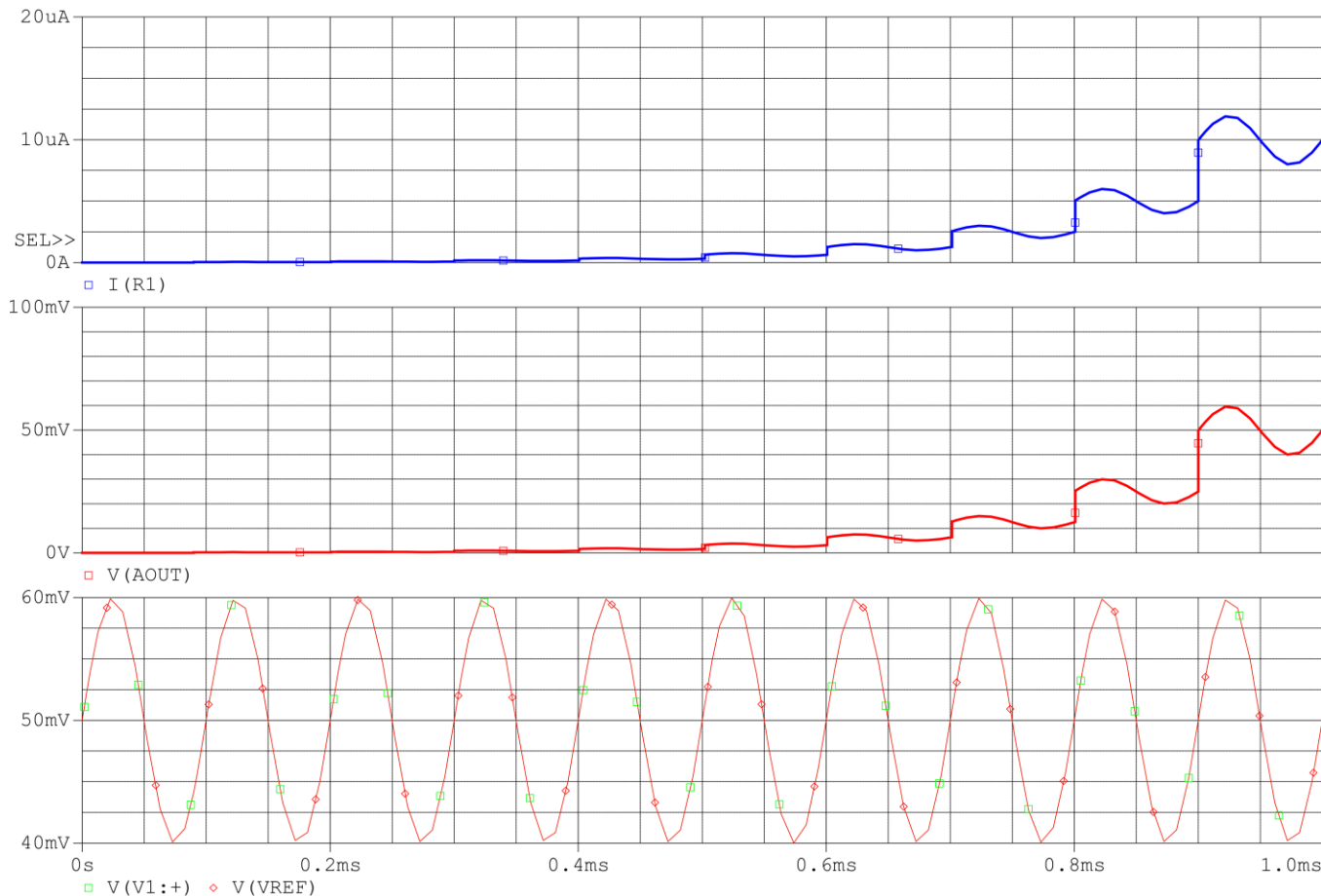| Trace Color	Trace Name	Y1
	X Values	2.0000K
Vref	V(VREF)	50.000m
Aout	V(AOUT)	195.312u
Iin — CURSOR 1,2	I(R1)	97.731n

$$= \frac{Aout}{R} = \frac{195.312\mu V}{2k\Omega} = 97.7nA$$

$$I_{in} = \frac{Vin - V^+}{R} = \frac{Vin - Vin + Vin\frac{Din}{2^8}}{R} = \frac{Vin \cdot Din}{2^8 \cdot R} = \frac{Aout}{R}$$

