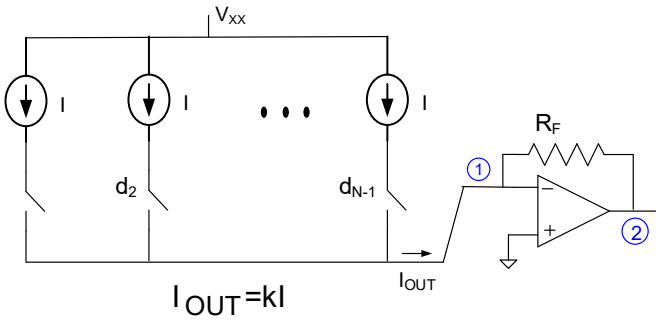
EE 435

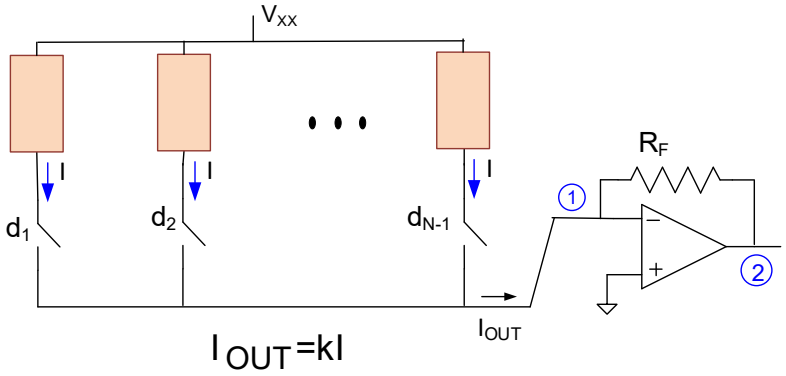
Lecture 35

- Current Steering DACs
- Charge Redistribution Circuits

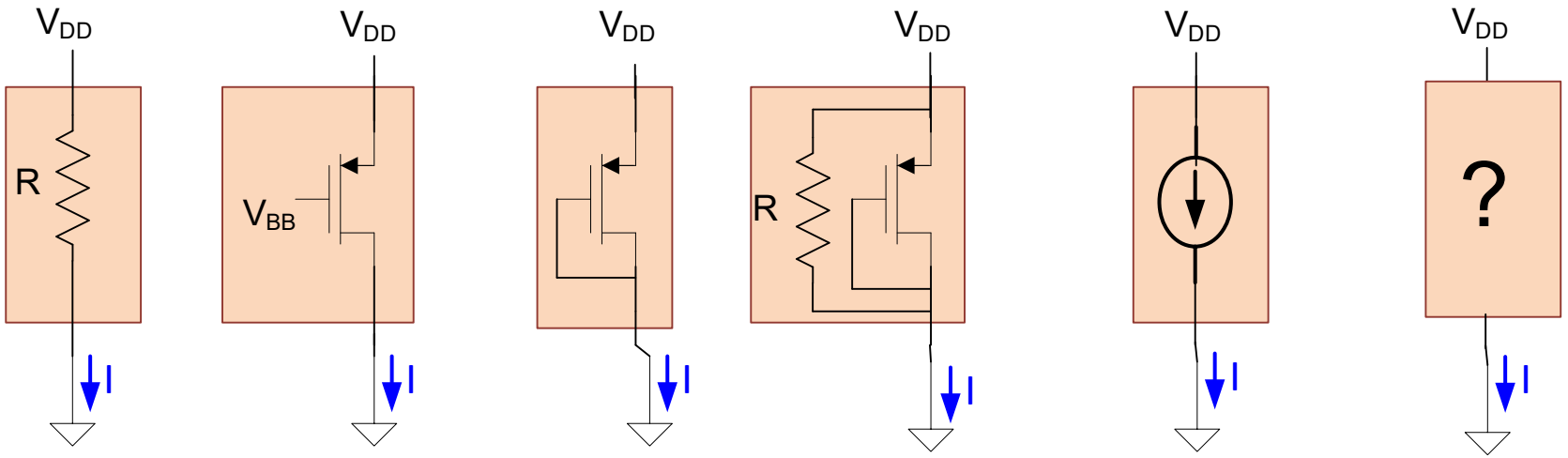
Review from Last Lecture

Current Steering DACs



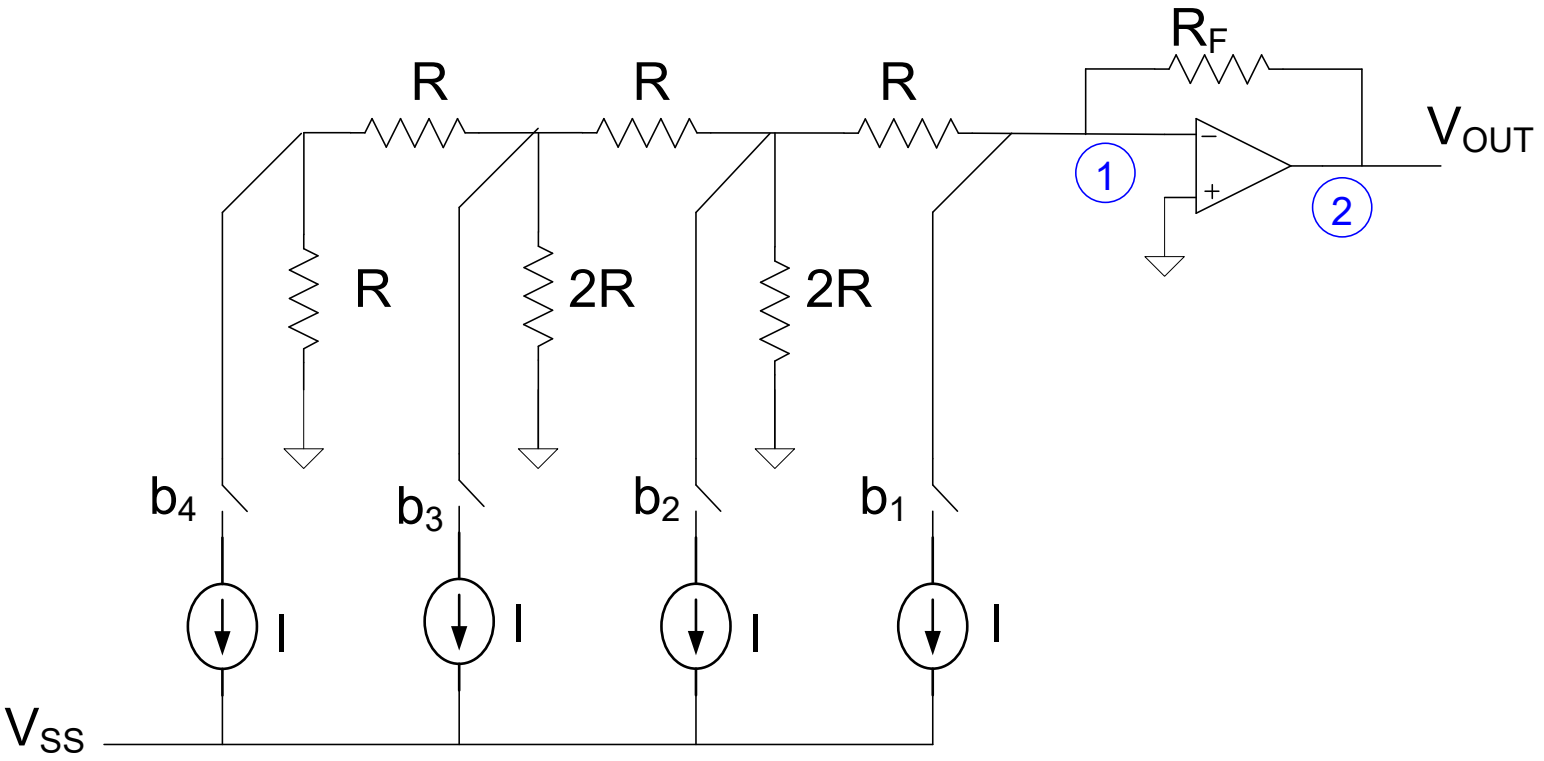


What is important is the current generated, not whether it comes from a “current source”



Many potential current generator blocks, just require that all be ideally identical

Another R-2R DAC



Requires matching both current sources and resistors

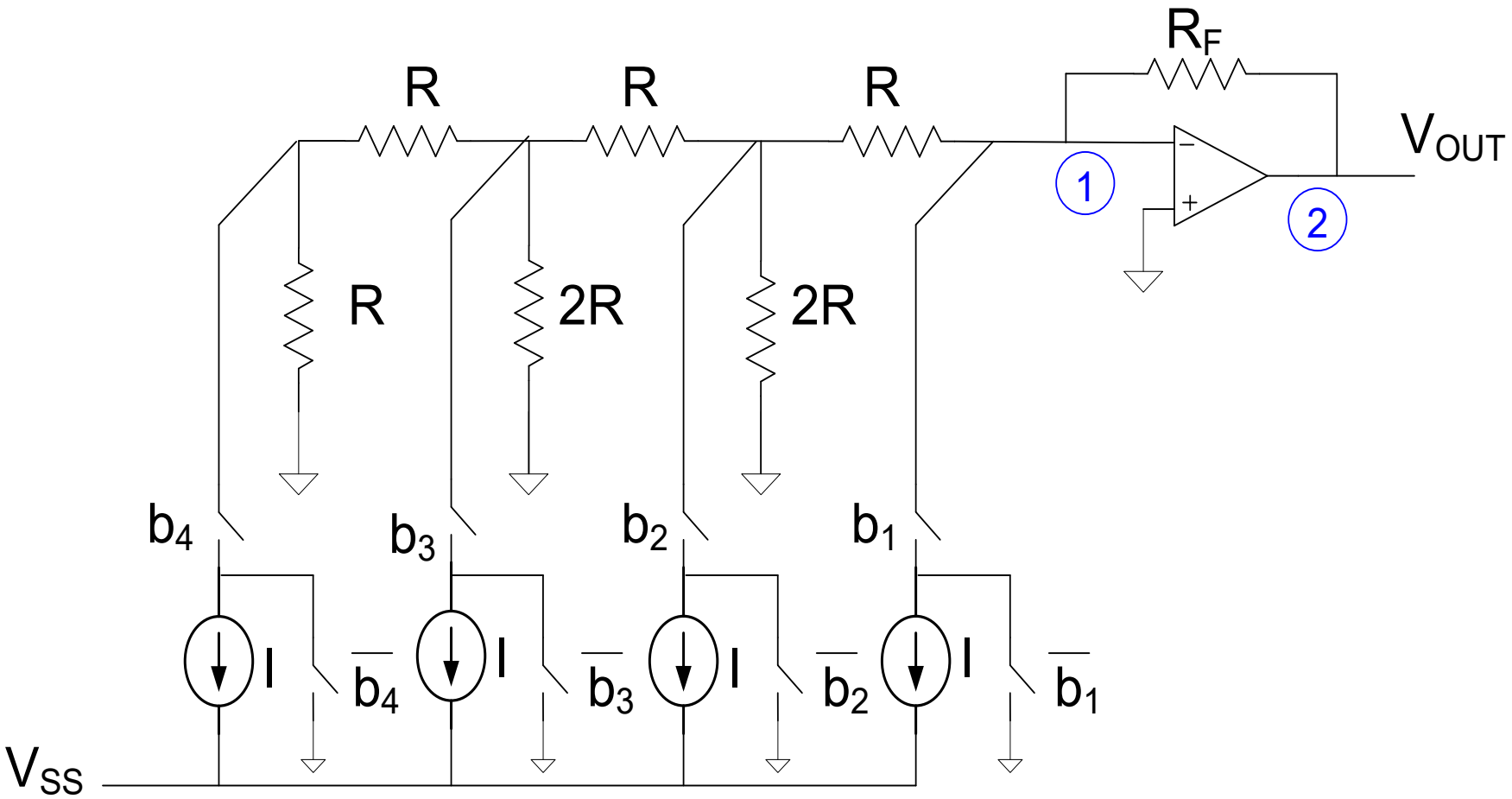
But switch impedance does not affect performance

