



50707921

Resolver cada problema en hojas separadas.

Duración de la prueba: 3 horas 30 minutos.

La prueba es sin material.

Los puntajes de los problemas se indican sobre un total de 100 puntos.

PROBLEMA 1 (37 puntos)

- Diseñar un amplificador diferencial con ganancia 200 y resistencia de entrada diferencial de $150\text{ k}\Omega$. El mismo estará basado en un único amplificador operacional, que para esta parte del problema se supondrá ideal.
- Si el amplificador diseñado se implementa con un TL071AC alimentado de $\pm 15\text{V}$ y operando a 25°C , cuyos datos se adjuntan. Determinar el máximo valor (peor caso) de la tensión de offset a la salida.
- Si las resistencias utilizadas son al 5% y el CMRR del operacional se supone infinito, estimar el CMRR del amplificador diseñado en un peor caso. De acuerdo al resultado obtenido, ¿es correcta la suposición de que el CMRR del operacional es infinito? Justificar.
- ¿Cuál es el ancho de banda del amplificador diseñado?

PROBLEMA 2 (37 puntos)

En el amplificador de la figura calcular:

- El punto de funcionamiento de los transistores
- La ganancia del circuito completo a frecuencias medias
- Dimensionar los capacitores $C1$, $C2$ y $C3$ para que la caída 3dB a baja frecuencia esté en 30Hz.

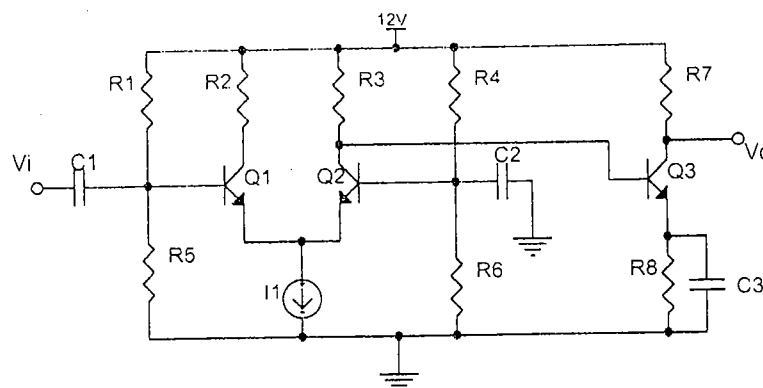
Datos:

$$Q1=Q2=Q3: V_{BE}=0.6\text{V}, \beta=100$$

$$R1=R4=18\text{k}, R5=R6=4.7\text{k}, R2=R3=6.8\text{k}, R7=6.8\text{k}, R8=8.2\text{k}$$

$$I1=2\text{mA}$$

$$C1 \equiv C2$$



PREGUNTA (26 puntos)

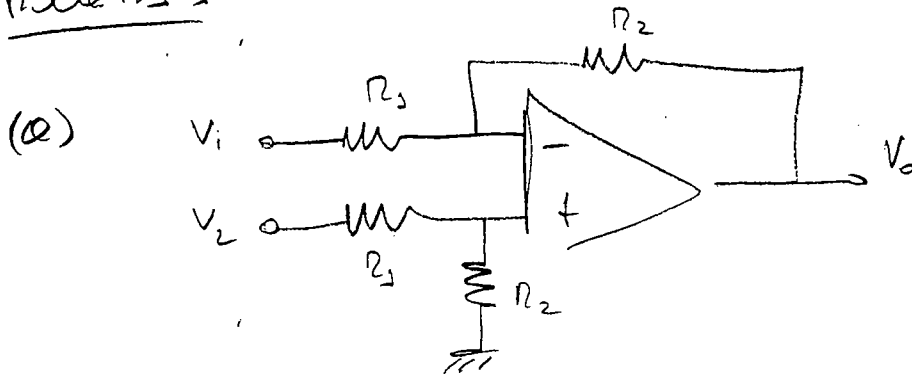
- Indicar gráficamente en la característica estática de transferencia de tensión entrada-salida de un inversor ($V_o = f(V_i)$) los valores de V_{OL} , V_{OH} , V_{IH} , V_{IL} , margen de ruido en nivel alto (NM_H) y margen de ruido en nivel bajo (NM_L). Explicar claramente cómo se definen los puntos V_{IH} y V_{IL} y porqué.
- Calcular V_{IH} y NM_H para un inversor CMOS con tensión de alimentación V_{DD} y con los siguientes datos para los transistores n y p: $\beta_n = \beta_p$, $V_{tn} = |V_{tp}|$, $\delta_n = \delta_p = 0$. Se despreciará el efecto Early.
- Determinar los valores de V_{IH} y NM_H determinados en b) para el caso de una tecnología con tensión umbral $V_{tn} = |V_{tp}| = 0.7V$ y tensión de alimentación $V_{DD} = 3.3V$.



