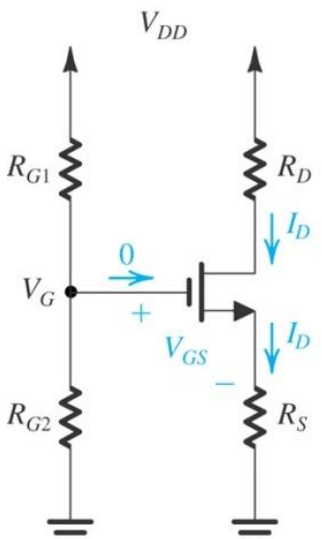
Homework #16

Problems 7.92, 7.117, 7.125, 7.129, and 7.135

Problem 7.92a

Consider the classical biasing scheme shown in Fig. 7.48(c), using a 9-V supply. For the MOSFET, V_t = 1 V, λ = 0, and k_n = 2 mA/V^2. Arrange that the drain current is 1 mA, with about one-third of the supply voltage across each of R_S and R_D. Use 22 MΩ for the larger of R_{G1} and R_{G2}. What are the values of R_{G1}, R_{G2}, R_S and R_D that you have chosen? Specify them to two significant digits. For your design, how far is the drain voltage from the edge of saturation?



(c)

$$\frac{9\text{V}}{3} = 3\text{V} = 1\text{mA} \times R_D$$

$$R_D = R_S = 3\text{k}\Omega$$

$$V_{OV} = \sqrt{\frac{I_D}{\frac{1}{2}k_n'\left(\frac{W}{L}\right)}}$$

$$V_{OV} := \sqrt{\frac{1\cdot\text{mA}}{\frac{1}{2}\cdot 2\cdot\frac{\text{mA}}{\text{V}^2}}} = 1\,\text{V}$$

$$V_{GS} = V_t + V_{OV} = (1+1)\text{V} = 2\text{V}$$

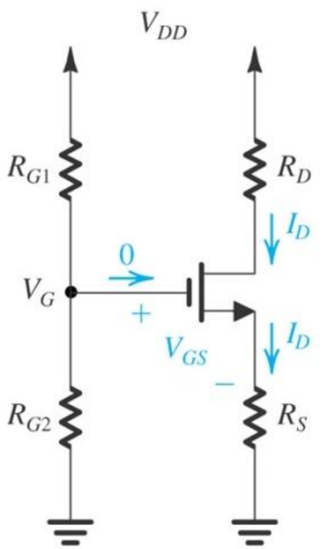
$$V_G = V_S + V_{GS} = (3+2)\text{V} = 5\text{V}$$

$$\frac{5V}{9V} = \frac{22\text{M}\Omega}{22\text{M}\Omega + R_{G1}}$$

$$R_{G1} = 17.6\text{M}\Omega \qquad R_{G2} = 22\text{M}\Omega$$

Problem 7.92b

Consider the classical biasing scheme shown in Fig. 7.48(c), using a 9-V supply. For the MOSFET, $V_t = 1$ V, $\lambda = 0$, and $k_n = 2$ mA/V^2. Arrange that the drain current is 1 mA, with about one-third of the supply voltage across each of R_S and R_D. Use 22 MΩ for the larger of R_{G1} and R_{G2}. What are the values of R_{G1}, R_{G2}, R_S and R_D that you have chosen? Specify them to two significant digits. For your design, how far is the drain voltage from the edge of saturation?



(c)

$R_D = R_S = 3\text{k}\Omega$

$R_{G1} = 17.6\text{M}\Omega$

$R_{G2} = 22\text{M}\Omega$

$V_{GS} = V_t + V_{OV} = (1+1)\text{V} = 2\text{V}$

$V_G = V_S + V_{GS} = (3+2)\text{V} = 5\text{V}$

saturation /triode boundary (B) is where $v_{GS} = v_{DS} + V_t$

$V_{GS}|_{triode} = V_{DS} + V_t = (3+1)\text{V} = 4\text{V}$

Therefore the device is biased 2 V from the triode/saturation boundary

Problem 7.117

Calculate the overall voltage gain G_v of a common source amplifier for which g_m = 2 mA/V, r_o = 50 kΩ, R_o =10 kΩ, and R_G = 10 MΩ. The amplifier is fed from a signal source with a Thevenin resistance of 0.5 MΩ, and the amplifier output is coupled to a load resistance of 20 kΩ.