β is independent of Boolean code

Node voltages in R/2R block must change for any input transitions

Review from Last Lecture

Another R-2R DAC



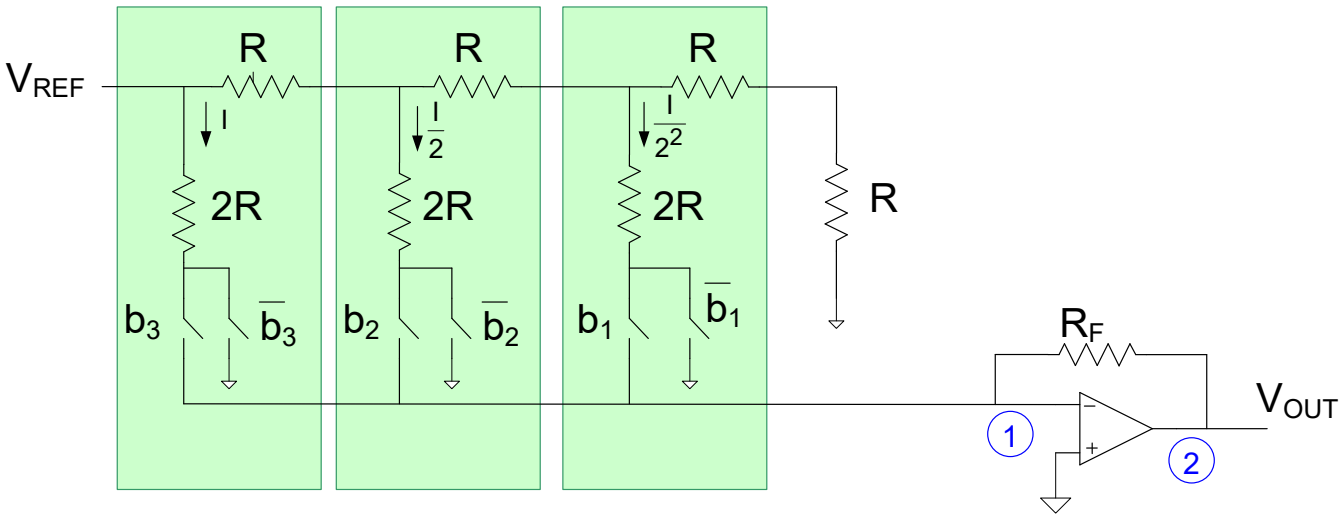
Clocks must be nonoverlapping

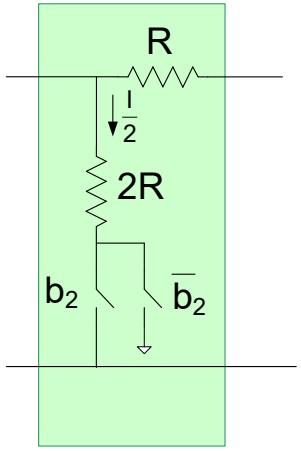
Does this offer any benefits over previous approach ?

Offers some compensation for capacitances on current sources

Are there other terminations for the current sources?

R-2R DACs





Bit Slice

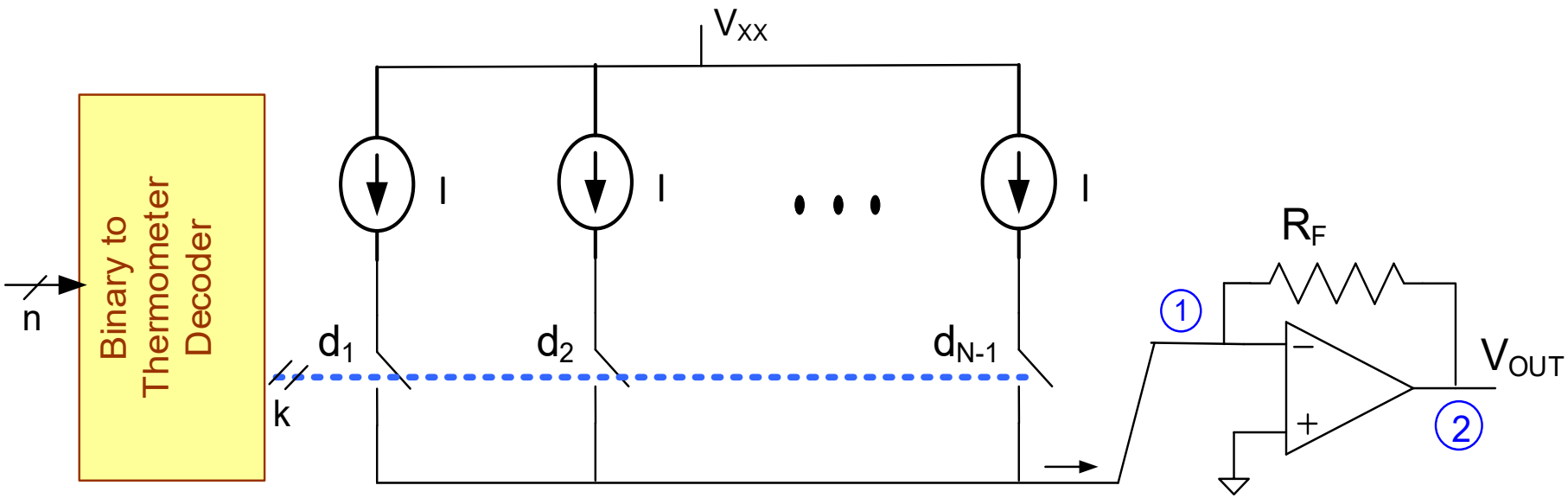
Key characteristic of R-2R Structures

- Area increases linearly with number of bits of resolution
- Binary to thermometer/bubble converter eliminated
- Simple unary cell can be used for R elements
- Common-centroid layout manageable ??

Key challenges of R-2R Structures

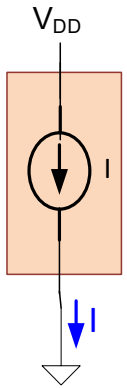
- Switches directly affect R-2R values and ratios
- Voltage on internal nodes must settle for some structures
- If unary cell used, area not optimally allocated for matching

