Fundamentals of Microelectronics

Behzad Razavi

Errata Sheet for Preview and First Editions

Preview Edition

- Change the right hand side of Eq. (2.55) to 1.17×10^4.
- Change the right hand side of Eq. (2.105) to 820 μA.
- In Fig. 2.39, change the values on the vertical axis from 1.3 and 2.2 to 0.13 and 0.175, respectively.
- In Fig. 3.1(a), the words inside the box should read Black Box.
- Add the following sentence before Section 3.3: It is important to remember that a diode about to turn on or off carries no current but sustains a voltage equal to $V_{D,on}$.
- In Fig. 3.17(d), the value of V_{in} on the left should read:

$$- (1 + \frac{R_1}{R_2}) V_{D,on} \qquad (1)$$

- The second sentence in Example 3.22 should read "... determine the change in V_{out}."
- In Eq. (3.73), change 0.5 mA to -0.5 mA. Also, in Eq. (3.74). change 6.5 mV to -6.5 mV.
- The plot of $I_{D3} = I_{D4}$ in Fig. 3.41 should be flipped vertically.
- The plot of I_{D1} in Fig. 3.58 should appear as shown below.
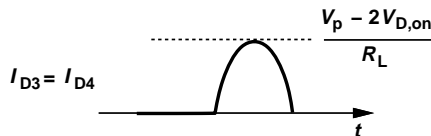
- In Fig. 3.61(d), the top current source should be called I_2.
- In Example 4.18, after Eq. (4.112) change V_{BE1} to V_{EB}. Also, in the second line after Eq. (4.114) change V_1 to V_{in}.
- Fig. (4.45) caption should end as "... equivalent of (c)"
- In Fig. 4.46(b) omit the ground connection on top of $r_{\pi 2}$.
- In Example 5.10, the third sentence should read "... if R_2 is 1.6% higher ..." Also, the first sentence of the last paragraph in the solution should read "If R_2 is 1.6% higher ..."
- The right hand side of Eq. (5.74) should read 2.44 kΩ.
- The first sentence of Example 5.15 should read "Calculate the collector current of Q_1 ..."
- The right hand side of Eq. (5.140) should read -35. Also, in the line below it, change 38 to -38.
- In the solution of Example 5.34, second line, change C_1 to C_2; in Eq. (5.231), change 6120 to 30607; in Eq.

(5.233) change 512 to 520. In the footnote, change C_1 to C_2.
- In Eq. (5.240), change 1.85 to 1.83; in Eq. (5.243), change 22.4 to 22.8; in Eq. (5.245), change 2.14 to 2.15.
- In the solution of Example 5.35, add "Thus, $R_C = 2.23$ kΩ. before the sentence "We can then write ..."
- In Example 5.42 change I_S to 5×10^{-19} A.
- In Eq. (5.328), change 1058 to 1328. Also, in the line below it, change 10.28 to 11.4.
- In Problem 5.35, assume $V_{CC} = 2.5$ V.
- The paragraph before Problem 7.1 should read "... unless otherwise stated, assume the transistors operate in saturation, ..."
- In Problem 7.8, add the following sentence to the end "... if the drain current is 1 mA without R_P."
- In Problem 7.38(a) add the following sentence to the end "for M_1 to remain in saturation?"
- In Fig. 8.26(a) the horizontal axis should be labeled $V_{in1} - V_{in2}$.
- In the denominator of Eq. (11.98), change C_{GD1} to C_{GS1}.
- Add C_{SB2} to C_{DB3} in the denominator of Eq. (11.99).
- Add C_{SB3} to the denominator of Eq. (11.107) inside the square brackets.
- In Fig. 12.42, label the one on the left (a) and the one on the right (b).
- In Eq. (12.135) and (12.136), multiply the numerator by R_{D1}.
- In Fig. 12.58(c), change the direction of I_1.
- On page 594, change footnote number 15 to "In general, it may not be possible ..."
- In solution of Example 12.40, fourth line, change (12.184) to (12.185).
- In Example 12.43, first line, change Fig. 12.74(a) to Fig. 12.74. Also, in the solution, omit the reference to Fig. 12.74(b).
- In Problem 12.39, change 12.28 to 12.47(a).
- The line above Eq. (13.20) should read "... assuming $(g_{m1} + g_{m2})$..."
- The line below Eq. (13.35) should read "where $T = 2\pi/\omega$.
- Change the word "ideal" to "realistic" in the caption of Fig. 14.2.
- In Fig. 14.13(c), add a zero at the origin.
- In Example 14.5, first sentence, change the right half plane to the left half plane.
- In Eq. (14.30), change ω_0 to ω_n.