Rvar
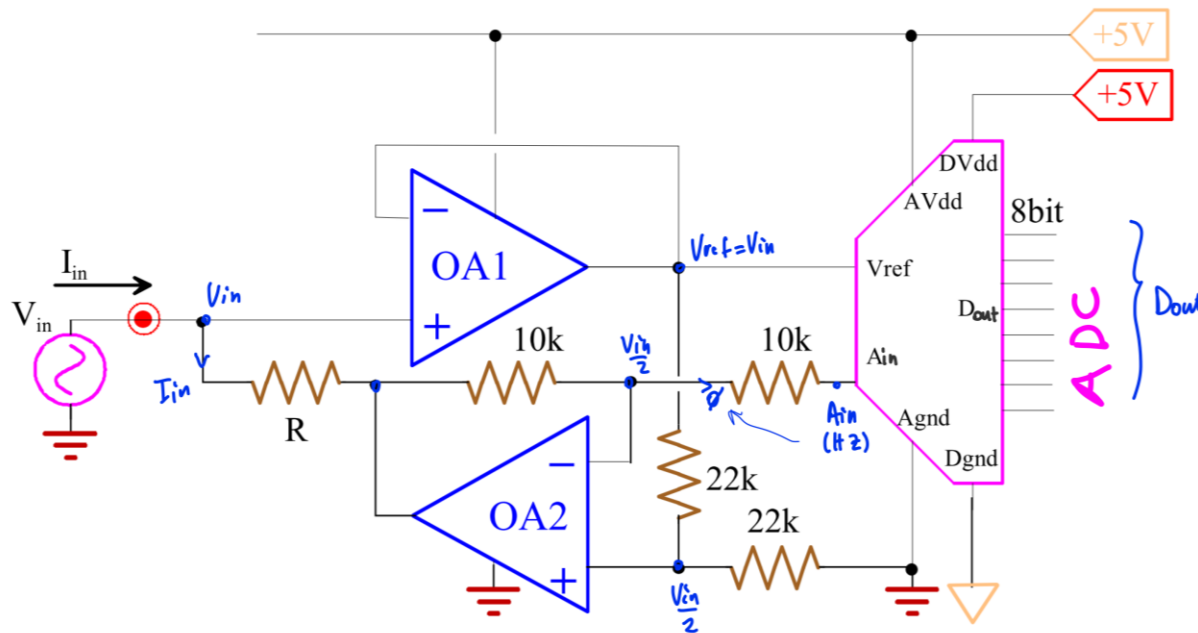
$$\bullet \; A_{in} = \frac{V_{in}}{2} \quad , \quad V_{ref} = V_{in}$$

$$\hookrightarrow D_{out} = \frac{A_{in}}{\dfrac{V_{ref}}{2^8}} = \frac{\dfrac{V_{in}}{2}}{\dfrac{V_{in}}{2^8}} = 2^7$$