$$G_v = -\frac{R_G}{R_G + R_{sig}} g_m (R_D \parallel R_L \parallel r_o)$$

$$G_v = -\frac{10\text{M}\Omega}{10\text{M}\Omega + 0.5\text{M}\Omega} 2\frac{\text{mA}}{\text{V}} (10\text{k}\Omega \parallel 20\text{k}\Omega \parallel 50\text{k}\Omega)$$

$$R_{eff} := \left(\frac{1}{50\text{k}\Omega} + \frac{1}{10\text{k}\Omega} + \frac{1}{20\cdot\text{k}\Omega}\right)^{-1} = 5882.353\,\Omega$$

$$G_v := \frac{10\text{M}\Omega}{10\text{M}\Omega + 500\text{k}\Omega} \cdot 2\frac{\text{mA}}{\text{V}} \cdot R_{eff} = 11.204$$

Problem 7.125

For the common-emitter amplifier shown in Fig. P7.125, let V_{CC} = 15 V, R_1 = 27 kΩ, R_2 = 15 kΩ, R_E = 2.4 kΩ, and R_C = 3.9 kΩ. The transistor has β = 100. Calculate the dc bias current I_C. If the amplifier operates between a source for which R_{sig} = 2 kΩ and a load of 2 kΩ, replace the transistor with its hybrid-π model, and find the values of R_{in}, and the overall voltage gain v_o/v_{sig}.

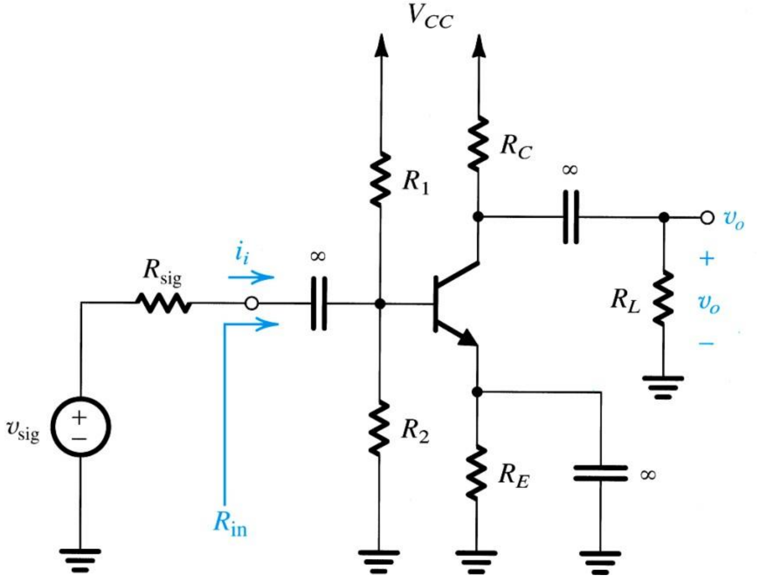


Figure P7.125

$$V_B = V_{CC}\frac{R_2}{R_2 + R_1} = 15\text{V}\frac{15\text{k}\Omega}{42\text{k}\Omega} = 5.357\text{V}$$

$$V_E = V_{BB} - V_{EB} = 4.657\text{V}$$

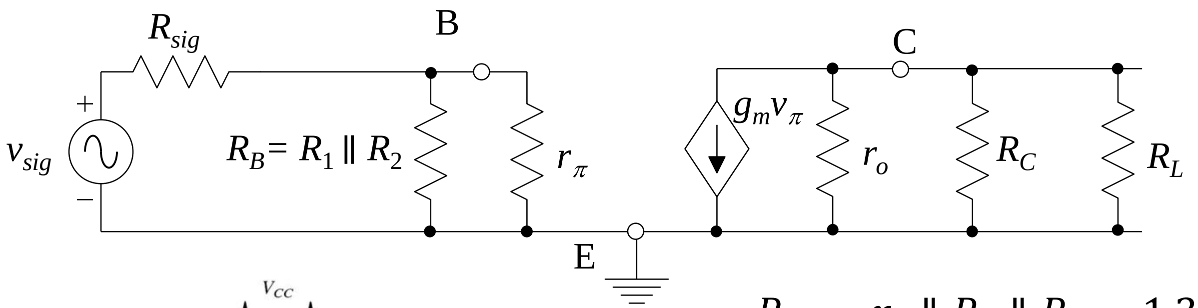
$$I_E = \frac{V_E}{R_E} = \frac{4.657\text{V}}{2.4\text{k}\Omega} = 1.94\text{mA}$$

$$I_C = \alpha I_E = \frac{\beta}{\beta + 1}1.94\text{mA} = 1.92\text{mA}$$

$$V_C = V_{CC} - I_C R_C = 15\text{V} - 1.94\text{mA} \times 3.9\text{k}\Omega = 7.512\text{V}$$