- The line above Eq. (14.75) should read "Differentiating the left-hand side with respect to Q and the right-hand side with respect to R_1 ...
- Example 14.28, first sentence, change 14.28 to 14.27.
- In Eq. (15.29), change 1.17 to 1.215. Also, in the line under it, change 1.17 to 1.215 and 640 to 617.
- In Eq. (15.83), replace $\parallel$ with $+$ on both sides. Eq. (15.84) should read

$$\frac{2}{\mu_n C_{ox}(W/L)_1(V_{DD} - V_{TH1})}. \qquad (2)$$

Other Typos
- Change R_L in Fig. 1.22 to R_E.
- In the solution of Example 2.5, change 0.74 ns to 7.4 ps.
- In Fig. 2.15, J_n should be expressed as $qn\mu_n E$ and J_p as $qp\mu_p E$.
- In Example 3.8, change 3.10(a) to 3.10(d).
- In Eq. (3.8), omit the factor of 2 in the denominator. Also, in the solutions of Examples 3.9 and 3.10 and in Fig. 3.12(b).
- In Fig. 3.26, change V to V_{out}.
- In Fig. 3.30(b), t_2 should denote the time at which V_{in} and V_{out} cross.
- In Fig. 3.41, change R_{out} to R_L.
- In Fig. 3.67, place a resistor in series with D_1 and call it R_2.
- In Fig. 3.68, place a resistor in series with V_B and call it R_2.
- In Problem 2.14, change Fig. 12 to Problem 12.
- In Fig. 4.5, flip the polarities of the battery.
- In Fig. 4.10, V_{out} is sensed from the collector with respect to ground.
- In Problem 4.10, change V_B to V_{CC}.
- In Problem 4.12, the end should read "the required circuit with minimum number of unit transistors."
- Problem 4.18 should read:The base-emitter junction of a transistor is driven by a constant voltage. Suppose a voltage source is applied between the base and collector. If the device operates in the forward active region, prove that a change in base-collector voltage results in no change in the collector and base currents. (Neglect the Early effect.)
- In Figs. 4.68, 4.69, and 4.70, the collectors should be tied to ground.
- In Figs. 4.83 and 4.84, the transistor connected to the output should be labeled Q_2.
- In Fig. 5.12, V_{out} is sensed from the collector to ground.
- In Example 5.34, the desired voltage gain is 20.
- Add R_E to the denominators of Eqs. (5.362) and (5.363).
- Change g_{m3} to g_{m1} in Eq. (5.367).
- In Figs. 5.154(c), (d), and (e), the pnp transistor should be labeled Q_2.
- In Fig. 5.159, the transistor on the right should be labeled Q_2.
- In Example 6.7, $V_{TH} = 0.4$ V. In Eq. (6.25), change 280 to 240. In Eq. (6.27), change 2.8 to 2.4. In Eq.

