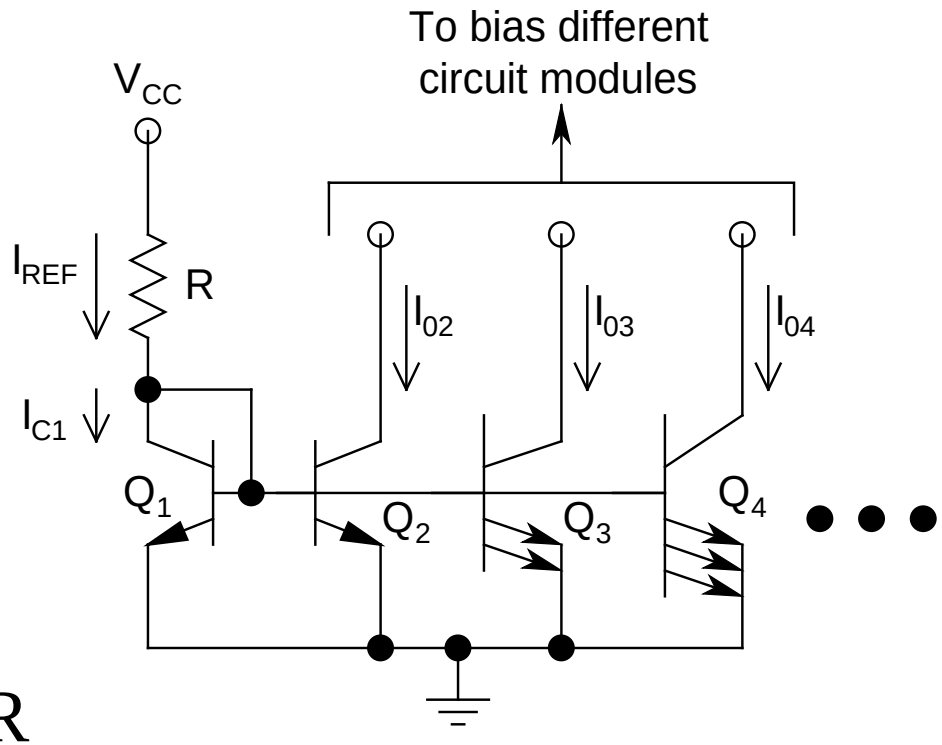
- ***npn Current Repeater***:
  - ***Uses multi-emitter BJTs***
  - ***Maximum number of emitters = 4***
  - ***All emitters tied together***
  - ***All Qs have same V_{BE}***
  - $I_{REF} = (V_{CC} - V_{BE})/R$

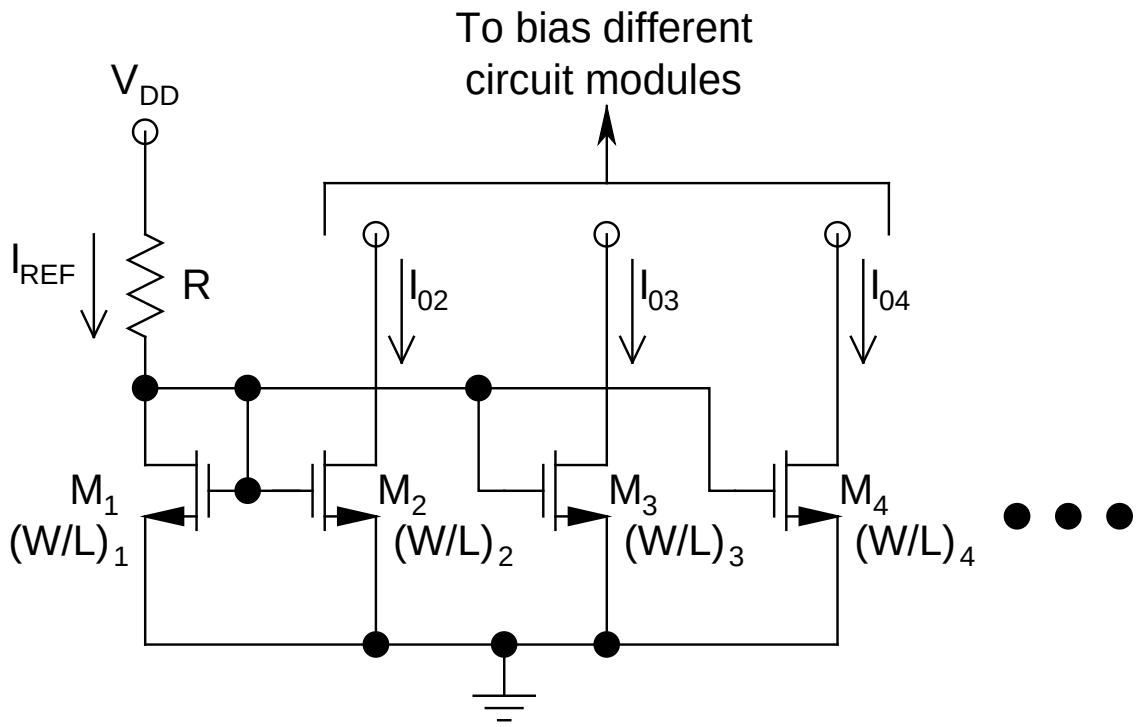


- ***Neglecting I_B***:

  $I_{02} = I_{REF}$, $I_{03} = 2I_{REF}$, $I_{04} = 3I_{REF}$, …

- ***Limitations***:
  - ***Output current can never be a non-integer ratio of I_{REF} $\Rightarrow$ no arbitrary scaling possible***
  - ***Loading Problem***:
    - ***I_{REF} not only supplies I_{C1}, but I_Bs of all the Qs***
    - ***As more Qs are added, I_Bs will keep on increasing***
    - ***I_{C1} starts to depart significantly from I_{REF}***
    - ***It's not I_{REF} that's mirrored, it's I_{C1}***
    - ***A reduction in I_{C1} will affect all output currents***
    - ***Hence, this circuit is not very popular***

- ***NMOS Current Repeater***:



- $I_{REF} = I_{D1} = (V_{DD} - V_{GS})/R$

$$I_{D1} = \frac{k'_N}{2}\left(\frac{W}{L}\right)_1 V_{GT}^2 \quad \left(\textbf{\textit{assuming } } \lambda V_{DS} < 0.1\right)$$

- ***All Ms have same V_{GS} and are matched***

$$\Rightarrow I_{0i} = \frac{(W/L)_i}{(W/L)_1} I_{REF} \quad (i = 2, 3, 4, \ldots)$$

- ***Tremendous flexibility***
  - ***Any arbitrary current ratio can be obtained***
  - ***No loading effect***
  - ***Highly popular and universal choice***

- ***More on W/L Ratio***:
  - ***Generally, in technology, W/L is kept between 0.01 and 100***
  - ***The ideal ratio is between 0.02 and 50***
  - ***Minimum Feature Size*** (MFS):
    - ***Minimum dimension that can be resolved in an IC chip***
      - ***Has gone down from 10s of μm in 80s to a few nm now***!
  - ***For W/L > 1 (or < 1), L (or W) is chosen equal to MFS***
    - ***Yields minimum possible device area*** (W × L)

- ***npn CM With Better β Insensitivity***:
  - $I_{REF} = (V_{CC} - 2V_{BE})/R$
  - Neglecting I_{B3}:

    $I_{C1} = I_{REF}$
  - ***If Q_1 and Q_2 are matched***:

    $I_0 = I_{C2} = I_{C1} = I_{REF}$

    $\Rightarrow$ ***Simple CM***
  - ***The actual advantage of the circuit lies elsewhere***!