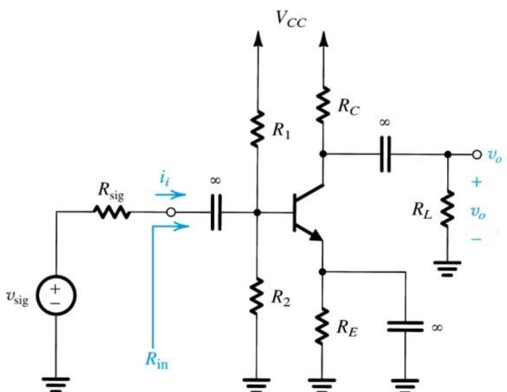
Problem 7.125

For the common-emitter amplifier shown in Fig. P7.125, let V_{CC} = 15 V, R_1 = 27 kΩ, R_2 = 15 kΩ, R_E = 2.4 kΩ, and R_C = 3.9 kΩ. The transistor has β = 100. Calculate the dc bias current I_C. If the amplifier operates between a source for which R_{sig} = 2 kΩ and a load of 2 kΩ, replace the transistor with its hybrid-π model, and find the values of R_{in}, and the overall voltage gain v_o/v_{sig}.



$$R_B = R_1 \parallel R_2 = 9.643\text{k}\Omega$$

$$r_\pi = \frac{V_T}{I_B} = \beta\frac{V_T}{I_C} = 1.302\text{k}\Omega$$



$$R_{in} = r_\pi \parallel R_1 \parallel R_2 = 1.302\text{k}\Omega \parallel 27\text{k}\Omega \parallel 15\text{k}\Omega = 1.187\text{k}\Omega$$

$$g_m = \frac{I_C}{V_T} = 76.832\ \text{mA/V}$$

$$G_v \equiv \frac{v_o}{v_{sig}} = -\frac{R_{in}}{R_{in}+R_{sig}} g_m(R_C \parallel R_L \parallel r_o) = -37.833\text{V/V}$$

Problem 7.129a,b

In the circuit of Fig. P6.146, v_{sig} is a small sine-wave signal with zero average. The transistor β is 100.

(a) Find the value of R_E to establish a dc emitter current of about 0.5 mA.

$$I_E = 0.5 \text{ mA} \qquad \Rightarrow I_B = \frac{I_E}{\beta+1} = \frac{0.5 \text{ mA}}{101} = 4.95\ \mu\text{A}$$

$$R_E = \frac{V_E - V_{EE}}{I_E} = \frac{-I_B R_B - V_{BE} - V_{EE}}{I_E} = \frac{-12 \text{ mV} - 0.7\text{V} + 5\text{V}}{0.5 \text{ mA}} = 8.576 \text{ k}\Omega$$

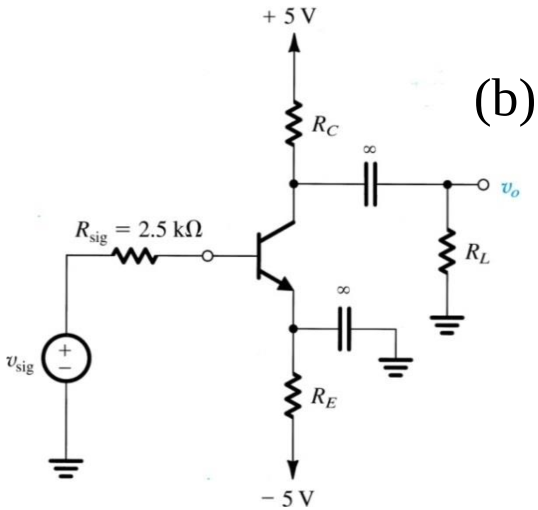


Figure P7.129

(b) Find R_C to establish a dc collector voltage of about + 1 V.

$$I_C = \alpha I_E = \frac{100}{101} 0.5 \text{ mA} = 0.495 \text{ mA}$$

$$R_E = \frac{V_{CC} - V_C}{I_C} = \frac{5 \text{ V} - 1\text{V}}{0.495 \text{ mA}} = 8.081 \text{ k}\Omega$$

Problem 7.129c

In the circuit of Fig. P6.146, v_{sig} is a small sine-wave signal with zero average. The transistor β is 100.

