Solutions to *The Art of Electronics 3rd Edition*

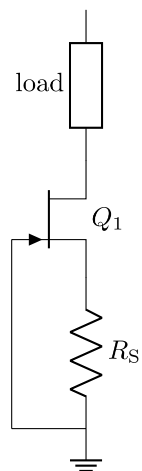
February 13, 2024

Contents

Solutions for Chapter 3

Exercise 3.1

Figure 1.1: JFET current source



From Figure 3.21 of the book, one can see that a drain current equal to 1 mA corresponds to a gate-source voltage of $-0.6\,\mathrm{V}$. Therefore:

$$\boxed{R_S = \frac{0.6\,\mathrm{V}}{1\,\mathrm{mA}} = 600\,\Omega}$$

Exercise 3.2

At $V_{GS} = V_{G0}$:

$$r_{GS} = r_{G0} = \frac{1}{2k\,(V_{G0} - V_{th})}$$

The ratio between r_{DS} and R_{G0} returns:

$$\boxed{\frac{r_{DS}}{r_{G0}} = \frac{2k\,(V_{G0} - V_{th})}{2k\,(V_{GS} - V_{th})}}$$

Exercise 3.3

Being g_{m} the differential conductance of the FET operated in aturation region, it can be expressed as:

$$g_{\mathrm{m}} = \frac{\partial I_{\mathrm{D}}}{\partial V_{\mathrm{GS}}} = \frac{\partial}{\partial V_{\mathrm{GS}}} k \left(V_{\mathrm{GS}} - V_{\mathrm{th}}\right)^2 = 2k \left(V_{\mathrm{GS}} - V_{\mathrm{th}}\right)$$

Therefore:

$$\boxed{g_{\mathrm{m}} = \frac{1}{r_{\mathrm{DS}}}}$$

Exercise 3.4

(a) The voltage across the drain-gate capacitance when the JFET is switched on ($V_{\mathrm{DS}} = 0\,\mathrm{V}$) is equal to 50 V-10 V=40 V. Considering a maximum current across this capacitance equal to 1 mA:

$$\boxed{t_{\mathrm{ON}} = \frac{40\,\mathrm{V}\,200\,\mathrm{pF}}{1\,\mathrm{mA}} = 8\,\mu\mathrm{s}}$$

(b) Since the current is equal to the charge over time, we have:

$$\boxed{t_{\mathrm{ON}} = \frac{40\,\mathrm{nC}}{1\,\mathrm{mA}} = 40\,\mu\mathrm{s}}$$

Exercise 3.5

The 1 pF drain-source capacitance happens to be in series with the 10 kΩ load resistance. The capacitive reactance is:

$$X_{\mathrm{DS}} = \frac{1}{2\pi 1\,\mathrm{MHz}\,1\,\mathrm{pF}} = 160\,\mathrm{k}\Omega$$

Therefore, the feedthrough is given by:

$$\boxed{20\log_{10}\frac{10\,\mathrm{k}\Omega}{10\,\mathrm{k}\Omega + 160\,\mathrm{k}\Omega} = -25\,\mathrm{dB}}$$

Exercise 3.6

In this case, the output 10 kΩ resistance is in parallel with the 50 Ω R_{ON} resistance. Their equivalent resistance is about 50 Ω. Similarly to the previous exercise, the feedthorugh is given by:

$$\boxed{20\log_{10}\frac{50\,\Omega}{50\,\Omega + 160\,\mathrm{k}\Omega} = -70\,\mathrm{dB}}$$

Exercise 3.7

Figure 1.2: Zero ohm R_{ON}

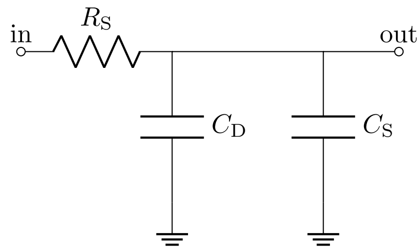
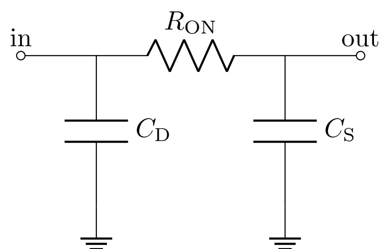


Figure 1.3: $75\,\Omega$ R_{ON}



For this exercise we assume that the load resistance of $100\,\mathrm{k}\Omega$ does not load the circuit.

(a) The circuit is that of Figure 1.2. Since $C_{\mathrm{D}} = C_{\mathrm{S}} = C_{\mathrm{T}} = 8\,\mathrm{pF}$, there is a single pole at the frequency f_{p}:

$$\boxed{f_{\mathrm{p}} = \frac{1}{4\pi R_{\mathrm{S}} C_{\mathrm{T}}} \approx 1\,\mathrm{MHz}}$$

(b) In this case the circuit is depicted in Figure 1.3. The circuit has one pole at DC and another pole at f_{p}:

$$\boxed{f_{\mathrm{p}} = \frac{1}{2\pi R_{\mathrm{ON}} C_{\mathrm{T}}} \approx 265\,\mathrm{MHz}}$$