ELECTRONICS I

#1/2

Problems 1

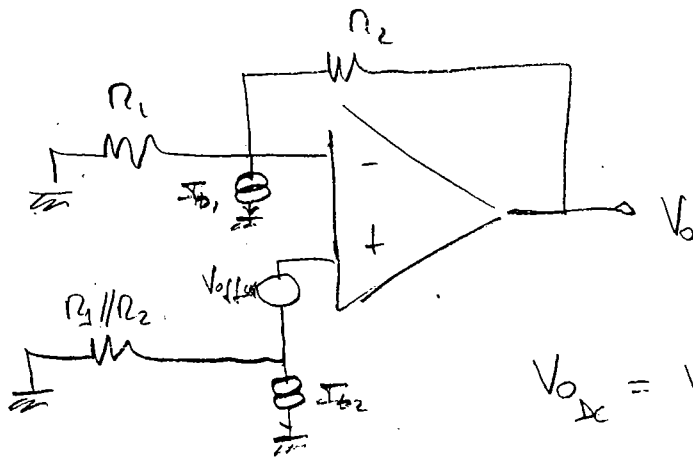


$$\frac{V_o}{V_2 - V_1} = \frac{R_2}{R_1} \quad R_{id} = 2R_1 = 150k\Omega$$

$$\Rightarrow R_1 = 75k\Omega$$

$$G_{AR} = 200 \Rightarrow \frac{R_2}{R_1} = 200 \Rightarrow R_2 = 15M\Omega$$

(b)



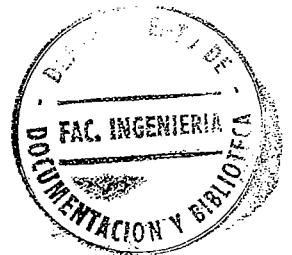
$$V_{Odc} = V_{off} \left(1 + \frac{R_2}{R_1} \right) + R_2 (I_{B1} - I_{B2})$$

I_{offset}

De la hoja de datos de 741C (T=25°C)

	Typ	Max	
I_{IO}	5	100	μA
V_{IO}	3	6	mV

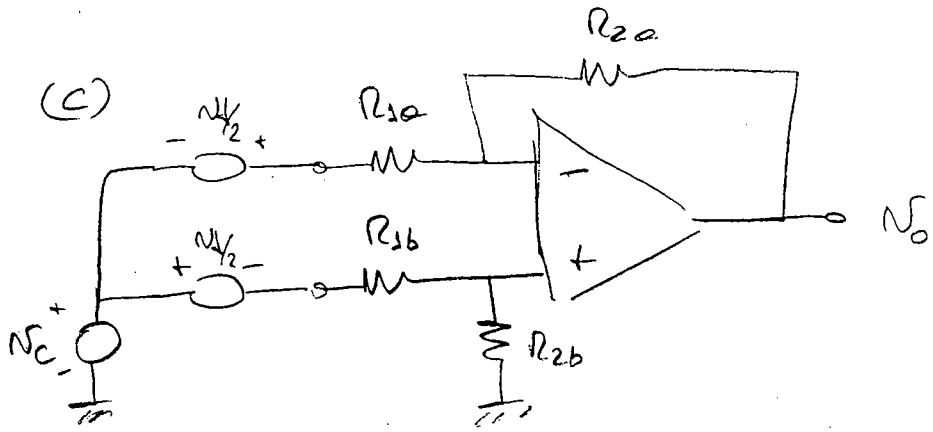
para caso: $V_{Odc} = 1.2V$



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#2/2



supuesto $CNRR_{on} = \infty$

gan. CN : $A_C (N_d = 0) = \frac{N_0}{N_c} = \frac{R_{2b} R_{1a} - R_{2a} R_{1b}}{R_{1a} (R_{1b} + R_{2b})}$