(c) For R_L = 10 kΩ, draw the small-signal equivalent circuit of the amplifier and determine its overall voltage gain.

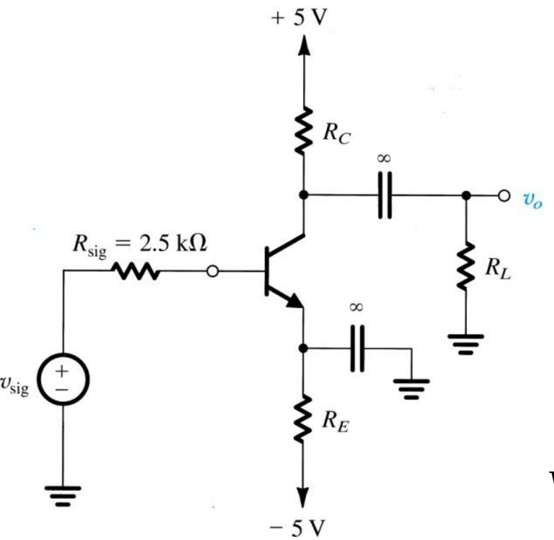
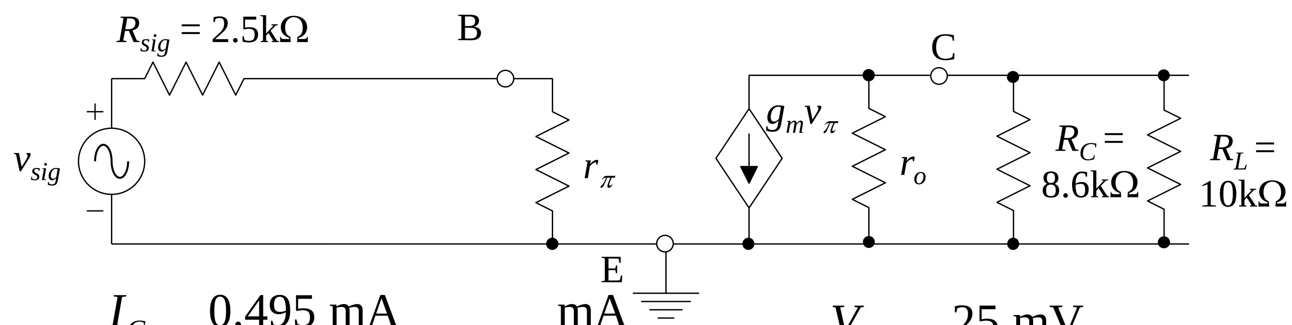


Figure P7.129



$$g_m = \frac{I_C}{V_T} = \frac{0.495\text{ mA}}{25\text{ mV}} = 19.8\,\frac{\text{mA}}{\text{V}}$$

$$r_\pi = \frac{V_T}{I_B} = \frac{25\text{ mV}}{4.95\ \mu\text{A}} = 5.05\text{ k}\Omega$$

$$v_o = (-g_m)v_{sig}\left(\frac{r_\pi}{r_\pi + R_{sig}}\right)(R_C \,\|\, r_o \,\|\, R_L)$$

$$G_v \equiv \frac{v_o}{v_{sig}} = (-g_m)\left(\frac{r_\pi}{r_\pi + R_{sig}}\right)(R_C \,\|\, r_o \,\|\, R_L) = -19.8\frac{\text{mA}}{\text{V}}\left(\frac{5.05\text{k}\Omega}{7.55\text{k}\Omega}\right)\left(\frac{8.576\text{k}\Omega \times 10\text{k}\Omega}{8.576\text{k}\Omega + 10\text{k}\Omega}\right)$$

$$= -61.23\frac{\text{V}}{\text{V}}$$

Problem 7.135a

For the emitter follower in Fig. P7.135, the signal source is directly coupled to the transistor base. If the dc component of v_{sig} is zero, find the dc emitter current. Assume β = 100. Neglecting r_o, find R_{in}, the voltage gain v_o/v_{sig}, the current gain i_o/i_i, and the output resistance R_{out}.