Current Steering DAC



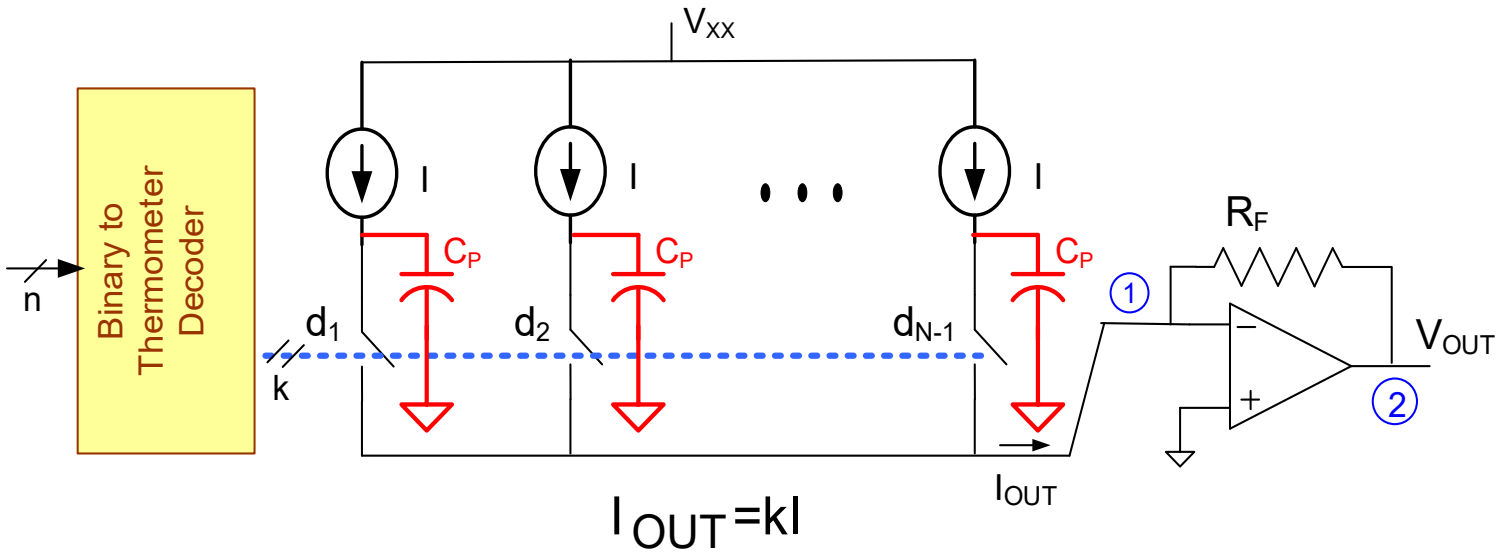
k: thermometer code

$I_{OUT}=kI$



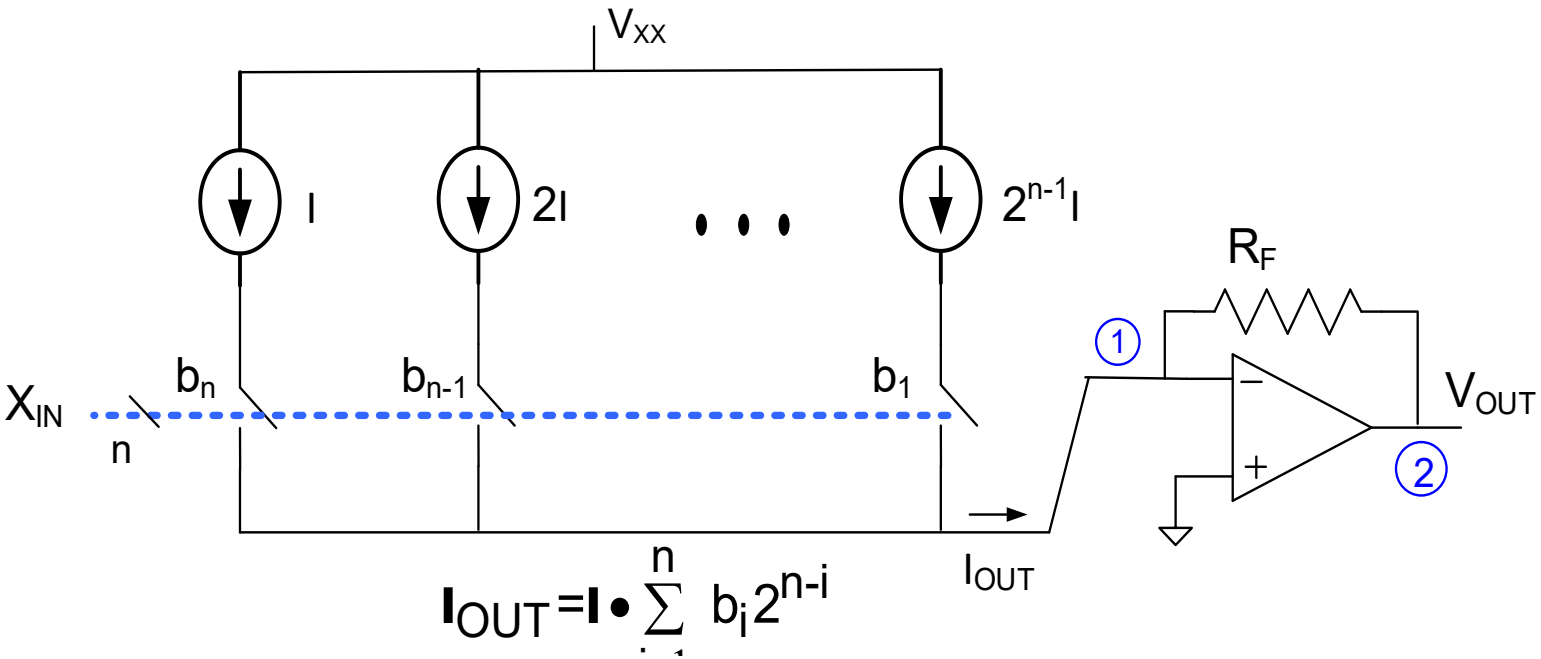
Switch impedance of little concern if current sources ideal

Current Steering DAC



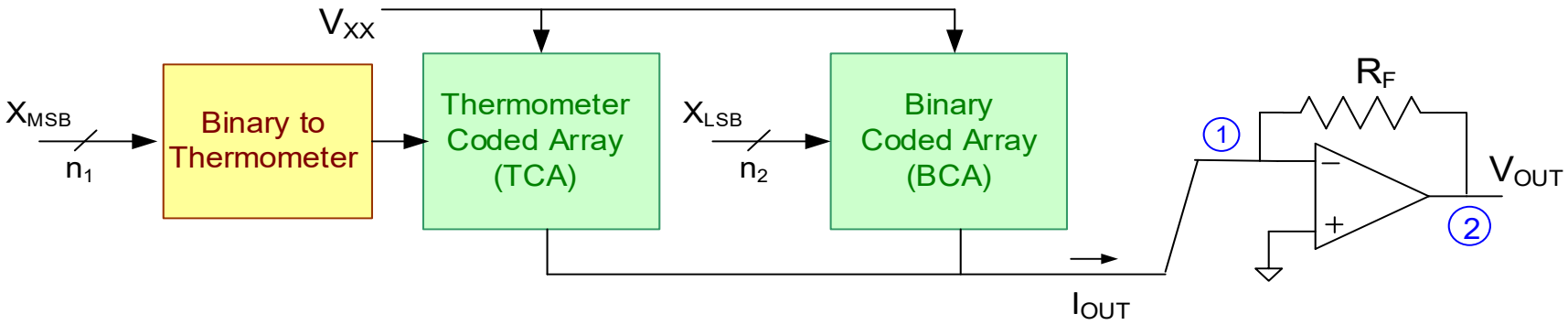
Critical parasitic capacitors in current-steering DAC

Current Steering DAC



- Binary to thermometer decoder eliminated
- Current sources bundled unary cells
- Bundles large for large n

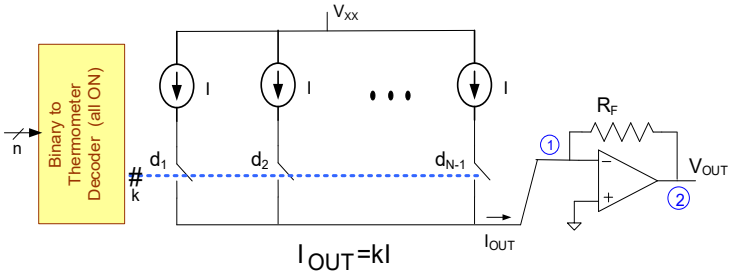
Current Steering DAC

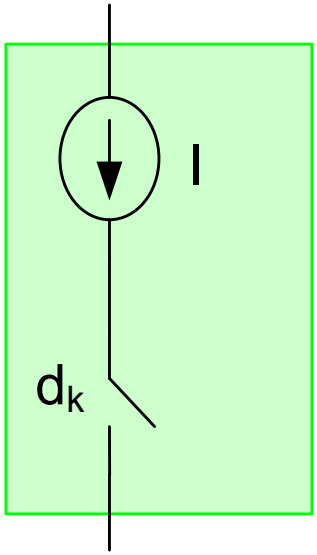


Segmented Structure

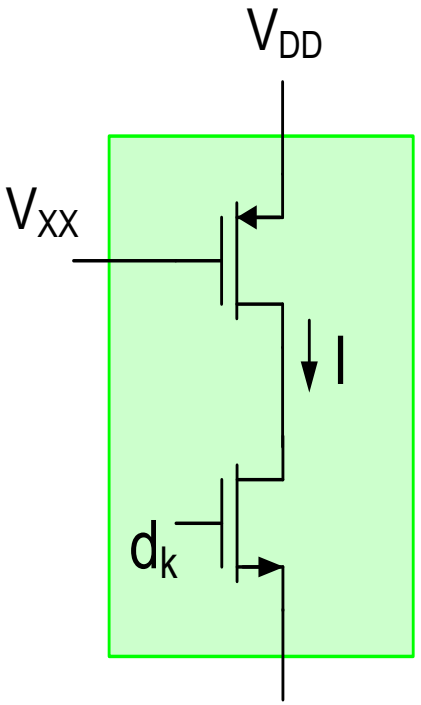
- Exploits benefits of both thermometer and binary coded structures
- Common-centroid layout likely only necessary on TCA
- Dramatic reduction in complexity of decoder possible