gan. Ad : $A_d (N_c = 0) = \frac{N_0}{N_d} = -\frac{1}{2} \frac{R_{2a} (R_{1b} + R_{2b}) + R_{2b} (R_{1a} + R_{2a})}{R_{1a} (R_{1b} + R_{2b})}$

$\Rightarrow CNRR = \frac{A_d}{A_C} = \frac{1}{2} \frac{R_{2a} (R_{1b} + R_{2b}) + R_{2b} (R_{1a} + R_{2a})}{R_{2b} R_{1a} - R_{2a} R_{1b}}$

proceso:

$$\begin{aligned} R_{2a} &= (1 - \delta) R_2 \\ R_{2b} &= (1 + \delta) R_2 \\ R_{1a} &= (1 + \delta) R_1 \\ R_{1b} &= (1 - \delta) R_1 \end{aligned}$$

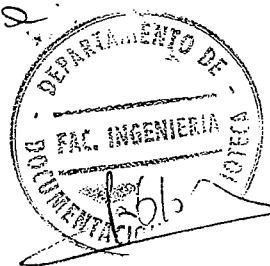
$\Rightarrow CNRR = \frac{1}{2} \frac{2 + 2\delta^2 + 2\frac{R_2}{R_1} (1 - \delta^2)}{4\delta} \xrightarrow{\delta^2 \rightarrow 0} \approx \frac{1 + \frac{R_2}{R_1}}{4\delta}$

$\delta = 0.05$
 $\frac{R_2}{R_1} = 200 \Rightarrow \boxed{CNRR = 1005 \approx 60dB}$

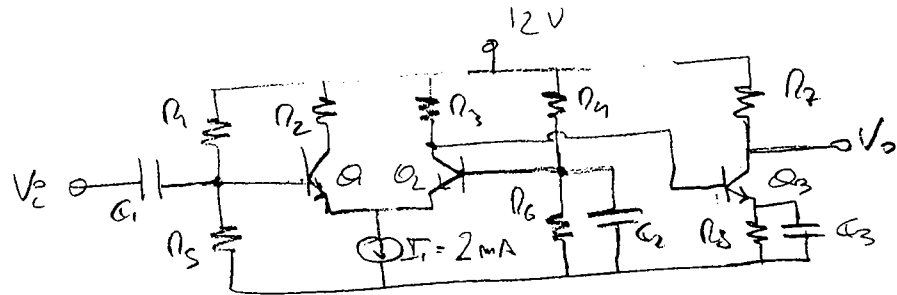
Hoy a dBs: para $CNRR_{on} = 75dB \gg 60dB$
 \Rightarrow estuvo bien la suposición.

(d)

$f_{3dB} = \frac{f_T}{1 + \frac{R_2}{R_1}} \Rightarrow \boxed{f_{3dB} \approx 15 kHz}$
 $H. de D. = f_T = 3 MHz$



Problema 2



(a)

Q1, Q2

Supo $I_{B1} \ll I_{R5}$
 $I_{B2} \ll I_{R6}$

$\rightarrow I_{R5} = 0,53 \text{ mA}$

$\Rightarrow \boxed{V_{B1} = V_{B2} = V_{CC} \frac{R_5}{R_1 + R_5} = \frac{24,8 \text{ V}}{2} \Rightarrow V_{B1} = V_{B2} = 12,4 \text{ V}}$

$I_{C1} = I_{C2} = I_{I/2} \Rightarrow V_{C1} = V_{C2} = V_{CC} - R_3 I_{I/2} \quad (\text{sup } I_{B3} \ll I_{C2})$

$\hookrightarrow I_{C1} = 1 \text{ mA} \rightarrow I_{B1} = 10 \mu\text{A} \ll I_{R5} \quad \checkmark$