$$V_B = I_B R_B = \left(\frac{1}{\beta+1}\right) I_E R_B = \frac{100}{101} I_E \left[I_E \text{ in mA}\right]$$

$$I_E = \frac{V_{CC} - V_B - V_{BE}}{R_C} = \frac{5 - V_B - 0.7}{3.3} = \frac{1}{3.3}\left(4.3 - \frac{100}{101} I_E\right)\left[I_E \text{ in mA}\right]$$

$$\Rightarrow I_E = \frac{4.3}{4.29} \simeq 1 \text{ mA} \qquad I_B = \frac{I_E}{\beta+1} \simeq 10 \text{ uA}; \ I_C = 0.99 \text{ mA}$$

$$r_e = \frac{V_T}{I_E} = \frac{25 \text{ mV}}{1 \text{ mA}} = 25\ \Omega$$

$$R_{in} = (\beta+1)(r_e + R_E \,||\, R_L) = 101(25\ \Omega + 3.3\text{ k}\Omega \,||\, 2\text{ k}\Omega)$$
$$= 101(1270\Omega) = 128.3\text{ k}\Omega$$

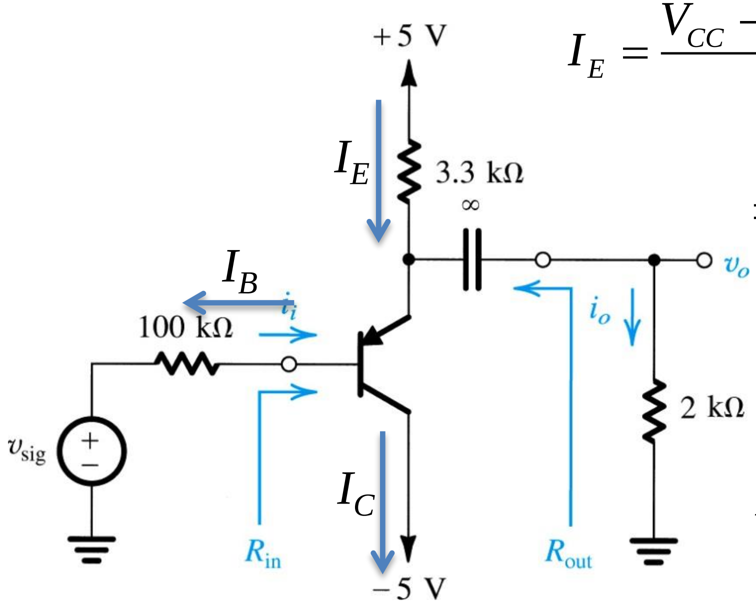


Figure P7.135

Problem 7.135b

For the emitter follower in Fig. P7.135, the signal source is directly coupled to the transistor base. If the dc component of v_{sig} is zero, find the dc emitter current. Assume β = 100. Neglecting r_o, find R_{in}, the voltage gain v_o/v_{sig}, the current gain i_o/i_i, and the output resistance R_{out}.

$$I_E = 1\text{ mA};\ I_B = \frac{I_E}{\beta+1} \simeq 10\text{ uA};\ I_C = 0.99\text{ mA}$$