Exercise 3.8

Figure 1.4: OFF-OFF

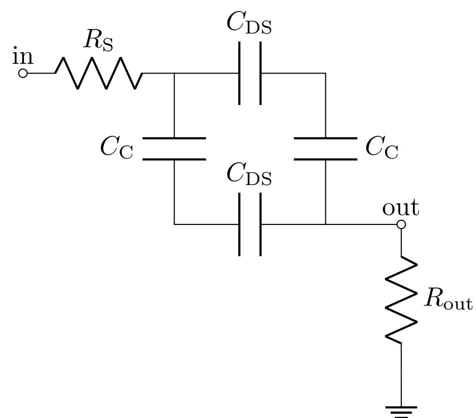


Figure 1.5: OFF-ON

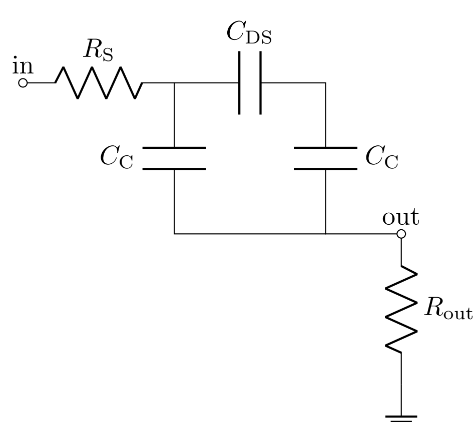


Figure 1.6: ON-OFF

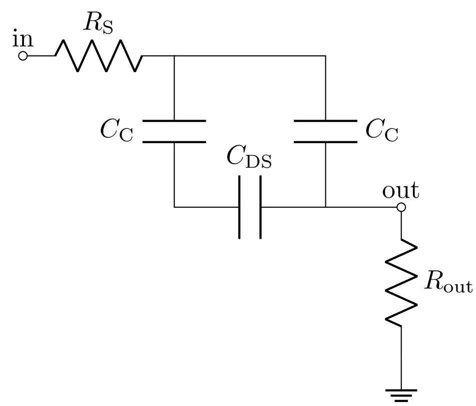
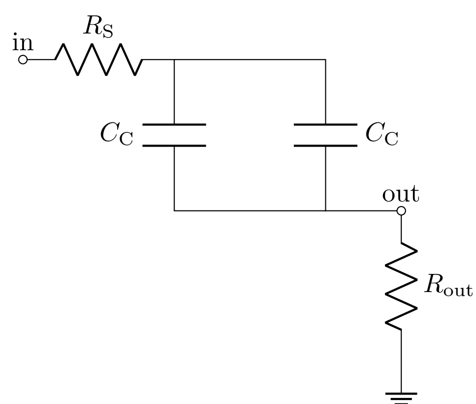


Figure 1.7: ON-ON



(a) In this case the reference circuit is depicted in Figure 1.4. The cross-coupling is given by:

$$\boxed{20\log_{10}\frac{R_{\text{out}}}{R_{\text{out}}+R_{\text{S}}+0.5(X_{\text{C}}+X_{\text{DS}})}=-10.75\,\text{dB}}$$

being $X_{\text{C}}=\frac{1}{2\pi f\,C_{\text{C}}}=320\,\text{k}\Omega$ and $X_{\text{DS}}=\frac{1}{2\pi f\,C_{\text{DS}}}=160\,\text{k}\Omega$

(b) In this case the reference circuit is depicted in Figure 1.5. The cross-coupling is given by:

$$\boxed{20\log_{10}\frac{R_{\text{out}}}{R_{\text{out}}+R_{\text{S}}+\frac{X_{\text{C}}(X_{\text{C}}+X_{\text{DS}})}{2X_{\text{C}}+X_{\text{DS}}}}=-9.6\,\text{dB}}$$

(c) In this case the reference circuit is depicted in Figure 1.6. The cross-coupling is the same as before

(d) In this case the reference circuit is depicted in Figure 1.7. The cross-coupling is given by:

$$\boxed{20\log_{10}\frac{R_{\text{out}}}{R_{\text{out}}+R_{\text{S}}+0.5X_{\text{C}}}=-8.6\,\text{dB}}$$

Exercise 3.9

(a) Considering the different combinations of resistors, the $-3\,\mathrm{dB}$ frequencies can be computed as:

$$\boxed{f_{\mathrm{3dB,n}} = \frac{n\,G_{\mathrm{10k}}}{2\pi C} \qquad n = 1\ldots15}$$

where $C = 0.01\,\mathrm{\mu F}$ and $G_{\mathrm{10k}} = 0.1\,\mathrm{mS}$

(b) The glitch amplitude voltage can be computed as:

$$\boxed{\Delta V = \frac{20\,\mathrm{pC}}{C} = 2\,\mathrm{mV}}$$

Exercise 3.10

The peak output current that the buffer has to provide can be given as the peak time derivative of the output voltage across the $10\,\mathrm{nF}$ capacitor multiplied by its value:

$$\boxed{I_{\mathrm{p}} = 10\,\mathrm{nF}\left.\frac{dV}{dt}\right|_{\mathrm{p}} = 10\,\mathrm{nF}\,2\pi 10\,\mathrm{kHz}\,1\,\mathrm{V} = 0.6\,\mathrm{mA}}$$

Exercise 3.11 TODO: write solution

Exercise 3.12 TODO: write solution

Exercise 3.13 TODO: write solution

Exercise 3.14 TODO: write solution

Exercise 3.15 TODO: write solution

Exercise 3.16 TODO: write solution

Exercise 3.17 TODO: write solution

Exercise 3.18 TODO: write solution