Current Steering DAC





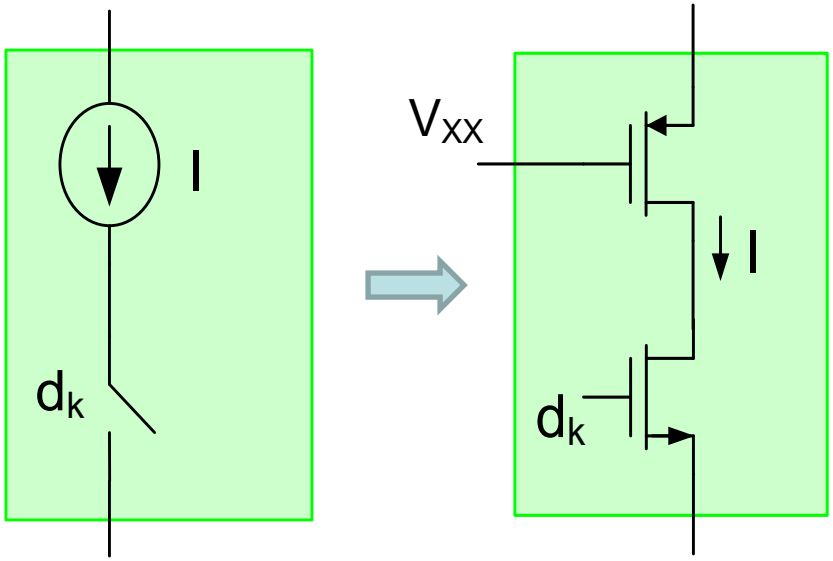
popular current source

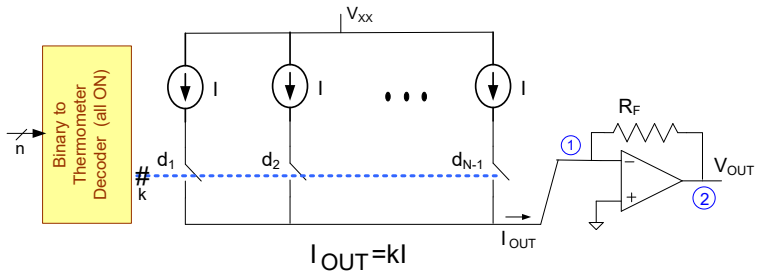


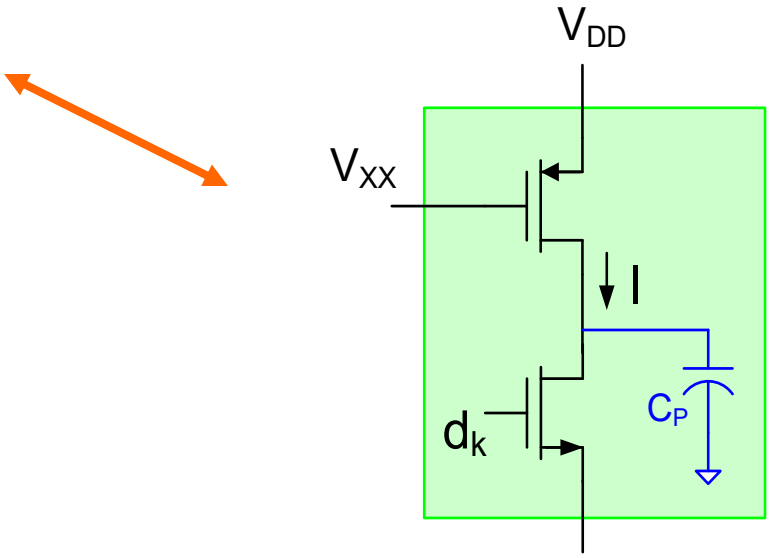
Is linearity or output impedance of current source of concern?

Not if individual slices are matched !

Current Steering DAC

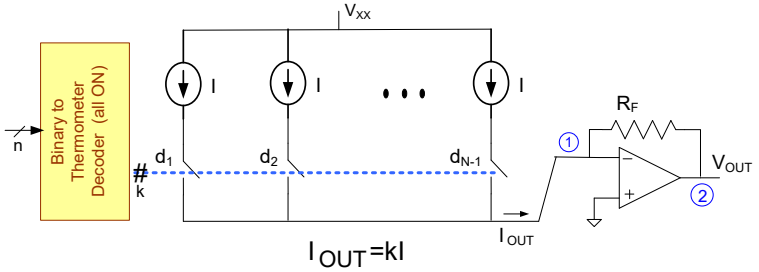


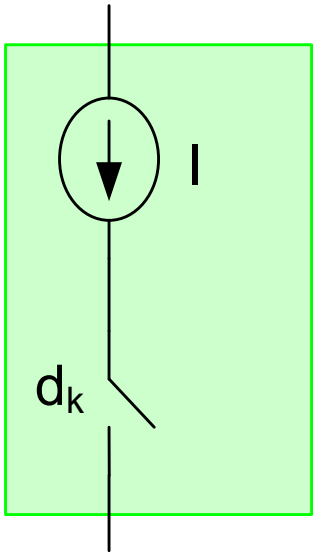




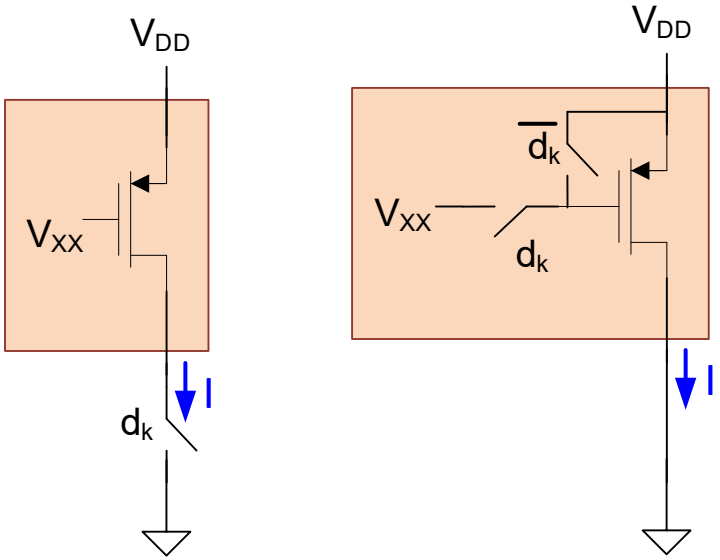
Parasitic capacitance on output of current source problematic

Current Steering DAC





Alternative current source cells

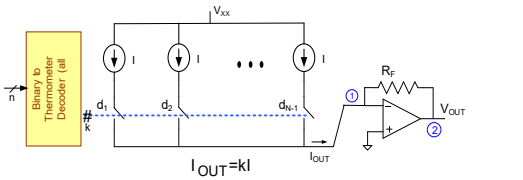


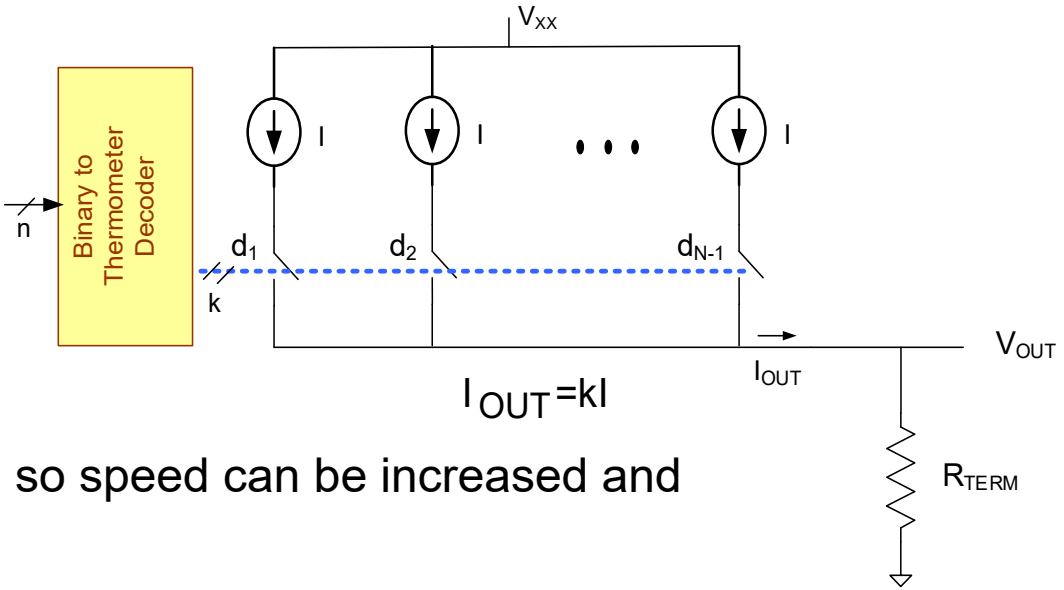
Which is better?

Effects of parasitic diffusion capacitance?

Effects of gate capacitance?

Current Steering DAC





Op Amp can be eliminated so speed can be increased and power reduced

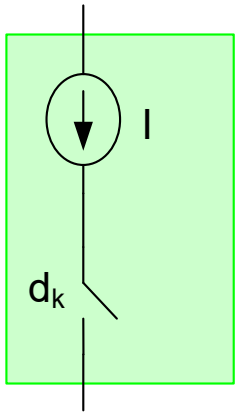
R_{TERM} often 50Ω or 100Ω

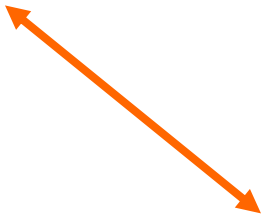
R_{TERM} can be internal or external

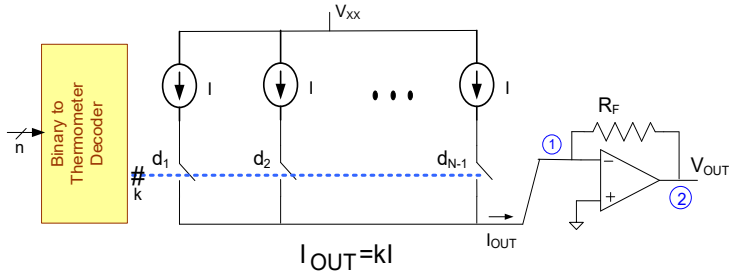
Switch impedance now of concern

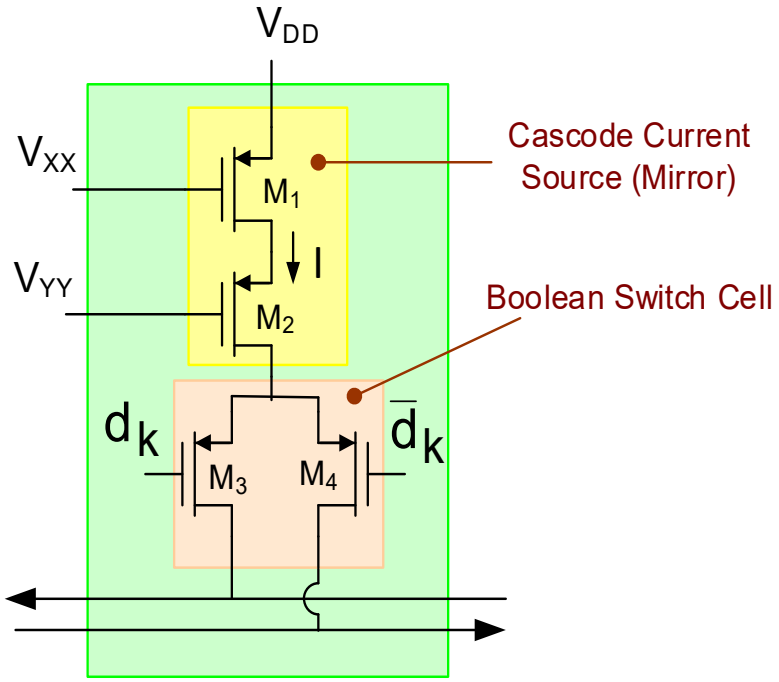
Output impedance of current sources now of concern