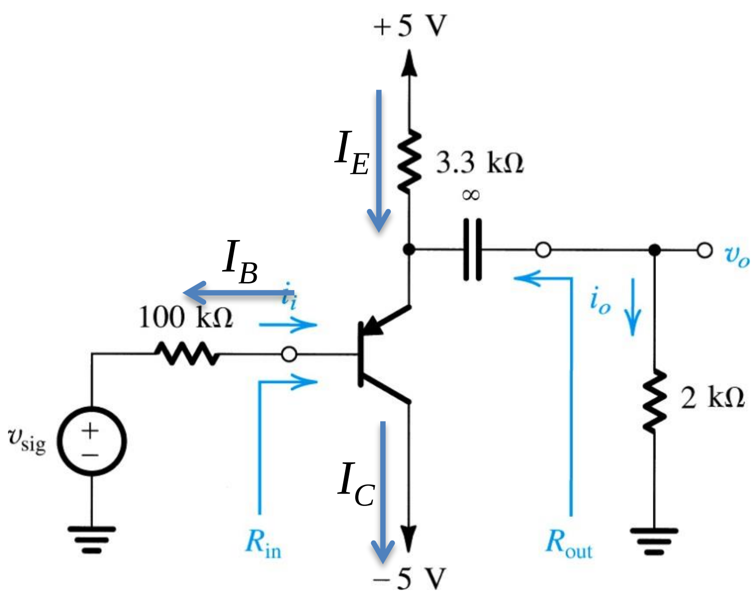


Figure P6.153

$$G_v \equiv \frac{v_o}{v_{sig}} = \frac{(\beta+1)(R_E \parallel R_L)}{(\beta+1)r_e + (\beta+1)(R_E \parallel R_L) + R_{sig}}$$

$$= \frac{101(1.25\text{ k}\Omega)}{101(25\ \Omega)+101(1.25\text{ k}\Omega)+100\text{ k}\Omega}$$

$$= \frac{125.77\text{ k}\Omega}{2.525\text{ k}\Omega+125.77\text{ k}\Omega+100\text{ k}\Omega}$$

$$= 0.551\text{ V/V}$$

Problem 7.135c

For the emitter follower in Fig. P7.135, the signal source is directly coupled to the transistor base. If the dc component of v_{sig} is zero, find the dc emitter current. Assume $\beta = 100$. Neglecting r_o, find R_{in}, the voltage gain v_o/v_{sig}, the current gain i_o/i_i, and the output resistance R_{out}.

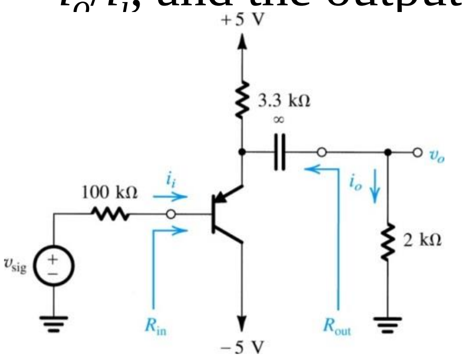
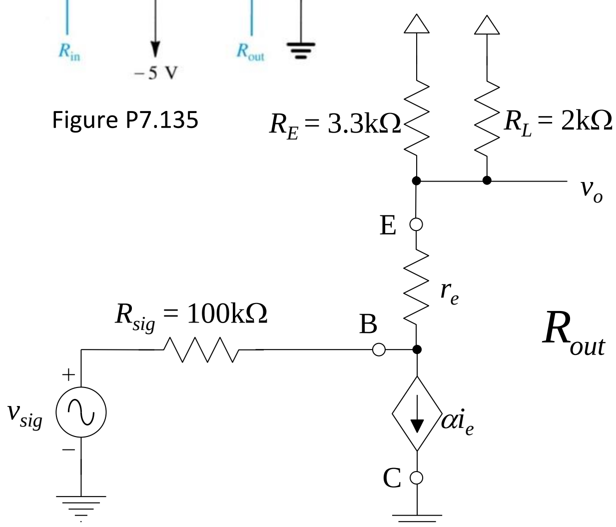


Figure P7.135



$$G_i \equiv \frac{i_O}{i_{sig}} = \frac{v_O / R_L}{v_{sig} / \left(R_{sig} + R_{in}\right)}$$

$$= \frac{R_{sig} + R_{in}}{R_L} \frac{v_O}{v_{sig}} = \frac{R_{sig} + R_{in}}{R_L} G_v$$

$$= \frac{100\text{ k}\Omega + 128.3\text{ k}\Omega}{2\text{ k}\Omega} 0.551\text{ V/V}$$

$$= 62.9\text{ A/A}$$

$$R_{out} = R_E \,||\, R_L \,||\left(r_e + \frac{R_{ig}}{(\beta+1)}\right) = 3.3\text{ k}\Omega \,||\, 2\text{ k}\Omega \,||\left(25\ \Omega + \frac{100\text{ k}\Omega}{101}\right)$$

$$= 3.3\text{ k}\Omega \,||\, 2\text{ k}\Omega \,||\, 990\ \Omega = 551\ \Omega$$