$\Rightarrow \boxed{V_{C2} = V_{C1} = 5,2 \text{ V}}$

Q3 $V_{E3} = V_{C2} - V_{BE3} = 4,6 \text{ V}$

$\Rightarrow I_{C3} = 0,56 \text{ mA} \Rightarrow I_{B3} \approx 5,6 \mu\text{A} \ll I_{C2} \quad \checkmark$

$\Rightarrow V_{C3} = 12 - I_{C3} R_7 \Rightarrow \boxed{V_{C3} = 8,2 \text{ V}}$



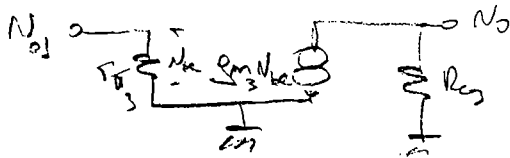
#2/4



(b)

2da etapa

$$g_{m3} = \frac{I_{E3}}{V_T} = 21,5 \frac{mA}{V}$$



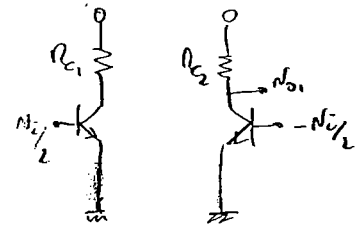
$$N_0 = -g_{m3} N_{01} R_{C3}$$

$$\Rightarrow \left| \frac{N_0}{N_{01}} \right| = -146,5 \text{ V/V}$$

$$R_{in3} = r_{\pi 3} = \frac{\beta}{g_m} = 4,64 \text{ k}\Omega$$

1ra etapa

Para el par diferencial a la mitad:



$$N_{0e2} = -\frac{N_{01}}{2} \Rightarrow N_{01} = -g_{m2} \left(-\frac{N_{01}}{2}\right) (R_{C2} \parallel R_{in3})$$

$$g_{m2} = \frac{I_{C2}}{V_T} = \frac{I_1}{2V_T} = 38,5 \frac{mA}{V}, \quad R_{C2} \parallel R_{in3} = 2,73 \text{ k}\Omega$$

$$\Rightarrow \frac{N_{01}}{N_{01}} = 53 \text{ V/V}$$



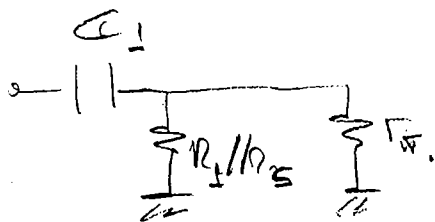
$$\Rightarrow \frac{N_0}{N_{01}} = -7,76 \text{ kV/V}$$

$$\left(\left| \frac{N_0}{N_{01}} \right| = 77,4 \text{ dB} \right)$$

Problem 2

(c)

C_1 y C_2 time associated to this R_{visita} :

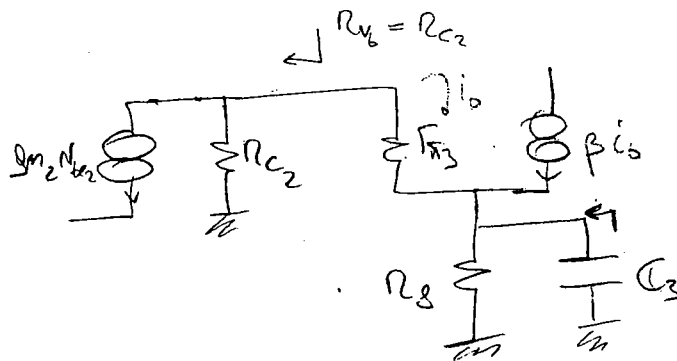


$$\omega_{p1} = \omega_{p2} = \frac{1}{C_1 (R_1 \parallel R_S \parallel R_{\pi 1})}$$

$$R_1 \parallel R_S \parallel R_{\pi 1} = 1.53 k\Omega$$

$$R_{\pi 1} = \frac{2V_T}{I_{D1}} = 2.6 k\Omega$$

C_3 : B1 pto asociado a C_3 es el de R_{visita} de C_3



$$R_{C3} = \left(\frac{R_{\pi 3} + R_{C2}}{\beta + 1} \right) \parallel R_8$$

$$\omega_{p3} = \frac{1}{C_3 (R_8 \parallel \frac{R_{\pi 3} + R_{C2}}{\beta + 1})}$$

$$R_8 \parallel \frac{R_{\pi 3} + R_{C2}}{\beta + 1} \approx \frac{R_{\pi 3} + R_{C2}}{\beta + 1} = 114 \Omega$$