- (6.28), change 280.93 to 248.04. In Eq. (6.30), change 4.65 to 4.02; also in the last line.
- In Example 6.9, the drain current is 1 mA.
- In Eq. (6.52), change -2ϕ to 2ϕ.
- Multiply the right hand side of Eq. (6.67) by a negative sign.
- In Fig. 6.32(b), I_D must point upward.
- In Eq. (6.68), multiply the right hand side by a negative sign.
- In Eqs. (6.69) and (6.70), add absolute value signs around $I_{D,sat}$ and $I_{D,tri}$.
- In the footnote on page 293, change 4040 to 4004.
- In the line under Eq. (6.80), change 3 to 2.
- In Fig. 7.22, change 447 to 0.447.
- In the denominator of Fig. (7.113), change R_D to R_S.
- On page 366, two lines above Eq. (8.61), change Fig. 8.7 to Fig. 8.5.
- In Fig. 8.47, $V_{in} = 1$ V.
- In Eq. (9.3), change g_m to g_{m1}.
- In Eqs. (9.45), (9.47), (9.48), (9.54) and (9.55) insert an $r_{\pi 2}$ in parallel with r_{O1}.
- In Eqs. (9.105) and (9.106), add $I_{C,REF}/\beta$ to the right hand side.
- In Eqs. (9.107) and (9.108), change 11 to 15.
- In Eq. (9.118), change 85.5 to -85.5.
- In Problem 9.18, $\lambda \propto L^{-1}$.
- Eq. (10.12) should read $V_2 = -V_0 \sin \omega t + V_{CM}$.
- In Fig. 10.10(a), swap I_{C1} and I_{C2}. Also, in Fig. 10.10(b), swap V_Y and V_X.
- In Example 10.5, $V_{CC} = 2.5$ V.
- In Fig. 10.13, swap I_{C1} and I_{C2}.
- In the last line on page 457, change Fig. 0.6(b) to Figs. 10.21(a) and (b).
- In Eq. (10.116), multiply the right hand side by 2.
- In Eq. (10.122), change 869 to 1738.
- In Eq. (10.155), omit the factor of 2.
- In Fig. 11.27(b), the capacitance tied between the output and ground is $C_{DB2} + C_{SB1}$.
- In the first line on page 526, change C_{GD} to C_{GS}.
- In Eq. (11.96), multiply the denominator by $1/g_{m2}$.
- In the last sentence of the solution to Example 12.8, change 30% to 18%.
- In Fig. 121.4, $R_{out} = 0$.
- In Fig. 12.27, label the drain of M_1 node X.
- The last sentence of the solution of Example 12.24 should end as "given by $-R_F/R_M$."
- In Fig. 12.58, label the drain of M_1 node X.
- In Problem 12.10, assume $\lambda > 0$.
- Change the left hand side of Eq. (12.197) to y.
- In Problem 12.40, assume $V_A < \infty$.
- In Eq. (13.37), change T_1 to I_1.

First Edition

- Change the right hand side of Eq. (2.55) to 1.17×10^4.
- Change the right hand side of Eq. (2.105) to 820 μA.
- In the exercise below Example 2.18, change 100 μA to

1 mA.

- In Fig. 2.39, change the values on the vertical axis from 1.3 and 2.2 to 0.13 and 0.175, respectively.
- In Fig. 3.1(a), the words inside the box should read Black Box.
- Add the following sentence before Section 3.3: It is important to remember that a diode about to turn on or off carries no current but sustains a voltage equal to $V_{D,on}$.
- In Fig. 3.17(d), the value of V_{in} on the left should read:

$$- (1 + \frac{R_1}{R_2})V_{D,on} \qquad (3)$$

- The second sentence in Example 3.22 should read "... determine the change in V_{out}..."
- In Eq. (3.73), change 0.5 mA to -0.5 mA. Also, in Eq. (3.74). change 6.5 mV to -6.5 mV.
- In the exercise below Eample 3.28, change 1000 μF to 0.2 F.
- The plot of $I_{D3} = I_{D4}$ in Fig. 3.41 should be flipped vertically.
- The plot of I_{D1} in Fig. 3.58 should appear as shown below.
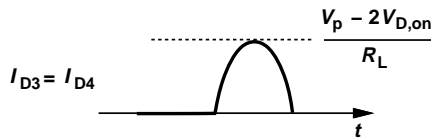
- In Fig. 3.61(d), the top current source should be called I_2.
- The exercise below Example 3.38 should read "... in the voltage at right plate of C_{j1} ... "
- The exercise below Example 4.4 should end as "0.15 μm $\times 0.15$ μm"...
- In Example 4.18, after Eq. (4.112) change V_{BE1} to V_{EB}. Also, in the second line after Eq. (4.114) change V_1 to V_{in}.
- Fig. (4.45) caption should end as " ... equivalent of (c)."
- In Fig. 4.46(b) omit the ground connection on top of $r_{\pi 2}$.
- In Example 5.10, the third sentence should read "... if R_2 is 1.6% higher ..." Also, the first sentence of the last paragraph in the solution should read "If R_2 is 1.6% higher ..."
- The right hand side of Eq. (5.74) should read 2.44 kΩ.
- The first sentence of Example 5.15 should read "Calculate the collector current of Q_1 ..."
- The right hand side of Eq. (5.140) should read -35. Also, in the line below it, change 38 to -38.
- In the solution of Example 5.34, second line, change C_1 to C_2; in Eq. (5.231), change 6120 to 30607; in Eq. (5.233) change 512 to 520. In the footnote, change C_1 to C_2.
- In Eq. (5.240), change 1.85 to 1.83; in Eq. (5.243), change 22.4 to 22.8; in Eq. (5.245), change 2.14 to 2.15.

