

- **Systematic Error:**

- Even if  $M_1$  and  $M_2$  are *perfectly matched*, still  $I_0$  *may not equal*  $I_{REF}$ !

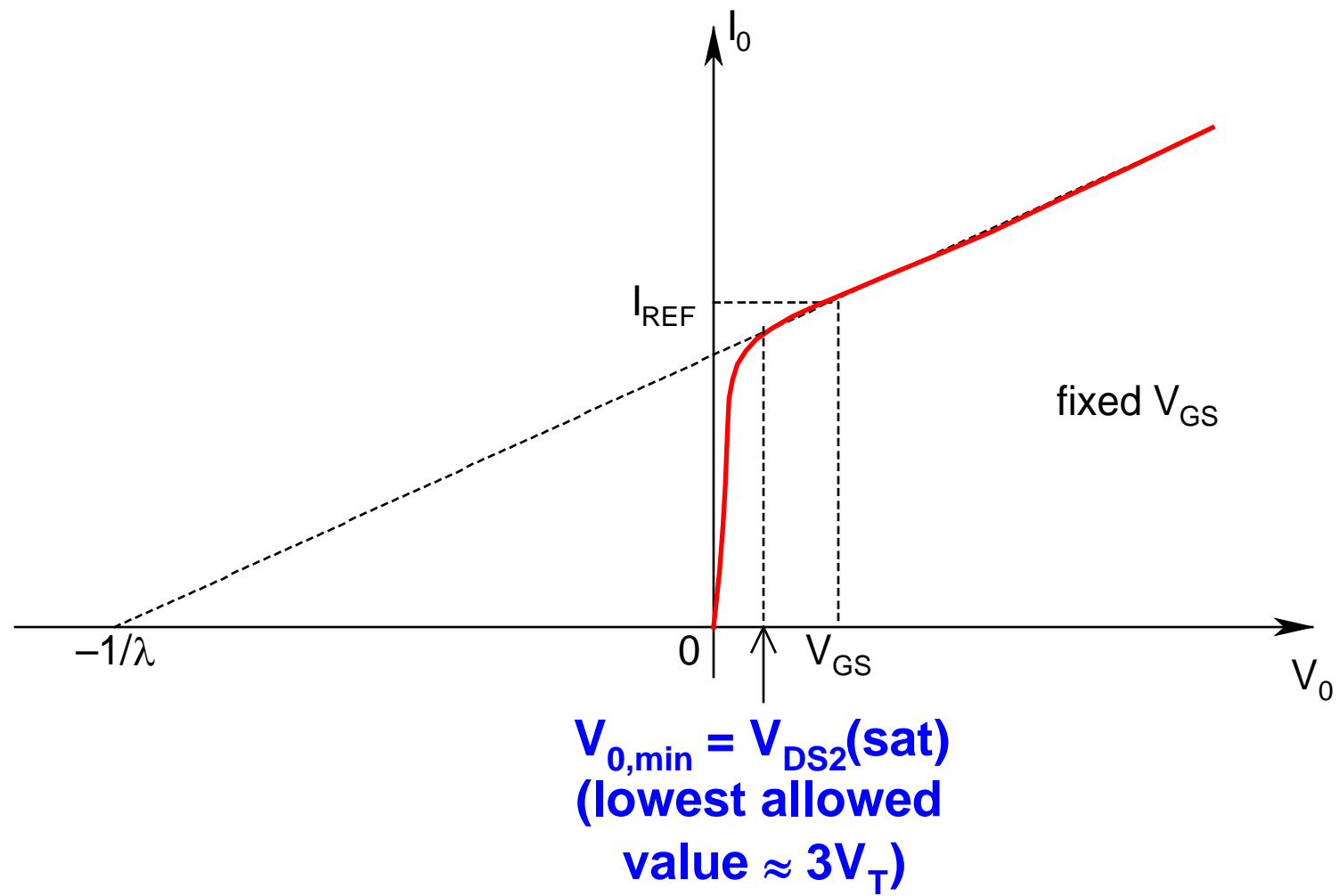
- Recall:

$$I_D = \frac{k_N}{2} V_{GT}^2 (1 + \lambda V_{DS})$$

- Thus:

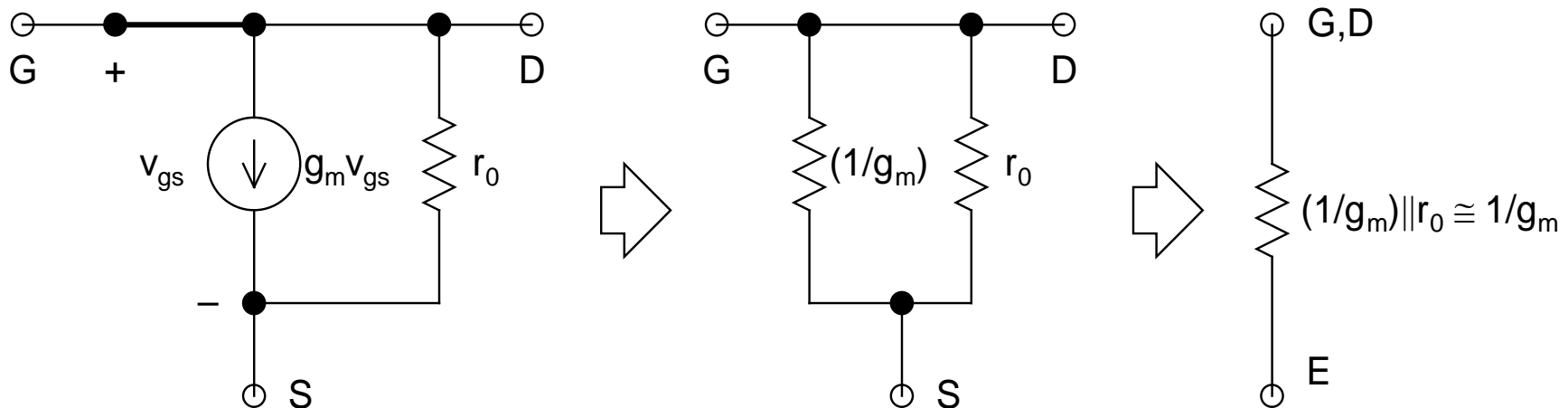
$$\frac{I_0}{I_{REF}} = \frac{1 + \lambda V_{DS2}}{1 + \lambda V_{DS1}} = \frac{1 + \lambda V_0}{1 + \lambda V_{GS}}$$

- Therefore,  **$I_0 = I_{REF}$  only when  $V_0 = V_{GS}$**



- **Output Resistance  $R_o$ :**

➤ First, *investigate  $M_1$*



- The *small-signal equivalent* consists simply of  $1/g_m$ , which is similar to  $r_D$  for *diodes*
- Hence the name *diode-connected MOSFET*

- *For the complete circuit:*

- *Left part of the circuit has no source*

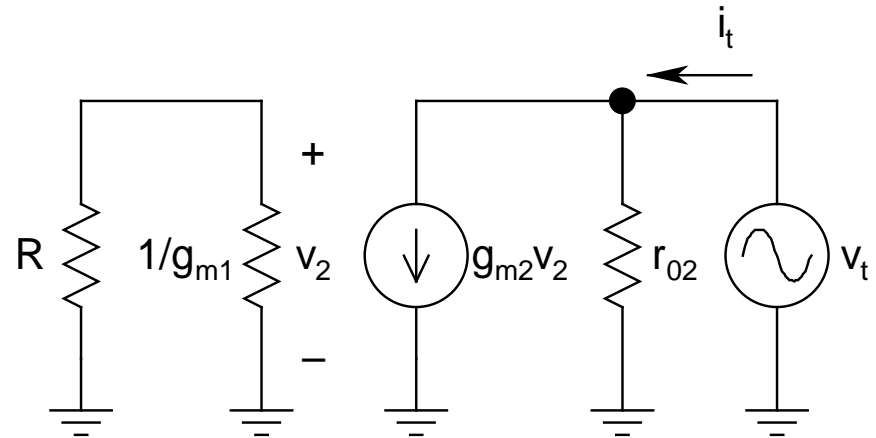
$$\Rightarrow v_2 = 0$$

$$\Rightarrow g_{m2}v_2 = 0$$

- Thus,  $R_0 = v_t/i_t = r_{o2} = 1/(\lambda I_0)$

- For a *good current source*,  $R_0$  should be as large as possible (*ideally infinite*)

$\Rightarrow \lambda$  should be as small as possible and/or  $I_0$  should be as small as possible



- *Golden Rule for Calculation of  $R_o$ :*

- For a *BJT* (or *MOSFET*):

- With E (or S) *grounded*
- *No electrical connection (feedback)* between C (or D) and B (or G)
- *Looking from* the C (or D)
  - ❖ *The only resistance seen will be the output resistance of the BJT (or MOSFET)*

- ***npn Current Repeater:***

- *Uses multi-emitter BJTs*

- *Maximum number of emitters = 4*

- *All emitters tied together*

- *All  $Q$ s have same  $V_{BE}$*

- $I_{REF} = (V_{CC} - V_{BE})/R$

