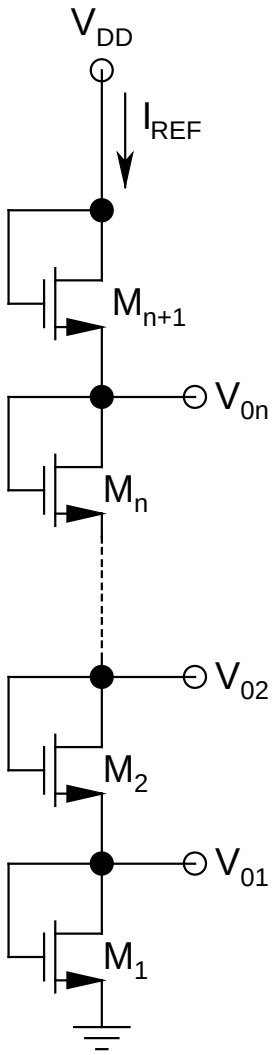
- ***NMOS Voltage Reference*:**
  - ***Highly popular due to its simplicity and effectiveness***
  - ***Can generate n voltage references from (n + 1) MOSFETs***
  - ***All MOSFETs diode-connected***
    ⇒ Always saturated
  - ***No resistors needed***
  - ***All bodies connected to ground***



- ***Only for M_1***, $V_{TN1} = V_{TN0}$
- ***All other MOSFETs will have body effect***,

  e.g., $V_{TN2} = V_{TN0} + \gamma\left(\sqrt{2\phi_F + V_{01}} - \sqrt{2\phi_F}\right)$
- Generally, ***all λs also same***, but ***aspect ratios are different***
- $V_{01}, V_{02}, \ldots, V_{0n}$ are the ***needed reference taps***
- $V_{GS1} = V_{DS1} = V_{01}$, $V_{GS2} = V_{DS2} = V_{02} - V_{01}$, $V_{GS3} = V_{DS3} = V_{03} - V_{02}, \ldots$
- $V_{SB1} = 0$, $V_{SB2} = V_{01}$, $V_{SB3} = V_{02}, \ldots$
- ***Same DC current I_{REF} flows through all MOSFETs***

- Assuming that ***all MOSFETs*** have ***same*** λ and ***same*** k'_N:

$$I_{REF} = \frac{k'_N}{2}\left(\frac{W}{L}\right)_1 \left(V_{01} - V_{TN1}\right)^2 \left(1+\lambda V_{01}\right)$$

$$= \frac{k'_N}{2}\left(\frac{W}{L}\right)_2 \left(V_{02} - V_{01} - V_{TN2}\right)^2 \left[1+\lambda\left(V_{02} - V_{01}\right)\right]$$

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- ***First I_{REF} needs to be found by ensuring that the circuit dissipates least DC power***
- ***Then, all (W/L)s can be calculated***

- ***Choice depends on several design paradigms***
- $P_D = V_{DD} \times I_{REF}$

  $\Rightarrow$ ***For minimum P_D, I_{REF} should be minimum***
- ***Need to pick up a reference MOSFET to start the design process***
- ***Area of a MOSFET*** = W × L
- ***For minimum area***, W = L = MFS
  - ***MFS***: ***Minimum Feature Size*** (***that is allowed by the technology***)
- Pick the ***reference MOSFET*** by choosing its ***(W/L) = 1***, and having the ***least*** $V_{GT}^2\left(1+\lambda V_{DS}\right)$

- ***This will yield minimum P_D***
- ***Once the reference MOSFET is chosen, I_{REF} becomes known***, and ***(W/L)s of all other MOSFETs can be calculated***
- ***Total area taken up by the circuit***:

$$\sum_{n}\left(W \times L\right)_{n}$$

- ***Care***: ***No dimension can be < MFS***
- ***Then what to do if (W/L) < 1***?