OrCAD circuit scheme

delay of 90us of the ADC
(ADC conversion pulse's parameters
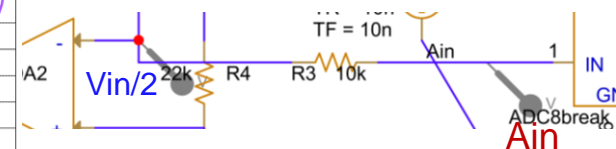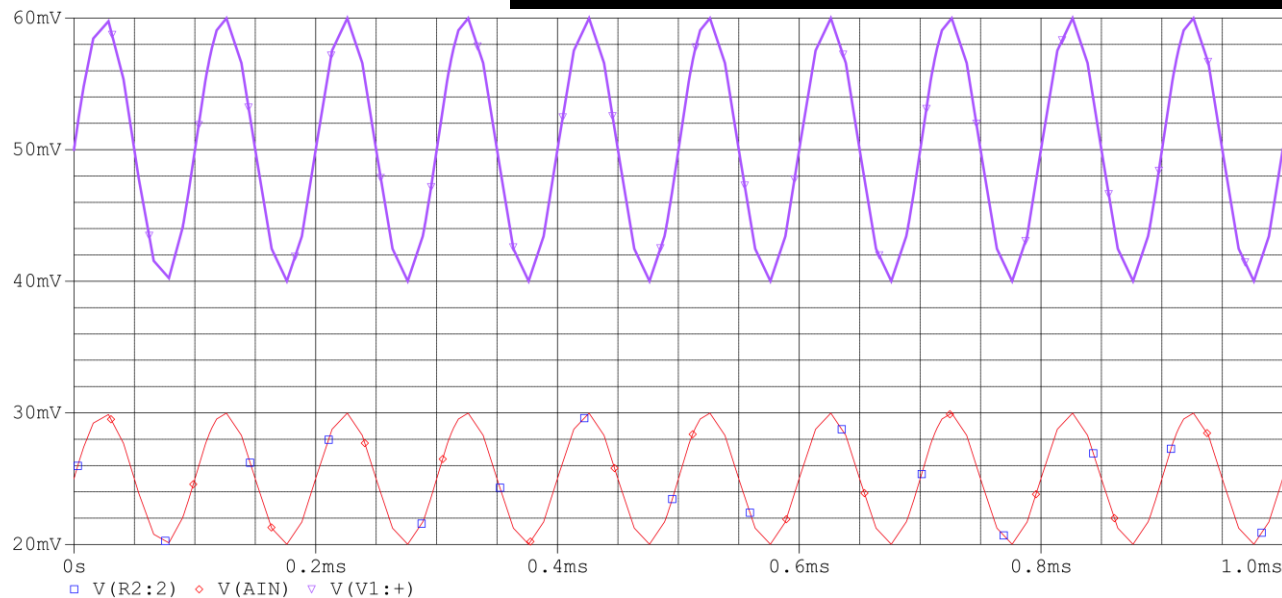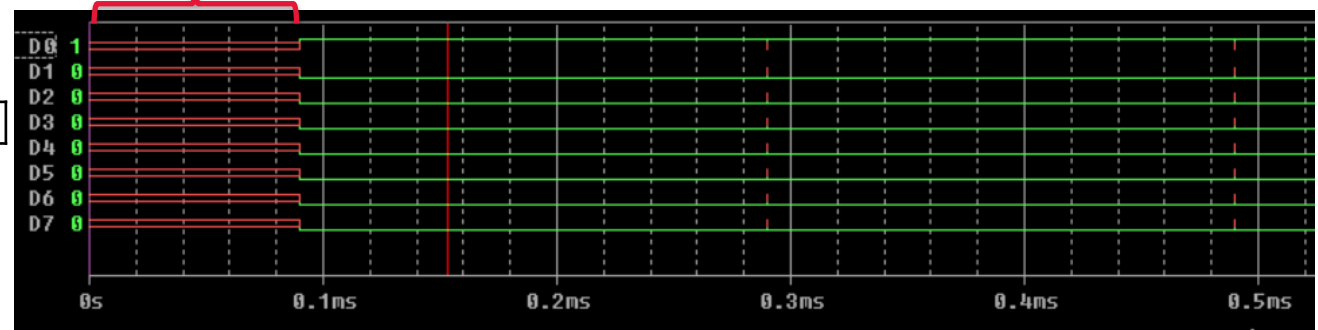chosen in order to clearly see the effect of the signal driving the conversion)