Current Steering DAC





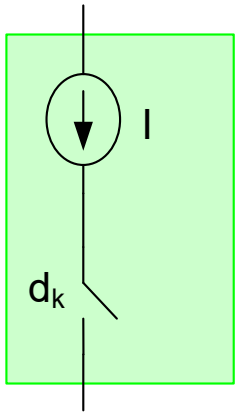


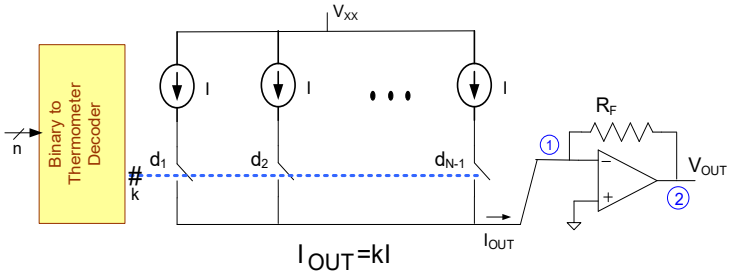


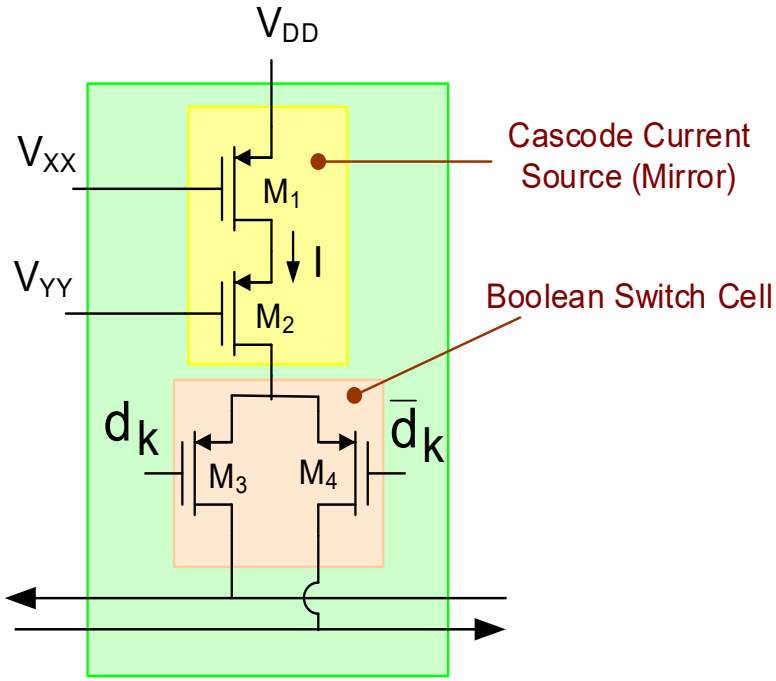
Cascoding reduces output conductance of current source

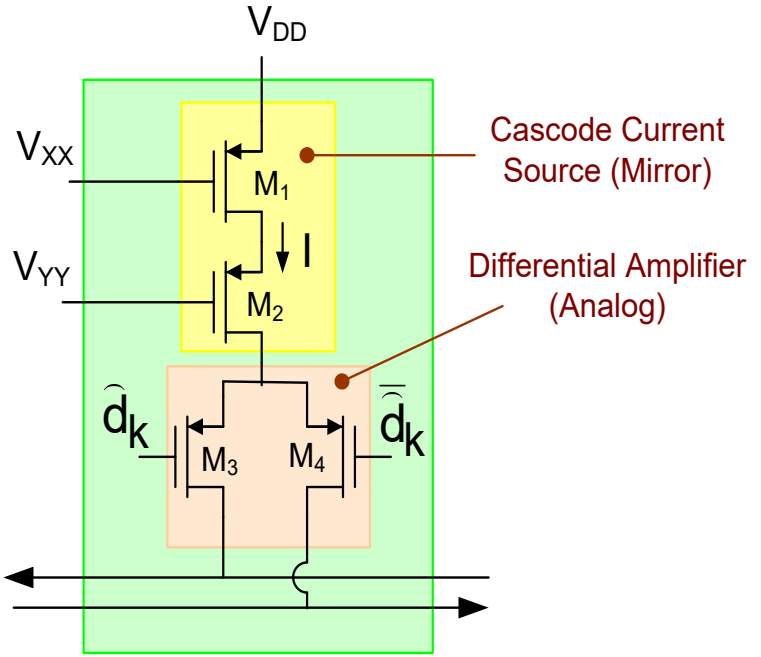
No power penalty, slight reduction in overhead

Current Steering DAC



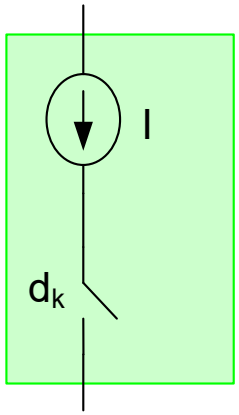


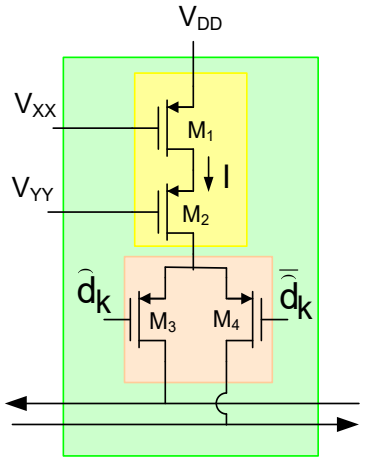


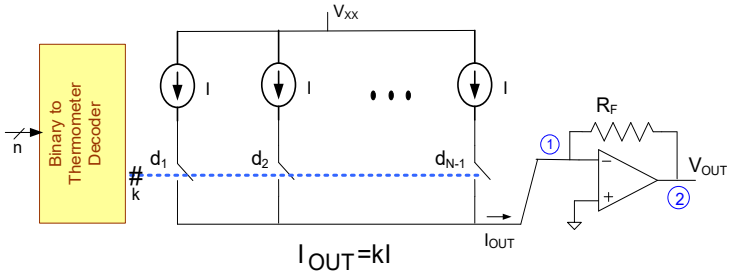


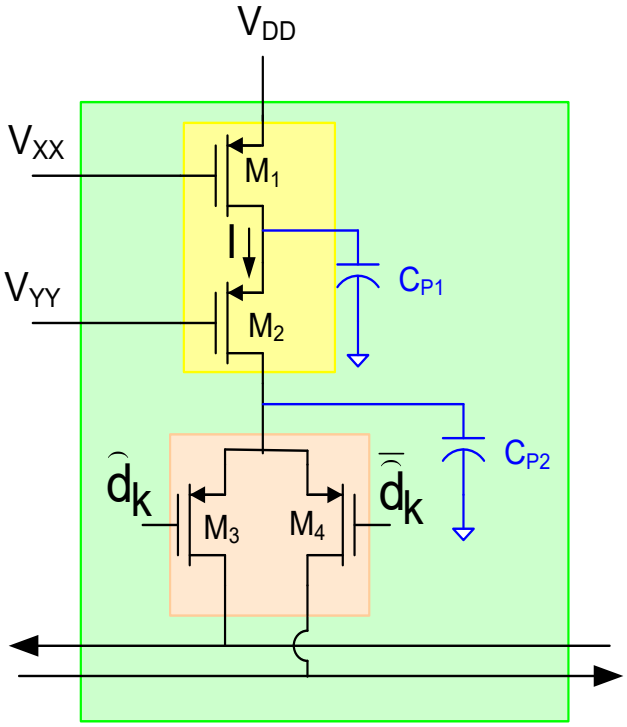
Steer rather than switch current
Reduced swing on control signals

