K. J. SOMAIYA COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
Differential Amplifier Circuits

Q1. For the differential amplifier :
- a) Name of the circuit
- b) Q point
- c) Differential gain A_d
- d) Common mode Gain

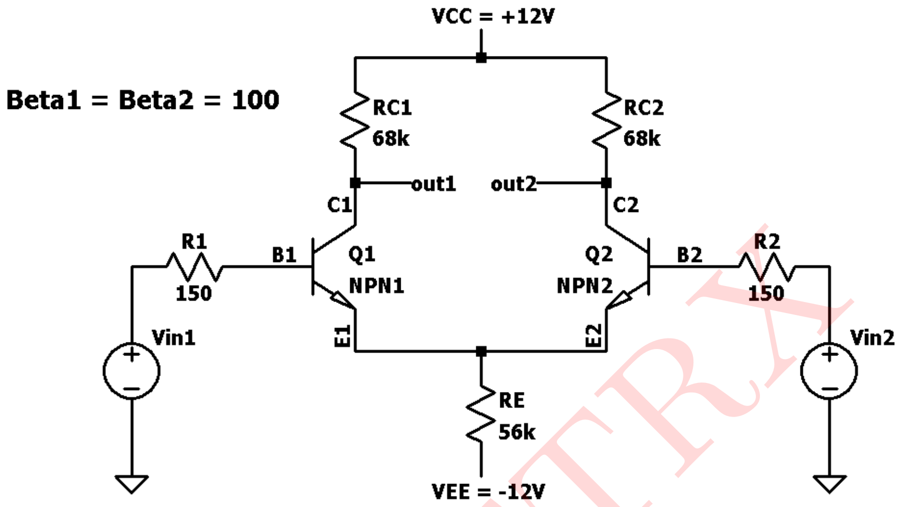

Figure 1: Circuit 1

Given:
$h_{fe} = 100$, $hie = 2k\Omega$

Solution:

The above circuit is a DIBO (Dual input balanced outout differential amplifier)

DC Analysis:

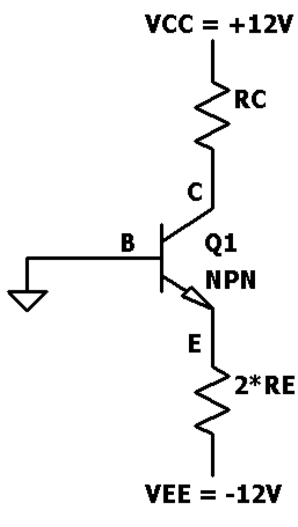

Figure 2: DC equivalent circuit

$$I_{CQ} = \beta\left(\frac{V_{EE} - V_{BE}}{R_1 + \beta(2R_E)}\right)$$
$$I_{CQ} = 100\left(\frac{12 - 0.7}{150 + 100(2 \times 56k)}\right)$$
$$I_{CQ} = 0.10\text{mA}$$
$$V_{CEQ} = V_{CC} + V_{EE} - I_{CQ}(R_C + 2R_E) = 12 + 12 - 0.1m(180k) = 6\text{V}$$
$$I_{BQ} = I_{CQ}/\beta = 0.1m/100 = \mathbf{1\mu A}$$
$$V_{C1} = V_{C2} = V_{CC} - I_C R_C = 12 - (0.1m)(68k) = \mathbf{5.2V}$$
$$V_E = V_C - V_{CE} = 5.2 - 6 = \mathbf{-0.8V}$$
$$r_\pi = \frac{\beta V_T}{I_C} = 100 \times 26/0.1m = 26k\Omega$$
$$|A_d| = \frac{\beta R_C}{R_s + r_\pi} = \frac{100 \times 68k}{150 + 26k} = \mathbf{260.038}$$
$$A_{cm} = \left|\frac{R_C}{2R_E}\right| = \left|\frac{68k}{116k}\right| = \mathbf{0.6071}$$
$$CMRR = \left|\frac{A_d}{A_{cm}}\right| = 260.038/0.6071 = \mathbf{428.328}$$
$$\text{CMRR in dB} = 20\log_{10}(428.328) = \mathbf{52.6355dB}$$

SIMULATED RESULTS:
Above circuit was simulated in LTSpice and results are presented below:

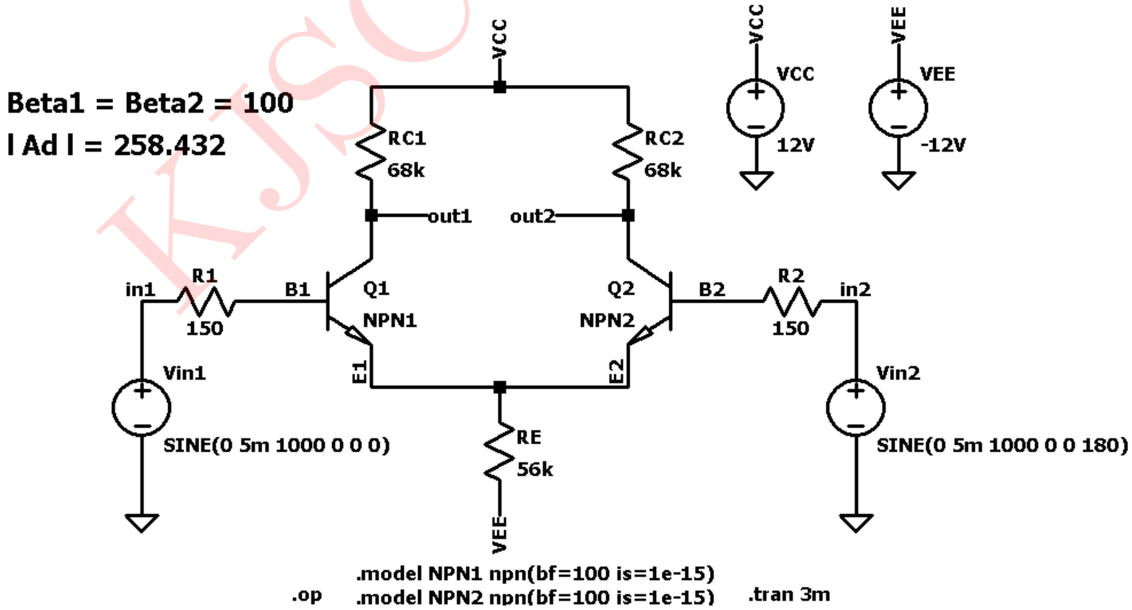

Figure 3: Circuit Schematic

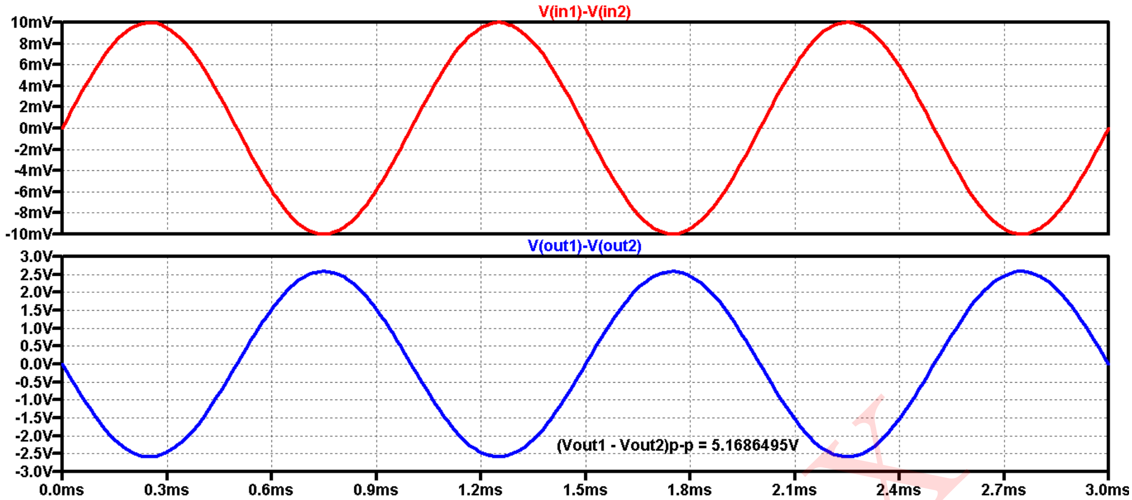

Figure 4: Input output waveform

Comparison of Theoretical and Simulated Values:

Parameters	Simulated	Theoretical
I_C	0.101mA	0.1mA
V_C	5.18V	5.2V
V_{CE}	6V	5.835V
A_d	258.432	260.038
A_{cm}	–	0.6071
CMRR in dB	–	52.6355dB

Table 1: Numerical 1

Q2. For the differential amplifier :

a) Name of the circuit

b) Current through R_{D1}, R_{D2}, R_{D3}

c) A_d

d) Common mode Gain

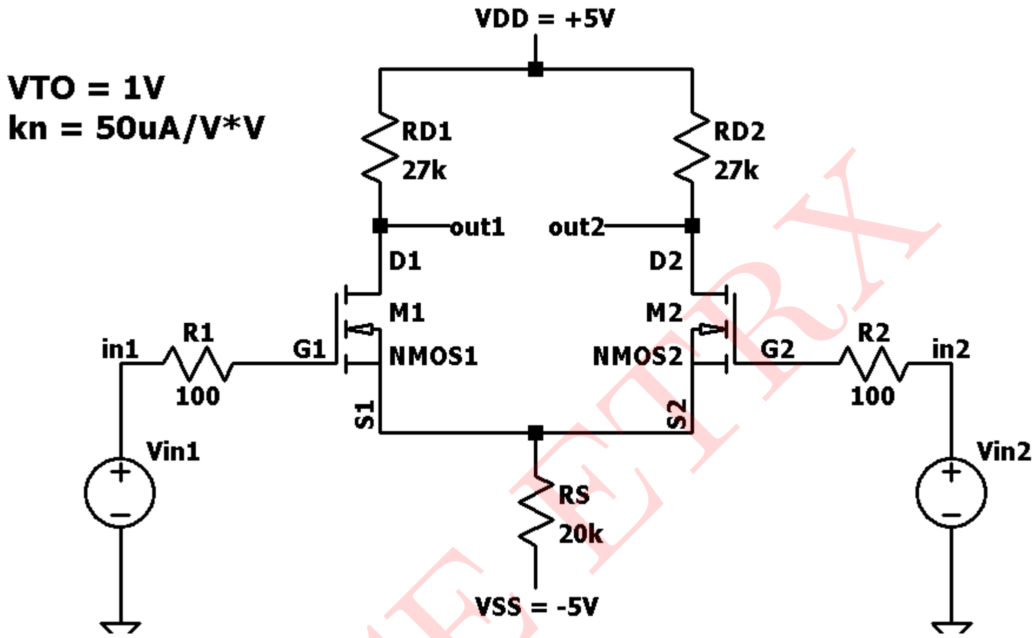

Figure 5: Circuit 2

Given:

$R_{D1} = R_{D2} = 27k\Omega$, $R_S = 20k$, $V_{DD} = 5V$

Solution:

The above circuit is a DIBO (Dual input balanced outout differential amplifier)

DC Analysis:

$V_{GSQ} = V_{SS} - 2I_{DQ}R_S$

$V_{GSQ} = 5 - 2I_{DQ}20k$ ——— (1)

$I_{DQ} = k_n(V_{GSQ} - V_{TN})^2$

$I_{DQ} = 50 \times 10^{-6}(V_{GSQ} - 1)^2$ ——— (2)

Put (2) in (1)

$V_{GSQ} = 5 - 2 \times 50 \times 10^{-6} \times 20k(V_{GSQ}^2 - 2V_{GSQ} + 1)$

$2V_{GSQ}^2 - 3V_{GSQ} - 3 = 0$

$V_{GSQ} = 2.186V or - 0.6861V$

$V_{GSQ} = \mathbf{2.186V}$ $(\because V_{GSQ} < V_T)$

$I_{DQ} = 50 \times 10^{-6}(2.186 - 1)^2$

$I_{DQ} = \mathbf{70.33\mu A}$

$V_{DSQ} = (V_{DD} + V_{SS}) - I_{DQ}(R_D + 2R_S) = 10 - (70.33\mu)(67k) = 5.2878V$

$V_{D1} = V_{DD} - I_D R_S = 5 - (70.33\mu)(27k) = 3.101V$

Current through R_{D1}, R_{D2}, R_S = $\mathbf{70.33\mu A}$

$|A_d| = g_m R_D = 0.118 \times 27k = \mathbf{3.186}$

$$A_{cm} = \left|\frac{g_m R_D}{1 + 2g_m R_S}\right| = \left|\frac{27k}{2 \times 20k}\right| = \mathbf{0.675}$$

$$\text{CMRR} = \left|\frac{A_d}{A_{cm}}\right| = 3.186/0.675 = \mathbf{4.72}$$

CMRR in dB $= 20\log_{10}(4.72) = \mathbf{13.478dB}$

SIMULATED RESULTS:

Above circuit was simulated in LTSpice and results are presented below:

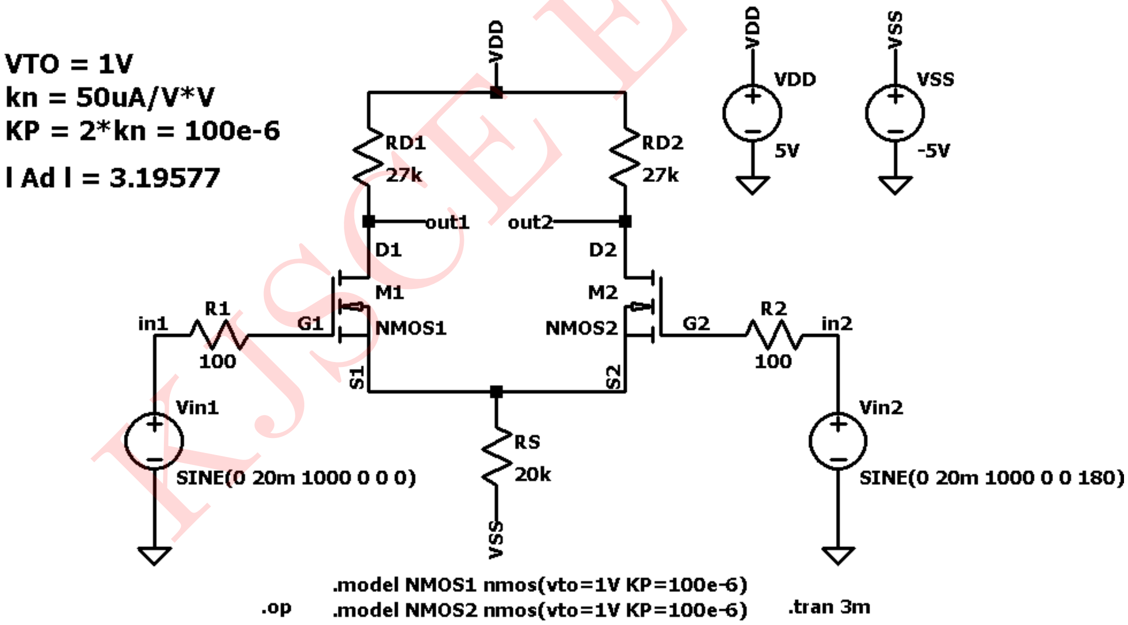

Figure 6: Circuit Schematic

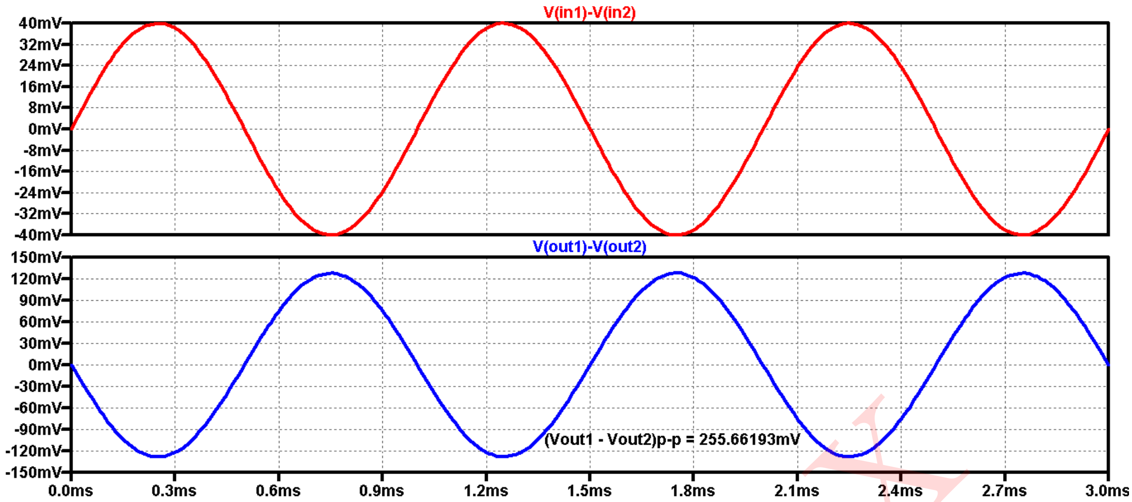

Figure 7: Input output waveform

Comparison of Theoretical and Simulated Values:

Parameters	Simulated	Theoretical
I_D	70.346μA	70.33μA
V_D	3.100V	3.101V
V_{DS}	5.286V	5.2878V
V_{GS}	2.1861V	2.186V
$\lvert A_d \rvert$	3.1957	3.186
A_{cm}	–	0.675
CMRR in dB	–	13.4788dB

Table 2: Numerical 2

Q3. For the differential amplifier :

a) Name of the circuit

b) I_{D1}, I_{D2}, V_{D1}, V_{D2}

c) A_d

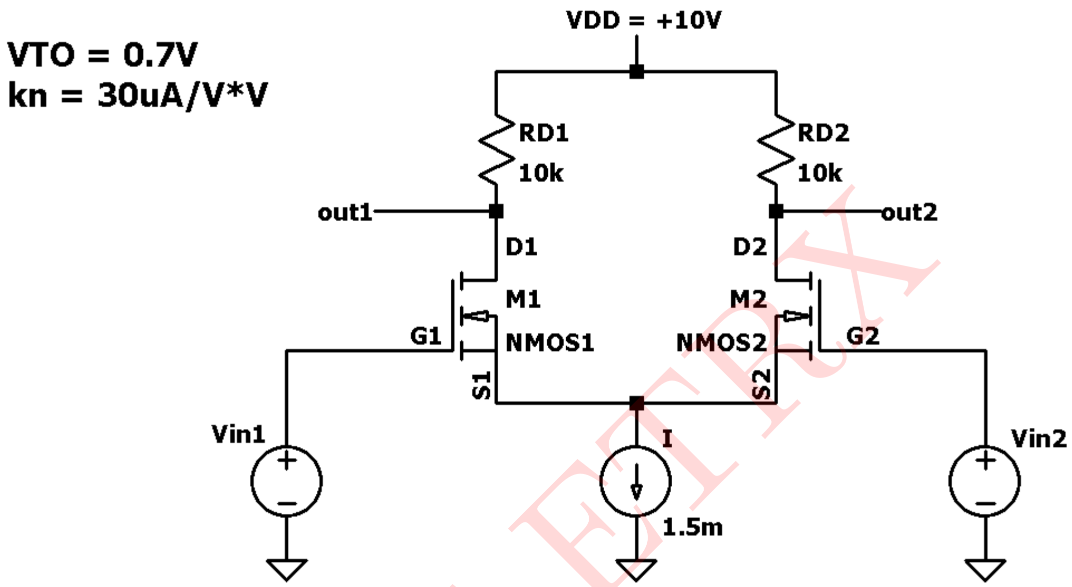

Figure 8: Circuit 3

Given:

$k_{n1} = k_{n2} = 30\mu A/V^2$, $I = 1.5mA$, $V_{DD} = 10V$

Solution:

The above circuit is a DIBO (Dual input balanced outout differential amplifier)

DC Analysis:

$I_{D1} = I_{D2} = I/2 = 1.5m/2 = 0.75mA$

$V_{D1} = V_{D2} = V_{DD} - I_D R_D = 10 - (0.75m \times 10k) = 2.5\text{V}$

$A_d = -g_m R_D$

$g_m = 2k_n(V_{GS} - V_{TN})$

Now,

$I_D = k_n(V_{GS} - V_{TN})^2$

$0.75m = 30 \times 10^{-6}(V_{GS} - 0.7)^2$

$25 = (V_{GS} - 0.7)^2$

$5 = (V_{GS} - 0.7)$

$V_{GS} = 5.7\text{V}$

$g_m = 2 \times 30 \times 10^{-6}(5.7 - 0.7) = 0.3\text{mA/V}$

$|A_d| = 0.3v \times 10^{-3}(10^4) = 3$

SIMULATED RESULTS:

Above circuit was simulated in LTSpice and results are presented below:

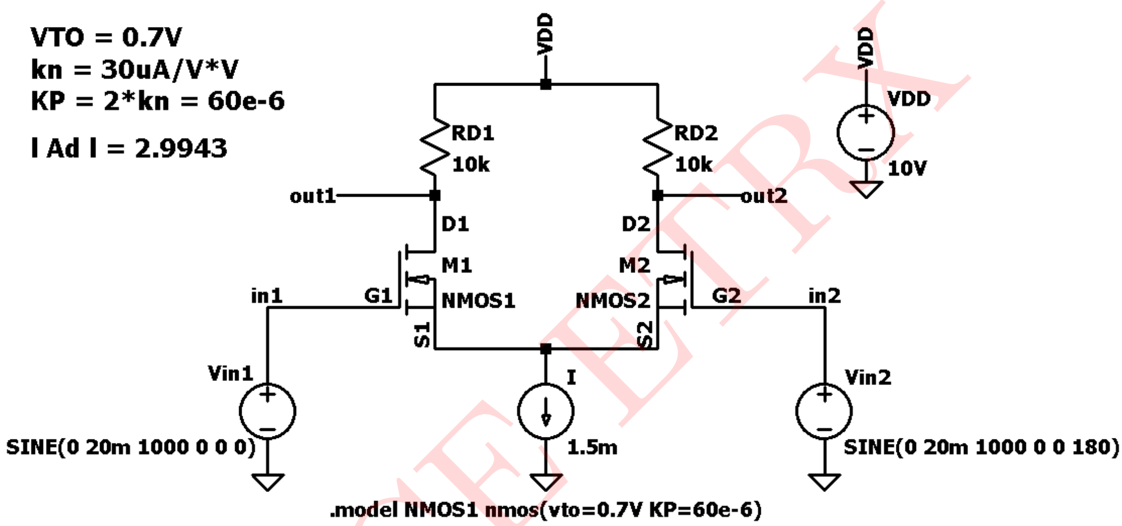

Figure 9: Circuit Schematic

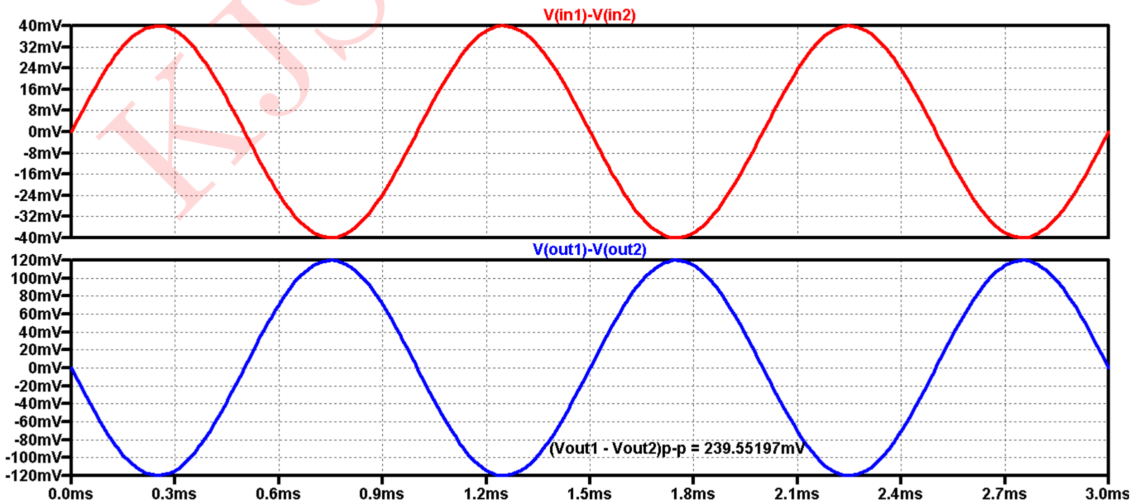

Figure 10: Input and output waveform

Comparison of Theoretical and Simulated Values:

Parameters	Simulated	Theoretical
I_D	0.75 mA	0.75mA
V_D	2.5V	2.5V
$\|A_d\|$	2.9943	3

Table 3: Numerical 3

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