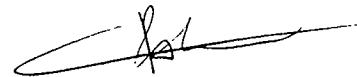
(c) (sigue)

La resistencia asociada a C_3 es \ll a
la asociada a C_1 y C_2

$$\rightarrow \omega_{p3} = 30 \text{ Hz}$$

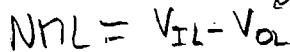
$$\omega_{p1} = \omega_{p2} \ll 30 \text{ Hz}, \rightarrow \omega_{p1} = \omega_{p2} = 3 \text{ Hz}$$

$$\Rightarrow \left\{ \begin{array}{l} C_3 = 46,5 \mu\text{F} \\ C_1 = C_2 = 39,7 \mu\text{F} \end{array} \right.$$




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1/2



$$W_{th} = V_{oh} - V_{iw}$$

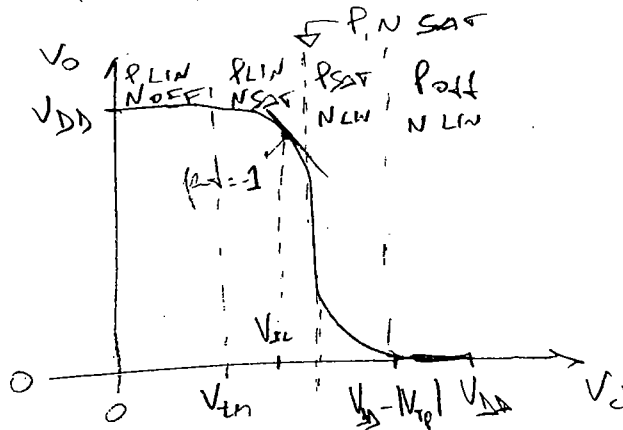
V_{IL} y V_{IH} se definen a los puntos donde la

pedirete de $V_0 = f(V_i)$ es -1 . Así se asegura

9' si $V_i < V_{IT}$ o $V_i > V_{IT}$ hay regeneración

de la información. Es decir q' una perturbación

«Atiende ya q' la ganancia es < 1 a rotulo



VIII ocurre en la zona de la el Transistor Morte e zona
linex y el transistor q esta saliendo \Rightarrow

$$I_{Dn} = \beta (V_{GS} - V_t) V_{DS} - \frac{1}{2} V_{DS}^2 = \beta \left[(V_i - V_t) V_o - \frac{1}{2} V_o^2 \right]$$

$$|I_{DQ}| = \frac{\beta}{2} (V_{GS} - V_t)^2 = \frac{\beta}{2} (V_{DD} - V_C - V_t)^2$$

10/11

$$\Rightarrow \text{como } I_{in} = |I_{DP}|$$

$$\Rightarrow \left(\frac{\beta}{2} (V_{DD} - V_t - V_o)^2 \right) = \beta \left[(V_i - V_t) V_o - \frac{1}{2} V_o^2 \right]$$

Derivo a ambos lados y evaluo en $\left\{ \begin{array}{l} V_i = V_{IH} \\ \frac{\Delta V_o}{\Delta V_i} = -1 \end{array} \right.$

$$\Rightarrow \text{obteniendo } V_o = V_{IH} - \frac{V_{DD}}{2}$$

Sustituyo en (*)

$$V_{IL} = \frac{\frac{5}{8} V_{DD}^2 - \frac{3}{2} V_t V_{DD} + \frac{1}{2} V_t^2}{V_{DD} - 2V_t} = \frac{\frac{5}{8} (V_{DD} - 2V_t)(V_{DD} - \frac{2}{5} V_t)}{(V_{DD} - 2V_t)}$$

$$\Rightarrow V_{IH} = \frac{1}{8} (5V_{DD} - 2V_t)$$

$$NMH = \underset{(V_{OH})}{V_{DD}} - V_{IH} = \frac{3}{8} V_{DD} + \frac{3}{8} V_t$$