Current Steering DAC

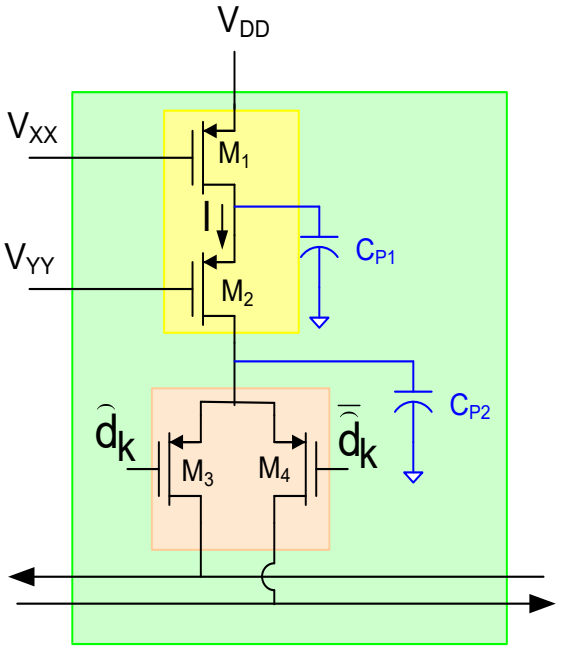


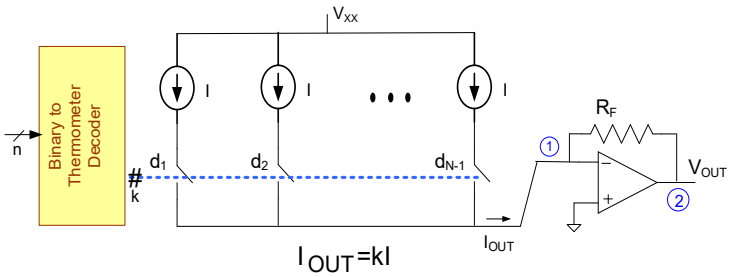


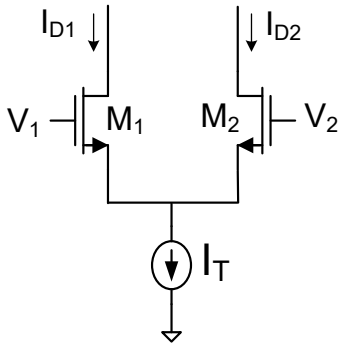


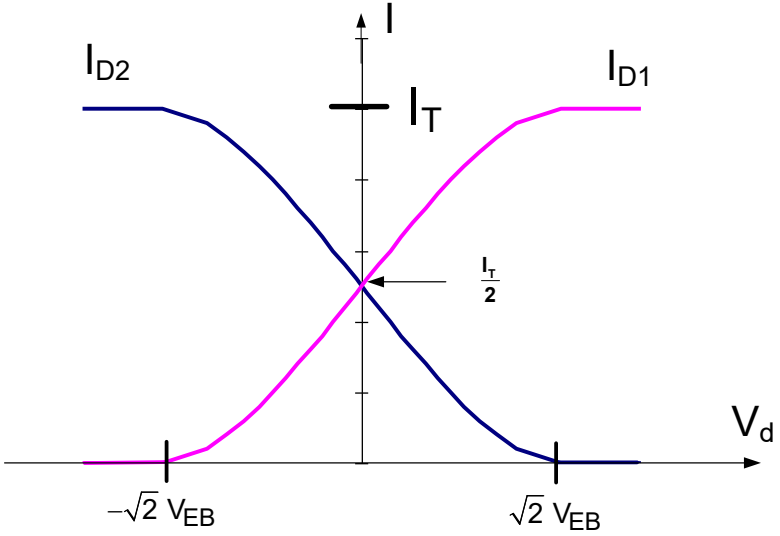


Current Steering DAC



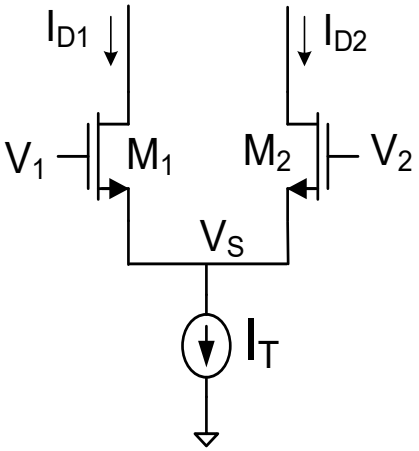


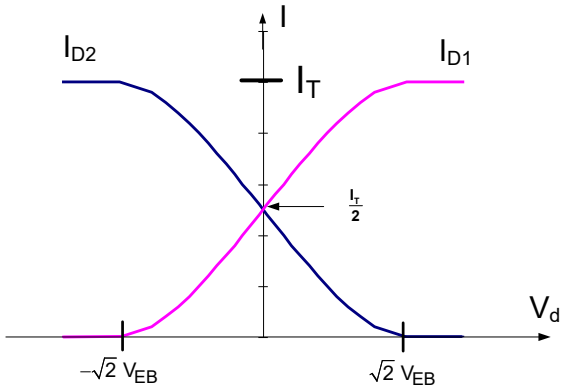




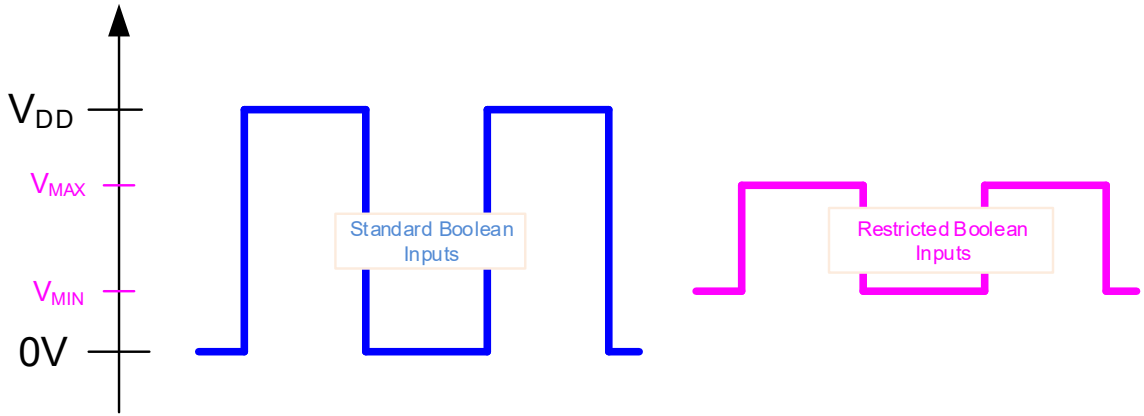
- Need only signal swing of $2\sqrt{2}V_{EB}$ to steer currents (so can reduce turn-on and turn-off times)
- Steering also results in cascoding with M_3 and M_4 thus increasing output impedance of current source (so can probably eliminate M_2)