- In the solution of Example 5.35, add "Thus, $R_C = 2.23$ kΩ. before the sentence "We can then write ..."
- In Example 5.42 change I_S to 5×10^{-19} A.
- In Eq. (5.328), change 1058 to 1328. Also, in the line below it, change 10.28 to 11.4.
- In Problem 5.35, assume $V_{CC} = 2.5$ V.
- The paragraph before Problem 7.1 should read "... unless otherwise stated, assume the transistors operate in saturation, ..."
- In Problem 7.8, add the following sentence to the end " if the drain current is 1 mA without R_P."
- In Problem 7.38(a) add the following sentence to the end "for M_1 to remain in saturation?"
- In Fig. 8.26(a) the horizontal axis should be labeled $V_{in1} - V_{in2}$.
- In Example 11.11, change C_1 in the fourth sentence to C_i.
- In the exercise below Example 11.17, $\lambda = 0$.
- In the denominator of Eq. (11.98), change C_{GD1} to C_{GS1}.
- In the third line on top of page 576, change R_D to R_L.
- Add C_{SB2} to C_{DB3} in the denominator of Eq. (11.145).
- Add C_{SB3} to the denominator of Eq. (11.153) inside the square brackets.
- In the third line on top pf page 592, change $r_{\pi 2}$ to $r_{\pi 1}$.
- In Eq. (11.170), change 42.4 to 37.1. Also, in the footnote, change R_{L2} to R_{D2} and express A_{v2} as $-g_{m2}(R_{D2}||8.7$ k$\Omega)$.
- In Eq. (11.176), change 308 to 242; in Eq. (11.177), change 2.15 to 2.74; in Eq. (11.179), change 1.21 to 0.829.
- In Fig. 12.42, label the one on the left (a) and the one on the right (b).
- In Eq. (12.135) and (12.136), multiply the numerator by R_{D1}.
- In Fig. 12.59(c), change the direction of I_1.
- On page 660, change footnote number 15 to "In general, it may not be possible ..."
- In solution of Example 12.40, fourth line, change (12.184) to (12.185).
- In Example 12.43, first line, change Fig. 12.75(a) to Fig. 12.75. Also, in the solution, omit the reference to Fig. 12.75(b).
- In Problem 12.39, change 12.28 to 12.47(a).
- On page 707, second line from top should read "... assuming $(g_{m1} + g_{m2})$ ..."
- The line below Eq. (13.35) should read "where $T = 2\pi/\omega$."
- Change the word "ideal" to "realistic" in the caption of Fig. 14.2.
- In Fig. 14.13(c), add a zero at the origin.
- In Example 14.5, first sentence, change the right half plane to the left half plane.
- In Eq. (14.30), change ω_0 to ω_n.
- The line above Eq. (14.75) should read "Differentiating

the left-hand side with respect to Q and the right-hand side with respect to R_1 ...

- Example 14.28, first sentence, change 14.28 to 14.27.
- In Eq. (15.29), change 1.17 to 1.215. Also, in the line under it, change 1.17 to 1.215 and 640 to 617.
- In Eq. (15.83), replace $\|$ with $+$ on both sides. Eq. (15.84) should read

$$\frac{2}{\mu_n C_{ox}(W/L)_1(V_{DD} - V_{TH1})}. \qquad (4)$$

- Inside back cover: The gain equations for CE and CS stages need a negative sign on the right hand side.