Dynamic Translinear Circuits

Wouter A. Serdijn and Jan Mulder

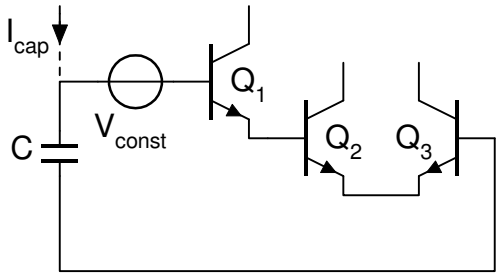
TU Delft
Technische Universiteit Delft

Dynamic translinear elements

- **The capacitor**
- The bipolar transistor
- The diode
- The MOS transistor in weak inversion (NB: body effect)
  - SOI, SOA
  - Bulk-driven
  - Triode region
- Voltage-translinear principle: MOSTs in strong inversion; quadratic relation between drain current and gate-source voltage

TU Delft

Generalized DTL principle



$$I_{cap} = CU_T\left(\frac{\dot{I}_{C1}}{I_{C1}} + \frac{\dot{I}_{C2}}{I_{C2}} - \frac{\dot{I}_{C3}}{I_{C3}}\right)$$

$$I_{cap} = CU_T \sum_i \pm \frac{\dot{I}_{Ci}}{I_{Ci}}$$

TU Delft

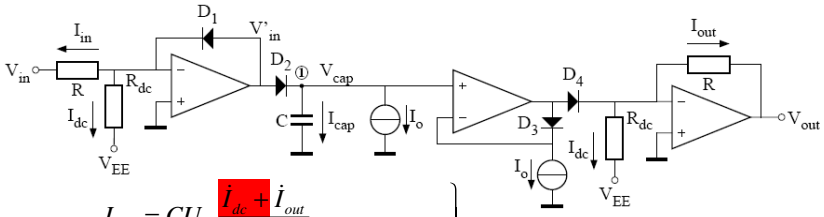
DTL analysis

Input: detailed circuit diagram

- Derivation of TL (collector-current) relations; KCLs (incl. capacitance currents)
- Obtain expressions for the capacitance currents
- Solve the system of equations

TU Delft

DTL analysis (II), example



$$I_{cap} = CU_T \frac{\dot{I}_{dc} + \dot{I}_{out}}{I_{dc} + I_{out}}$$

$$(I_{dc} + I_{in})I_o = (I_o + I_{cap})(I_{dc} + I_{out})$$

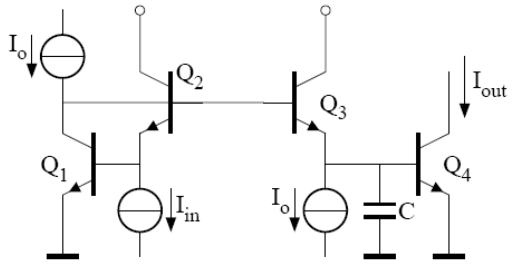
$$CU_T \dot{I}_{out} + I_o I_{out} = I_o I_{in}$$

$$\frac{CU_T}{I_o}\dot{I}_{out} + I_{out} = I_{in}$$

$$H(s) = \frac{1}{1 + s\tau};\ \tau = \frac{CU_T}{I_o}$$

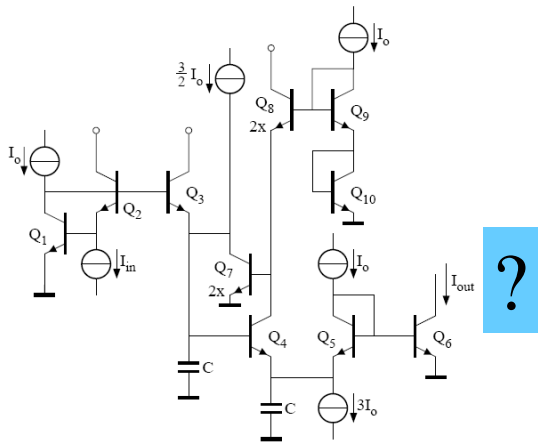
TUDelft

DTL analysis (III), example (II)



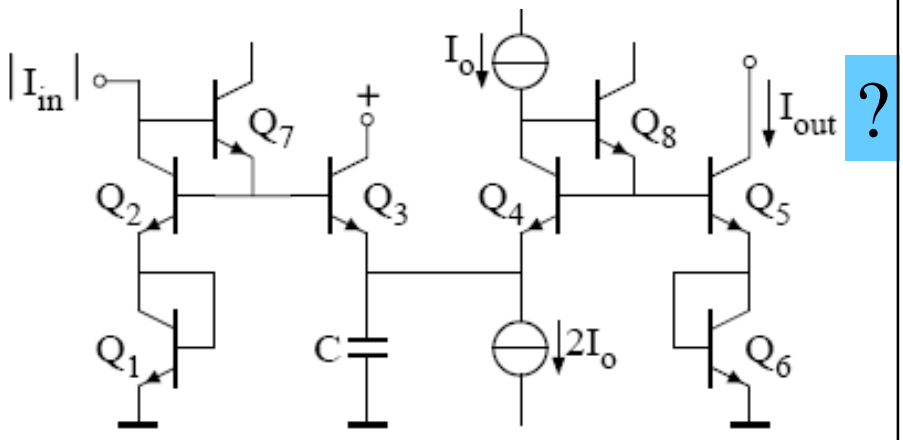
TUDelft

DTL analysis (IV), example (III)



TUDelft

DTL analysis (V), example (IV)



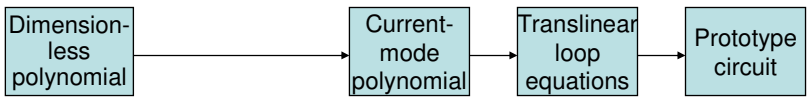
TUDelft

DTL synthesis

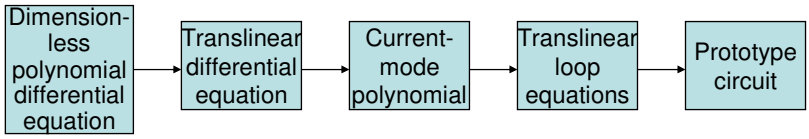
1. Add dimensions (current and time)
   - We now have a current-mode differential equation
2. Define capacitance currents
   - We now have a current-mode polynomial without derivatives
3. Do the TL composition, i.e., map the polynomial onto equations that comprise products of currents only
   - Research is still going on; often heuristically found solutions
4. Compose the circuit at signal level
   - We now have a circuit topology that comprises transistors (and/or diodes), capacitances, and current sources
5. Do the biasing, i.e., replace the ideal bias sources by realistic ones

TU Delft

Synthesis procedure



Static translinear circuits



Dynamic translinear circuits

TU Delft