(c) $V_t = 0.7 \text{ V}$
 $V_{DD} = 3.3 \text{ V}$

$$\Rightarrow \left\{ \begin{array}{l} V_{IH} = 1.89 \text{ V} \\ NMH = 1.41 \text{ V} \end{array} \right.$$



11/11

21

TEXAS
INSTRUMENTS

electrical characteristics, $V_{CC1} = \pm 15\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	T _A ‡	TL071C TL072C TL074C			TL071AC TL072AC TL074AC			TL071BC TL072BC TL074BC			TL071I TL072I TL074I			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage	V _O = 0, R _S = 50 Ω	Full range			Full range			Full range			Full range			mV
αV _{IO}	Temperature coefficient of input offset voltage	V _O = 0, R _S = 50 Ω	Full range			Full range			Full range			Full range			μV/°C
I _{IO}	Input offset current	V _O = 0	25°C			25°C			25°C			25°C			pA
I _{IB}	Input bias current§	V _O = 0	Full range			Full range			Full range			Full range			pA
V _{ICR}	Common-mode input voltage range		25°C			25°C			25°C			25°C			V
V _{OM}	Maximum peak output voltage swing	R _L = 10 kΩ R _L ≥ 10 kΩ R _L ≥ 2 kΩ	Full range			Full range			Full range			Full range			V
A _{VD}	Large-signal differential voltage amplification	V _O = ±10 V, R _L ≥ 2 kΩ	25°C			25°C			25°C			25°C			V/mV
B ₁	Unity-gain bandwidth		25°C			25°C			25°C			25°C			MHz
r _i	Input resistance		25°C			25°C			25°C			25°C			Ω
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICRmin} , V _O = 0, R _S = 50 Ω	25°C			25°C			25°C			25°C			dB
k _{SVR}	Supply-voltage rejection ratio (ΔV _{CC} /ΔV _{IO})	V _{CC} = ±9 V to ±15 V, V _O = 0, R _S = 50 Ω	25°C			25°C			25°C			25°C			dB
I _{CC}	Supply current (each amplifier)	V _O = 0, No load	25°C			25°C			25°C			25°C			mA
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100	25°C			25°C			25°C			25°C			dB

† All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified.
‡ Full range is T_A = 0°C to 70°C for TL071C, TL071AC, TL071BC and is T_A = -40°C to 85°C for TL071I.
§ Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 4. Pulse techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.

TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL074C, TL074D, TL074E, TL074F, TL074G, TL074H, TL074I, TL074J, TL074K, TL074L, TL074M, TL074N, TL074P, TL074Q, TL074R, TL074S, TL074T, TL074U, TL074V, TL074W, TL074X, TL074Y, TL074Z, TL075, TL075A, TL075B, TL075C, TL075D, TL075E, TL075F, TL075G, TL075H, TL075I, TL075J, TL075K, TL075L, TL075M, TL075N, TL075P, TL075Q, TL075R, TL075S, TL075T, TL075U, TL075V, TL075W, TL075X, TL075Y, TL075Z, TL076, TL076A, TL076B, TL076C, TL076D, TL076E, TL076F, TL076G, TL076H, TL076I, TL076J, TL076K, TL076L, TL076M, TL076N, TL076P, TL076Q, TL076R, TL076S, TL076T, TL076U, TL076V, TL076W, TL076X, TL076Y, TL076Z, TL077, TL077A, TL077B, TL077C, TL077D, TL077E, TL077F, TL077G, TL077H, TL077I, TL077J, TL077K, TL077L, TL077M, TL077N, TL077P, TL077Q, TL077R, TL077S, TL077T, TL077U, TL077V, TL077W, TL077X, TL077Y, TL077Z, TL078, TL078A, TL078B, TL078C, TL078D, TL078E, TL078F, TL078G, TL078H, TL078I, TL078J, TL078K, TL078L, TL078M, TL078N, TL078P, 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