Current Steering DAC

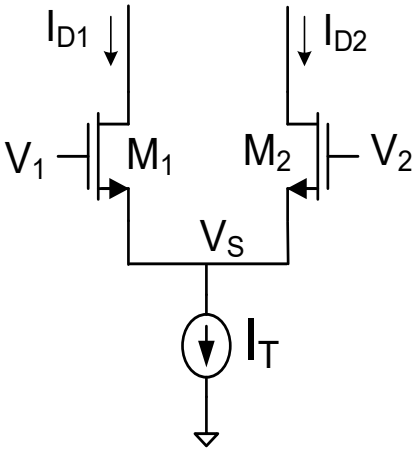


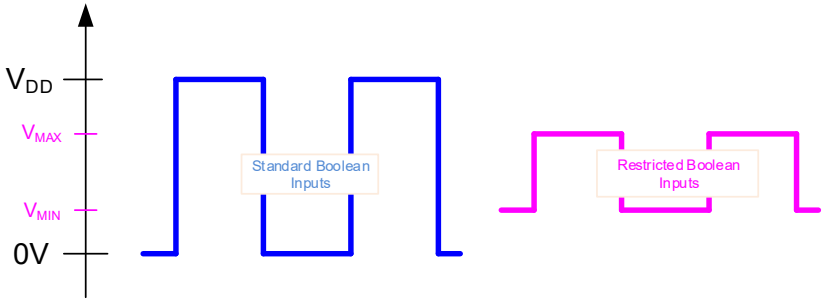


Reduced Signal Swing on V_S Node with Current Steering

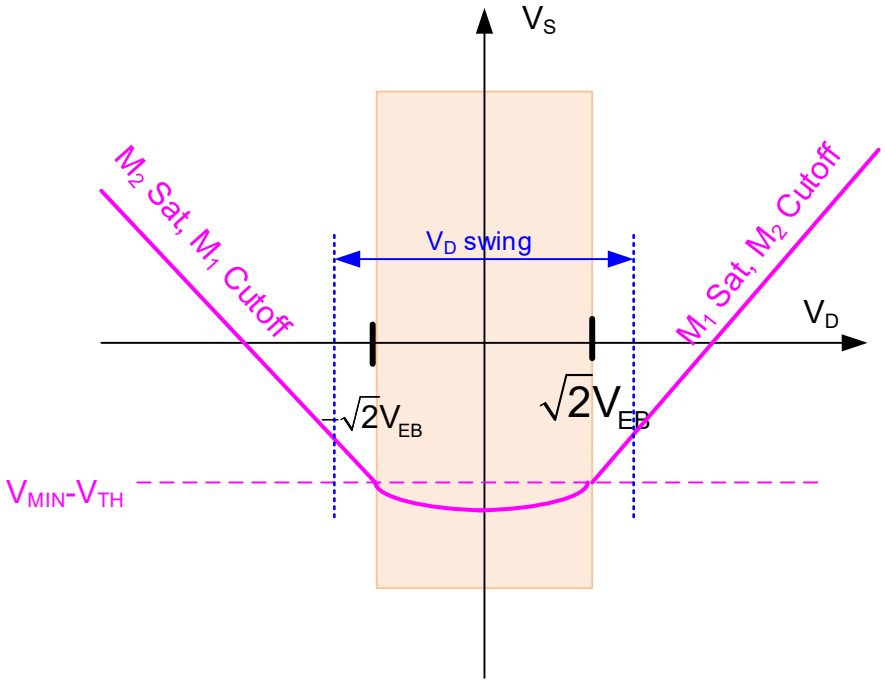


Current Steering DAC

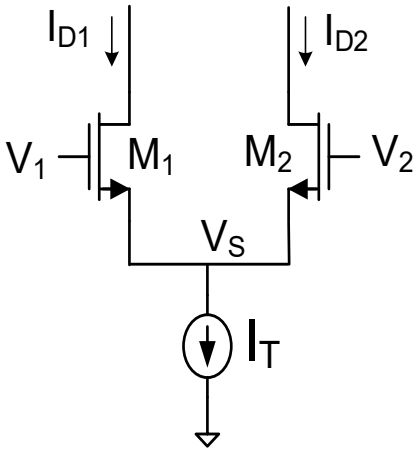


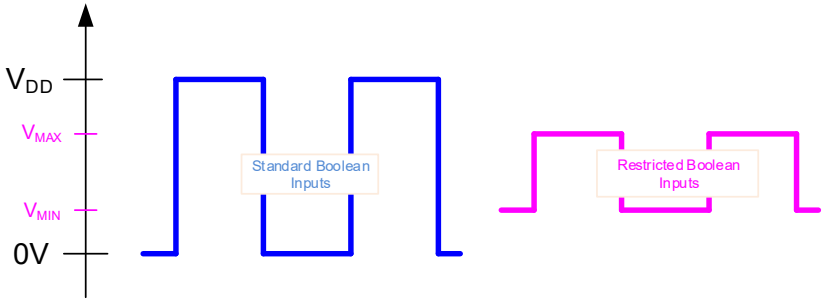


Reduced Signal Swing on V_S Node with Current Steering



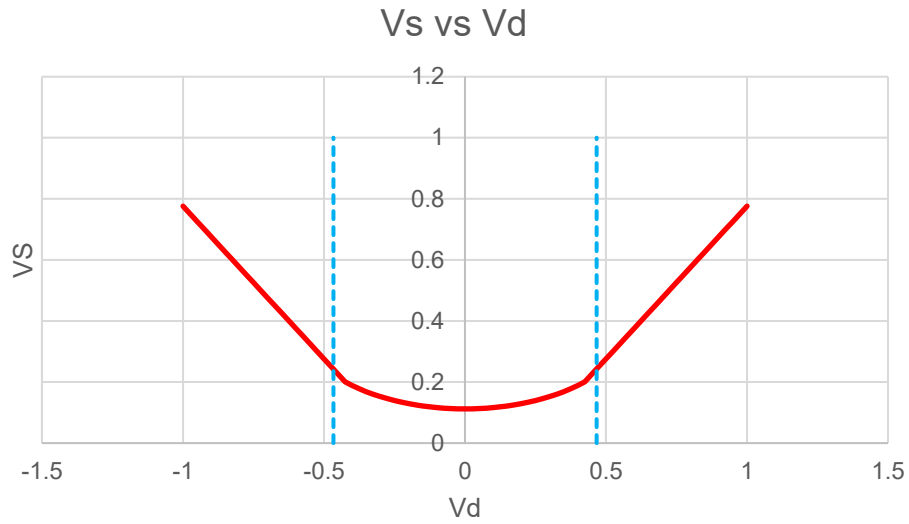
Current Steering DAC





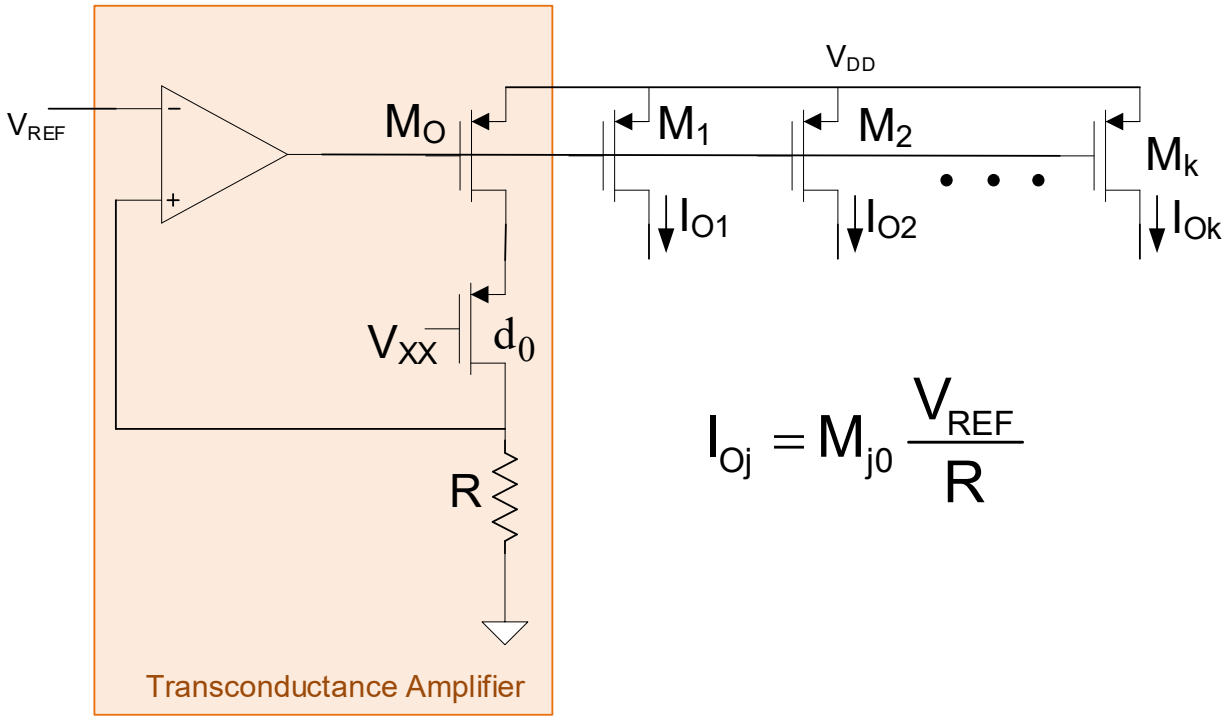
Reduced Signal Swing on V_S Node with Current Steering

Simulation Results: V_{TH}=0.4V, V_{MIN}=0.6V, V_{MAX}=1.07V,V_{EB}=0.3V,γ=1.1



V_S swing about 100mV

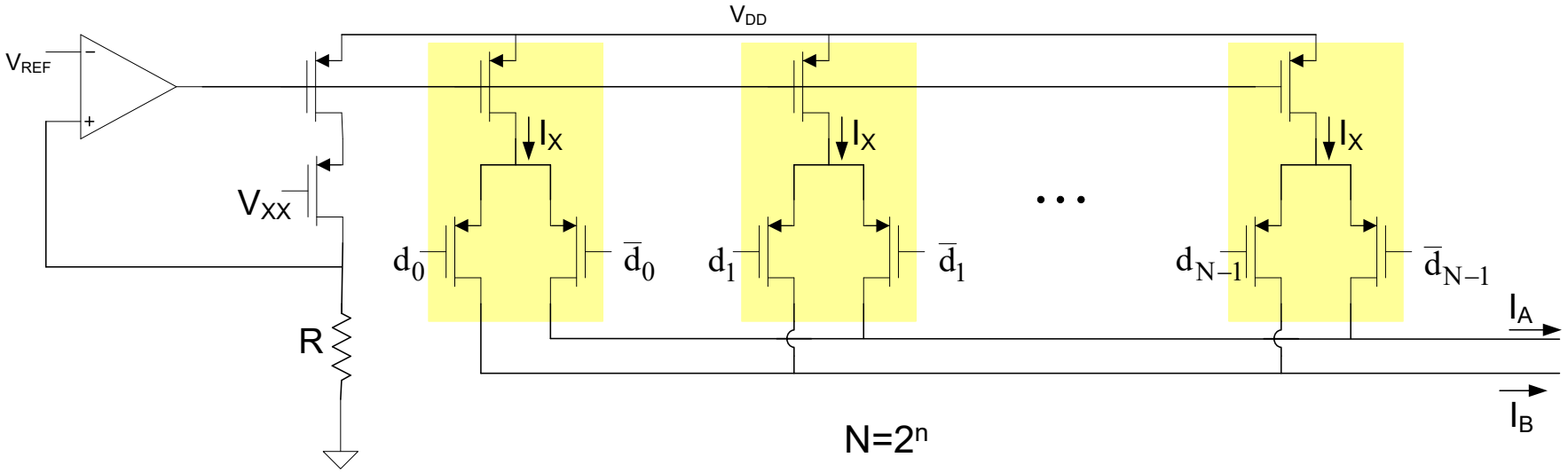
Multiple-output Transconductance Amplifier



$$I_{Oj} = M_{j0} \frac{V_{REF}}{R}$$

- Good linearity
- Each additional output requires only one additional transistor
- Relevant is MDAC output desired
- Cascoding of output devices useful if driving resistive load

Current Steering DAC with Supply Independent Biasing



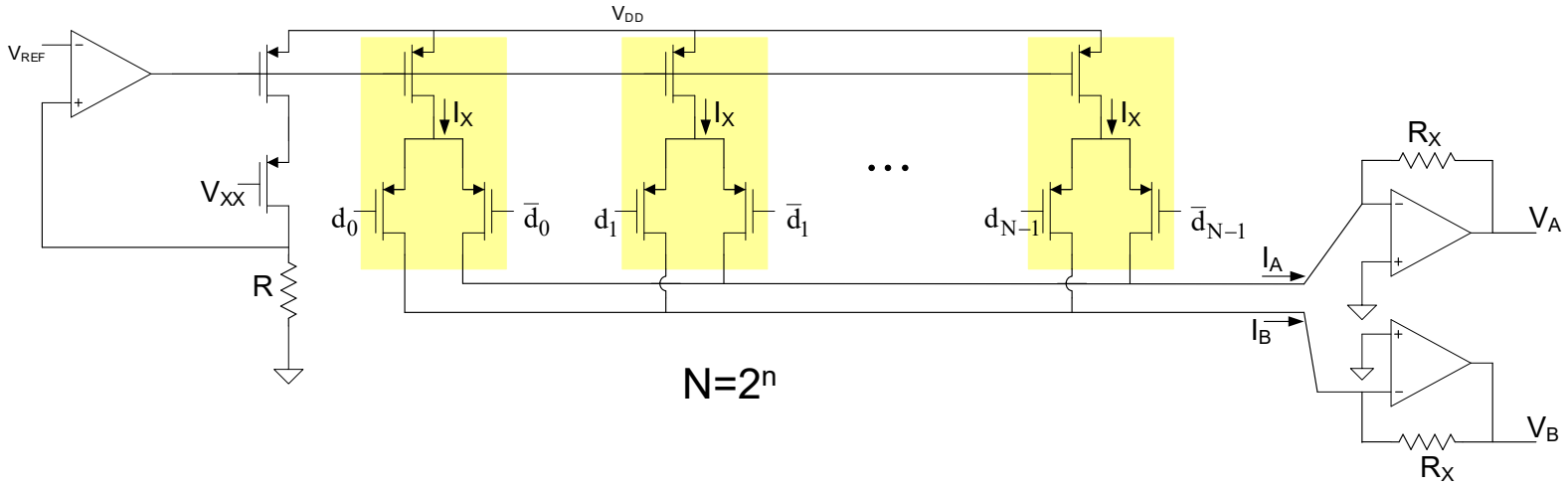
If transistors on top row are all matched, $I_X = V_{REF}/R$

Thermometer coded structure (requires binary to thermometer decoder)

