There are lots of errata in the textbook's version of this example.

On page 614
In the 9th line of the blue text-box replace "2% mismatch" with "1% mismatch".
In equation 9.87 change 0.02 to 0.01.
About 2/3 down the page replace R_{SS} = 1 MΩ with R_{SS} = 500 $k\Omega$
Two more lines down replace $\frac{V_A}{I}$ = 1 MΩ with $\frac{V_A}{I}$ = 500 kΩ
Two more lines down replace V_A = 200 V with V_A = 100 V
Two more lines down replace L = 40 μm with L = 20μm

On page 615
At the top of the text box the caption label is missing. Insert "Example 9.4 *continued*" similar to that on page 614.
About a quarter of the way down the page
Replace 1000 = 2 × r_o^2 with 500 kΩ = 2 × r_o^2
On the next line replace r_o = 22.36 kΩ with 15.81 kΩ
Two lines down replace 2.36 with 15.81 kΩ
On the next line replace V_A = 4.47 V with V_A = 3.16 V
Two lines down replace $L = \frac{4.47}{V_A} = \frac{4.47}{5}$ = 0.89 μm with $L = \frac{3.16}{V_A} = \frac{3.16}{5}$ = 0.89 μm

The corrections above are minimal. There remain issues with units that are omitted.
The example shown below contains additional corrections to units.

As printed in the textbook, some of the example is missing various units and algebraic details are omitted.
The presentation below shows the units consistently and shows more of the algebra.

Example 9.4b More complete algebra and units more consistently represented.

In this example we consider the design of the current source that supplies the bias current of a MOS differential amplifier. Let it be required to achieve a CMRR of 100 dB and assume that the only source of mismatch between Q_1 and Q_2 is a 2% mismatch in their W/L ratios. Let I = 200 µA and assume

Example 9.4b *continued*

that all transistors are to be operated at $V_{OV} = 0.2\text{ V}$. For the 0.18 μm CMOS fabrication process available, $V_A' = 5\,V/\mu\text{m}$. If a simple current source is utilized for I, what channel length is required? If a cascode current source is used, what channel length is needed for the two transistors in cascode?

Solution

A mismatch in W/L results in a g_m mismatch that can be found from the expression of g_m. The expression on the next line can be derived from Eq (7.41) on Page 386 and Eq (5.11) on Page 252.

$$g_m = \sqrt{2(\mu_n C_{ox})\left(\frac{W}{L}\right)I_D} \qquad 9.86b$$

Define $\left(\frac{W}{L}\right)_{max} = 1.02\left(\frac{W}{L}\right)$, a 2% increase. Similarly define $g_{m_{max}} = g_m + \Delta g_m$

$$g_{m_{max}} = \sqrt{2(\mu_n C_{ox})\left(\frac{W}{L}\right)_{max} I_D} = \sqrt{2(\mu_n C_{ox})(1.02)\left(\frac{W}{L}\right)_{max} I_D} = \sqrt{1.02}g_m = 1.01g_m \qquad 9.87b$$

It is thus shown that an error of 2% in W/L will result in an error in g_m of 1%. That is, the 2% mismatch in the W/L ratios of Q_1 and Q_2 will result in a 1% mismatch in their g_m values. The resulting CMRR can be found from Eq. (9.85), repeated here:

$$CMRR = (2g_m R_{SS})/\left(\frac{\Delta g_m}{g_m}\right)$$

Now, a 100 dB CMRR for the input voltages corresponds to a ratio of $10^{\left(\frac{100\text{ dB}}{20}\right)} = 10^5$; thus,

$$10^5 = (2g_m R_{SS})/0.01$$

The value of g_m can be found from

$$g_m = \frac{2I_D}{V_{OV}} = \frac{2(I/2)}{V_{OV}} = \frac{2(200\ \mu\text{A})/2}{(0.2\text{ V})} = (1000\ \mu\text{A/V}) = 1\text{ mA/V}$$

Solving Eq. (9.90b) for R_{SS} gives

$$R_{SS} = CMRR\left(\frac{\Delta g_m}{g_m}\right)/(2g_m) = [10^5(0.01)]/[2(1\text{ mA/V})] = 1000/(2\text{ mA/V}) = 500\text{ k}\Omega$$

Now if the current source is implemented with a single transistor, its r_o must be

$$r_o = R_{SS} = 500\text{ k}\Omega$$

Thus,

$$\frac{V_A}{I} = 500\text{ k}\Omega$$

Substituting $I = 200\ \mu\text{A} = 0.2\text{ mA}$, we find the required value of V_A as

$$V_A = Ir_o = (0.200\text{ mA})(500\text{ k}\Omega) = 100\text{ V}$$

Since $V_A = V_A' L = (5\text{ V}/\mu\text{m})L$, the required value of L will be

$$L = V_A/V_A' = (100\text{ V})/(5\text{ V}/\mu\text{m}) = 20\ \mu\text{m}$$

which is very large!

Example 9.4b *continued*

Using a cascode current source, we have

$$R_{SS} = (g_m r_o) r_o \quad \text{or, solving for } r_o, \quad r_o = \sqrt{R_{SS} / g_m}$$

where

$$g_m = \frac{2I}{V_{OV}} = \frac{2(200\ \mu\text{A})}{(0.2\ \text{V})} = 2\ \text{mA/V}$$

Thus,

$$r_o = \sqrt{\frac{500\ \text{k}\Omega}{2\ \text{mA/V}}} = \sqrt{250 \times 10^6\ \Omega^2} = 15.81\ \text{k}\Omega$$

and the required V_A now becomes

$$r_o = V_A / I \quad \text{or, solving for } V_A, \quad V_A = I r_o$$

$$V_A = (0.200\ \text{mA})(15.81\ \text{k}\Omega) = 3.16\ \text{V}$$

which implies a channel length for each of the two transistors in the cascode of

$$L = \frac{V_A}{V_A'} = \frac{3.16\ \text{V}}{5\ \text{V}/\mu\text{m}} = 0.63\ \mu\text{m}$$

a considerable reduction from the case of a simple current source, and indeed a practical value.