

Wide swing cascode with precise current gain.

The six MOSFET mirror shown in Fig. 9 solves the problem of the output voltage range, since V_{min} can be designed to be as small as $2V_{DSAT}$. Unfortunately, its precision is poor, since M_2 and M_1 has different V_{DS} . Furthermore, the input voltage is still $2V_{GS}$.

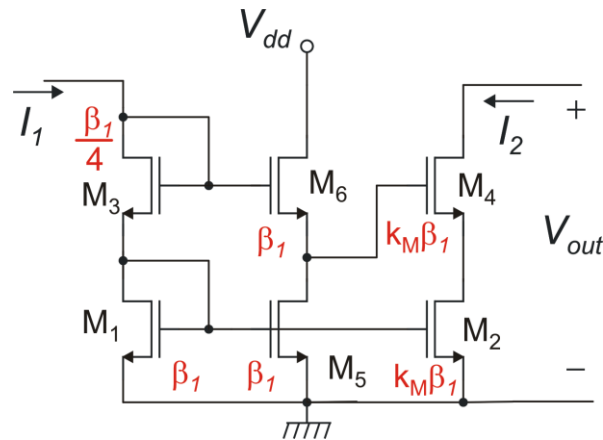


Figure 9. Low precision, wide swing cascode current mirror

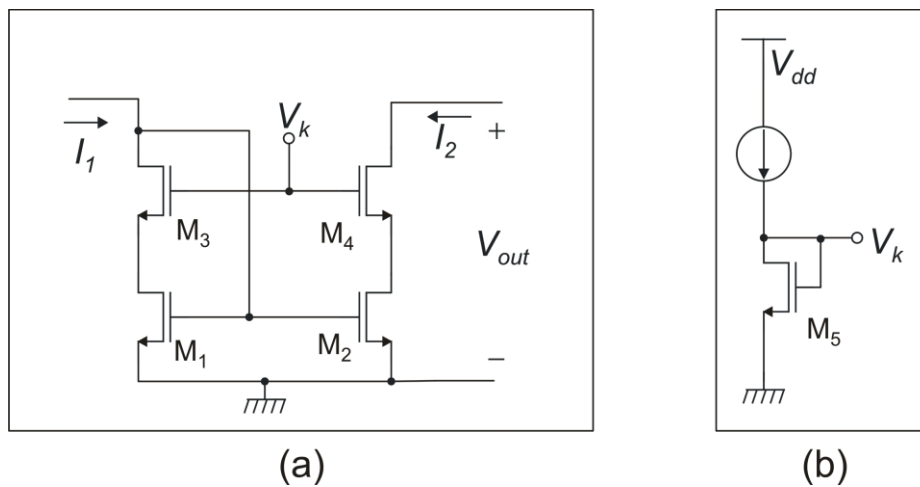


Figure 10. (a) High precision, wide swing cascode current mirror with low input voltage. (b) Generation of bias voltage V_k

The cascode mirror shown in Fig.10 (a) solves all these problems. It requires an auxiliary voltage, V_k , to bias the gates of M_3 and M_4 . To study this circuit, we can start by writing V_{DS1} and V_{DS2} :

$$\begin{aligned} V_{DS1} &= V_k - V_{GS3} \\ V_{DS2} &= V_k - V_{GS4} \end{aligned} \tag{31}$$

Choosing $\beta_4/\beta_3 = \beta_2/\beta_1 = k_M$ we obtain $V_{GS3} = V_{GS4}$, as in a conventional cascode, so that $V_{DS1} = V_{DS2}$. This relationship guarantees that the mirror is precise, in the sense that the actual current gain is equal to the ratio β_2/β_1 .

Voltage V_k should be chosen to keep M_1 and M_2 in saturation region. Therefore:

$$V_k \geq V_{DSAT2} + V_{GS4} \quad (32)$$

Voltage V_k can be properly chosen to make V_{DS1} and V_{DS2} close to the transition to triode region, so that:

$$V_{DS2} \cong V_{DSAT2} = V_{GS2} - V_t \quad \Rightarrow \quad V_{min} \cong V_{DSAT2} + V_{DSAT4} \quad (33)$$

In this way V_{min} is only equal to $2V_{DSAT}$. The condition on V_k becomes:

$$V_k = V_{DS2} + V_{GS4} = (V_{GS} - V_t)_2 + (V_{GS} - V_t)_4 + V_{t4} \quad (34)$$

Voltage V_k can be produced by the circuit shown in Fig.10 (b). Considering Eq.(34) we can write:

$$V_k = V_{GS5} = V_{t5} + (V_{GS} - V_t)_5 = (V_{GS} - V_t)_2 + (V_{GS} - V_t)_4 + V_{t4} \quad (35)$$

Note that the source of M_5 is grounded, while M_4 source is at potential V_{DS2} , which, being close to V_{DSAT2} , is of the order of a few hundred millivolts. Therefore, the body effect on V_{t4} is small and we can consider that $V_{t4} \cong V_{t5}$. Then:

$$(V_{GS} - V_t)_5 = (V_{GS} - V_t)_2 + (V_{GS} - V_t)_4 \quad (36)$$

Current I_{bias} and M_4 aspect ratio (W/L) should be properly designed to obtain the equality (36). Voltage V_k should also keep M_3 in saturation region. Note that $V_{D3} = V_{GS1}$. Therefore, we must guarantee that:

$$V_{D3} = V_{GS1} \geq V_k - V_{t3} \quad (37)$$

Finally, we note that the input voltage is simply equal to V_{GS1} , like in simple current mirrors.

Final considerations.

- The precision, wide swing cascode current mirror shown in Fig.10 offers a low V_{min} ($V_{min} = 2V_{DSAT}$), relatively low input voltage ($V_{in} = V_{GS}$), and also precise current gains.
- This mirror requires accurate design in order to satisfy conditions (32) and (37) over the whole range of input currents.