ADC instead of DAC
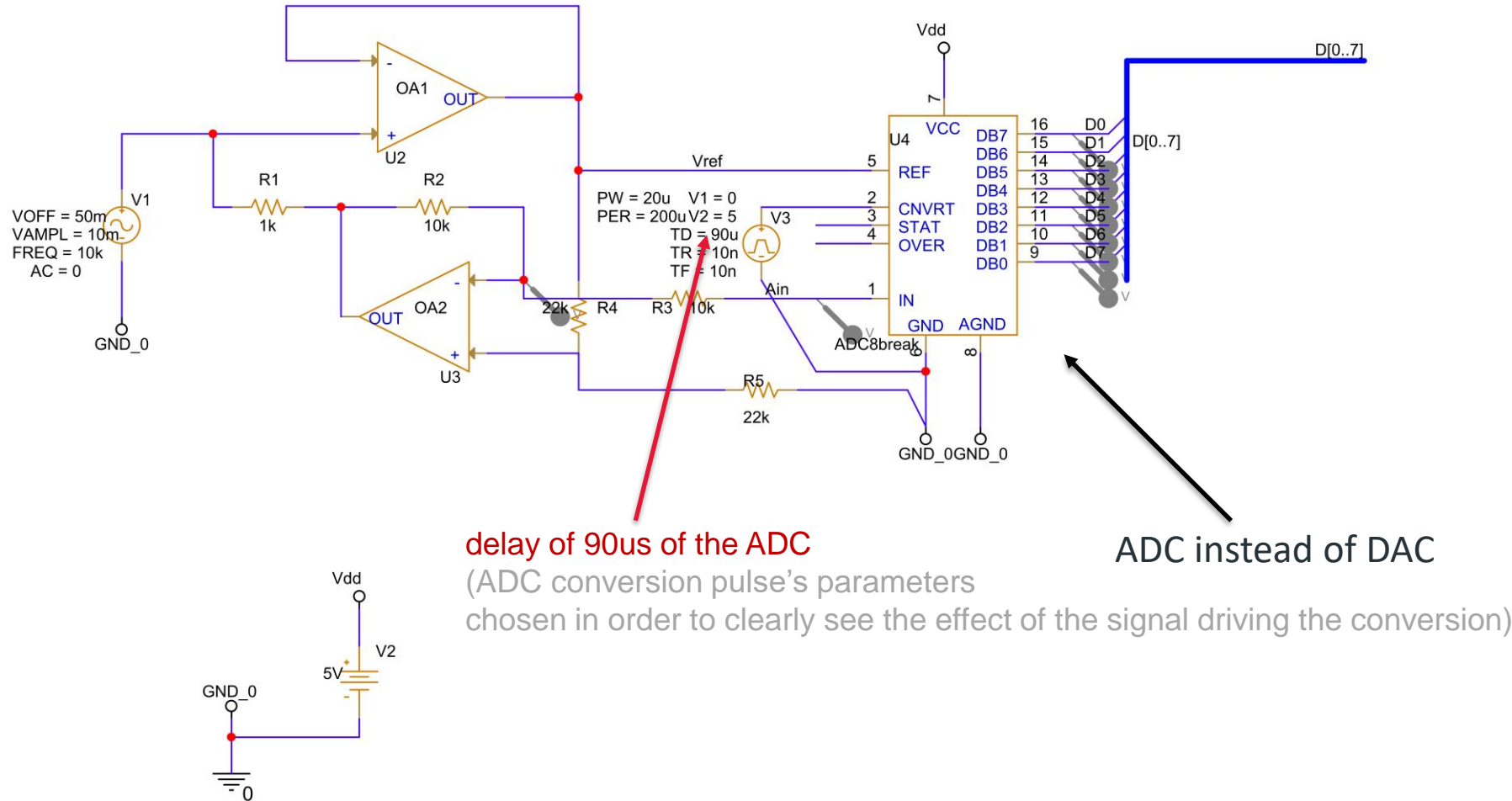
ES3b
Simulation Results

(**simulation: es3b_sim**) with R(R1)=1kΩ   delay of 90us of the ADC

$Dout=1000000=2^7$

D0	D1	D2	D3	D4	D5	D6	D7

Vin/2   22k   R4   R3   10k   Ain   TF = 10n   ADC8break   Ain

Vin , Ain , Vin/2

CURSOR 1,2	V(R2:2)	22.491m
	V(AIN)	22.491m
	V(V1:+)	44.908m

□ V(R2:2)   ◇ V(AIN)   ▽ V(V1:+)