$$I_A = \left(\frac{V_{REF}}{R}\right)\sum_{i=0}^{N-1} d_i$$

Provides Differential Output Currents

Current Steering DAC with Supply Independent Biasing

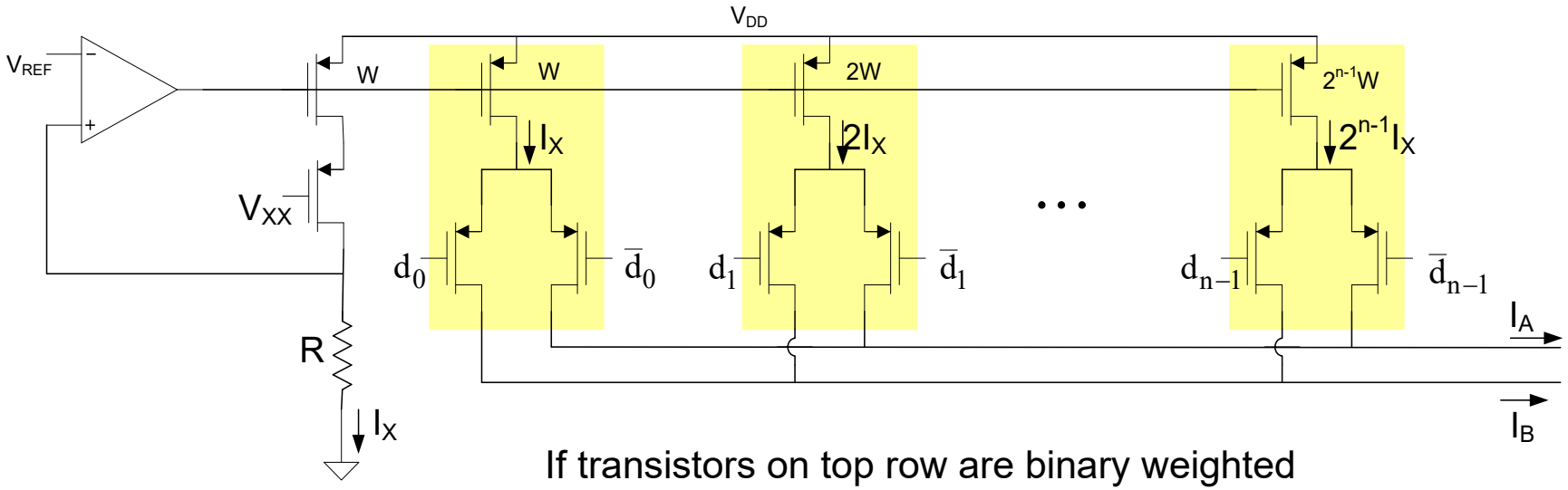


If transistors on top row are all matched, $I_X = V_{REF}/R$

$$V_A = \left(-V_{REF} \frac{R_A}{R} \right) \sum_{i=0}^{N-1} d_i$$

Provides Differential Output Voltages

Current Current Steering DAC with Supply Independent Biasing



If transistors on top row are binary weighted

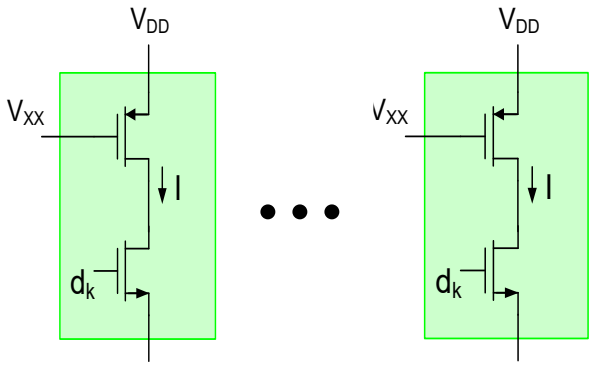
$$I_A = \left(\frac{V_{REF}}{R}\right)\sum_{i=0}^{n-1} d_i 2^i$$

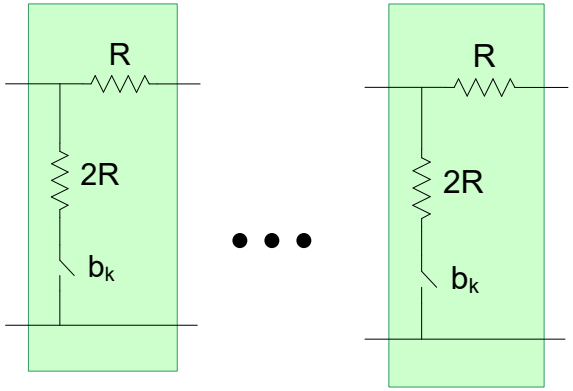
Provides Differential Output Currents

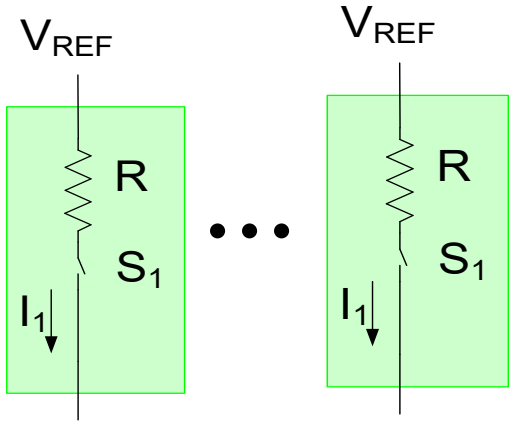
Usually use bundled unary cells
Can use current steering rather than current switching

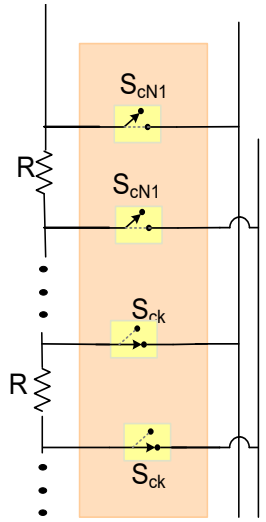
(switched LSB:MSB notation)

Matching is Critical in all DAC Considered



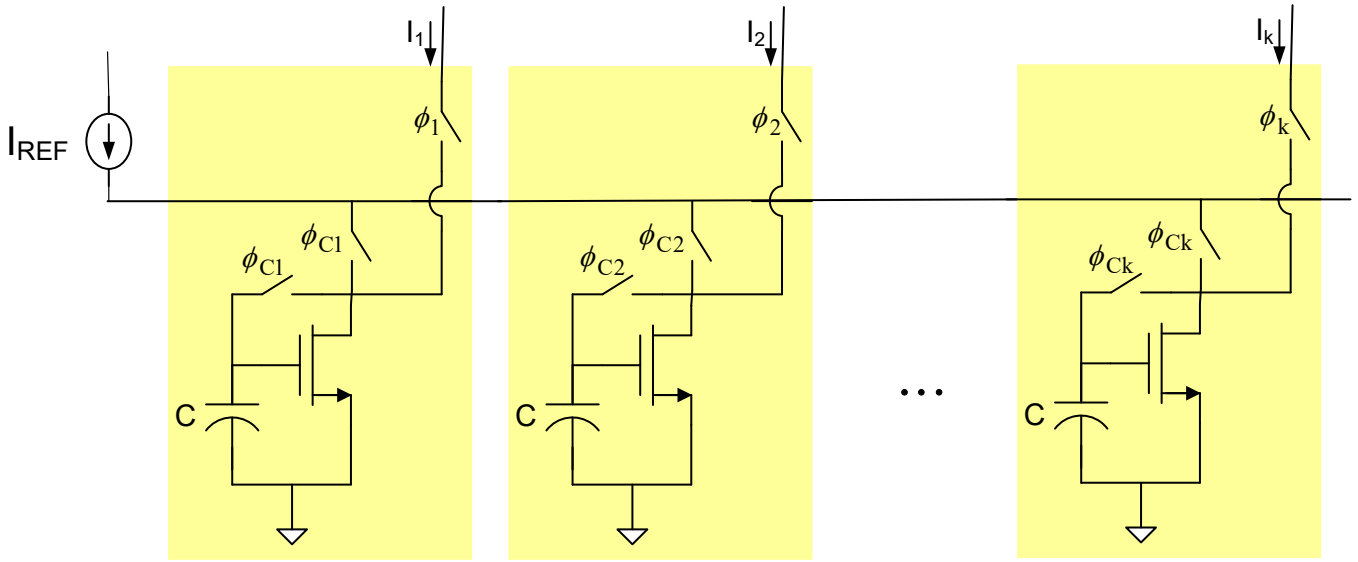






Obtaining adequate matching remains one of the major challenges facing the designer!

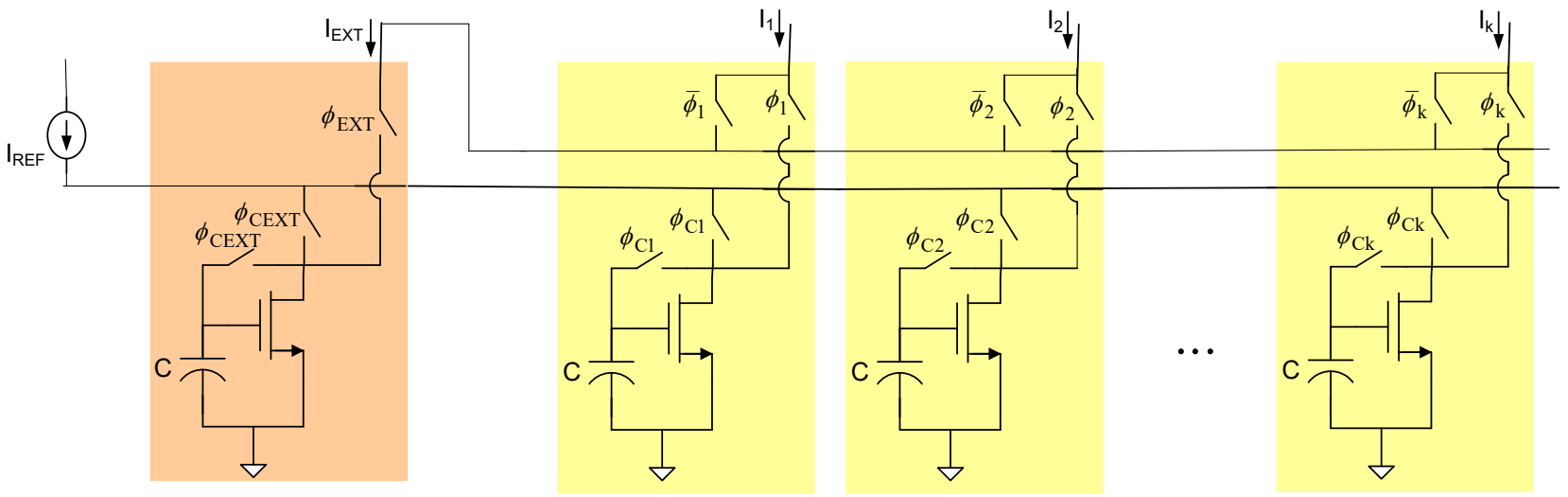
Dynamic Current Source Matching



- $\varphi_1,\ldots\varphi_k\ldots\varphi_n$ distinct from $d_1,\ldots d_n$ (not shown)
- Correct charge is stored on C to make all currents equal to I_{REF}
- Does not require matching of transistors or capacitors
- Requires refreshing to keep charge on C
- Form of self-calibration
- Calibrates current sources one at a time
- Current source unavailable for use while calibrating
- Can be directly used in DACs (thermometer of binary coded)

Often termed “Current Copier” or “Current Replication” circuit

Dynamic Current Source Matching



Extra current source can be added to facilitate background calibration

Stay Safe and Stay Healthy !

End of Lecture 35