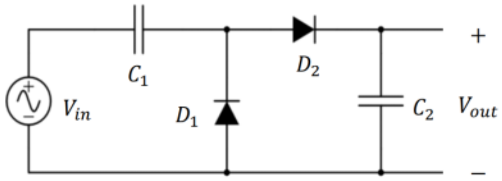
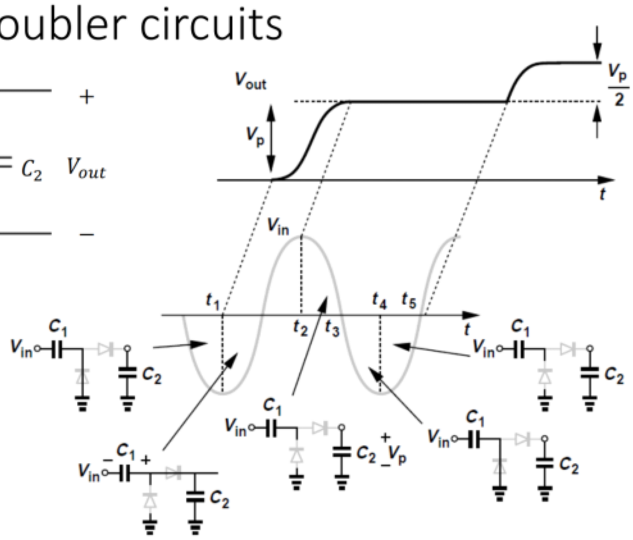
LEC-3SmallSigaAndMore

Thursday, 23 May 2024 10.28

Actual voltage doubler circuits



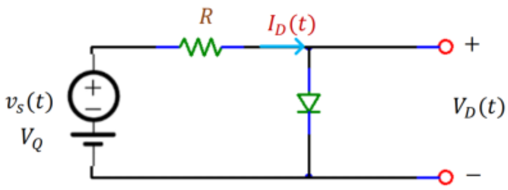


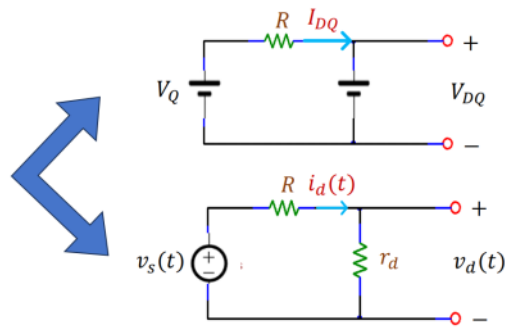
$V_{in}(t) = V_p \sin(2\pi f t)$

Assume ideal diode model

Procedure

- DC analysis to get I_{DQ}.
- Calculate the diode small-signal resistance $r_d = \frac{V_T}{I_{DQ}}|_{V_{DQ}}$.
- $v_d(t) = \frac{v_s(t) r_d}{r_d + R}$





Small-signal model approximation error

$$I_D(t) = I_s e^{[V_{DQ}+v_d(t)]/nV_T} = I_s e^{V_{DQ}/nV_T}\, e^{v_d(t)/nV_T} = I_{DQ}\, e^{v_d(t)/nV_T}$$

$$I_D(t) = \mathrm{I_{DQ}} + i_d(t)$$

$$\rightarrow i_d(t) = I_D(t) - \mathrm{I_{DQ}} = I_{DQ}(\, e^{v_d(t)/nV_T} - 1) \quad \text{actual } i_d(t)$$

Small-signal approximated $i_d(t)$: $\widehat{i_d}(t) = I_{DQ}\, v_d(t)/nV_T$

$$\rightarrow \frac{i_d(t)}{\widehat{i_d}(t)} = \frac{e^{v_d(t)/nV_T} - 1}{v_d(t)/nV_T}$$

$v_d(t)/nV_T$	0.1	0.2	0.3	0.4	0.5	0.6	0.7
$\frac{i_d(t)}{\widehat{i_d}(t)}$	1.05	1.11	1.17	1.23	1.30	1.37	1.45

Kursusløsning:

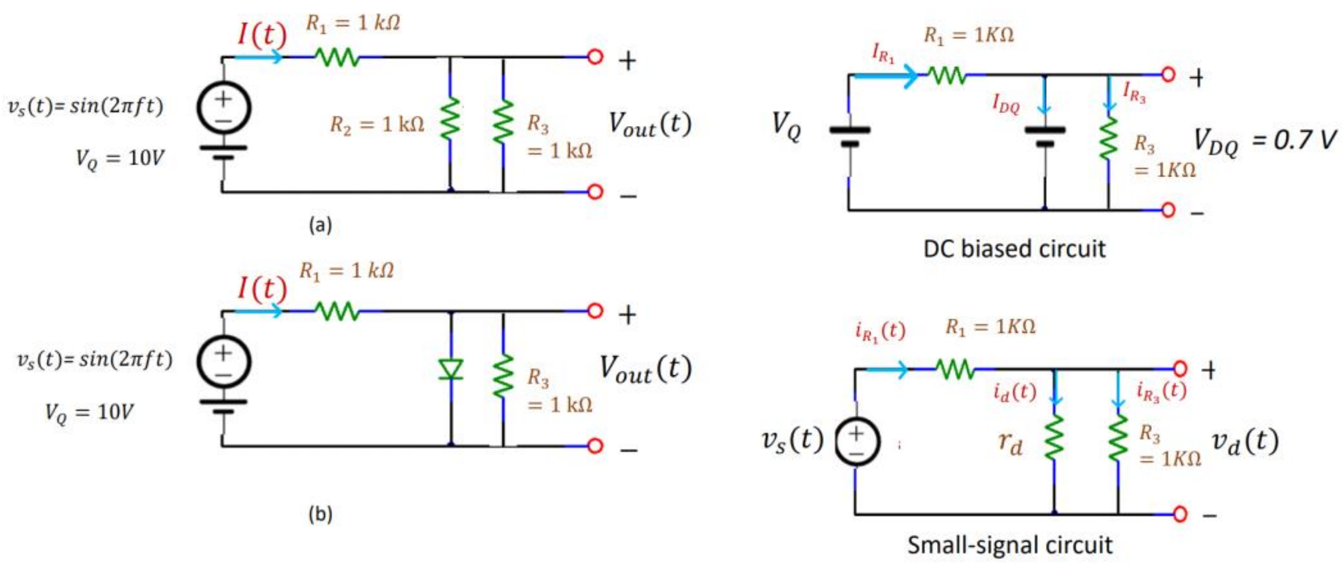
Assignments:

3.1:

Assume the diode has a voltage drop of 0.7 V when only DC voltage V_Q is applied. For the circuits in Fig. 1 (a) and (b),

- What is the expression of $V_{out}(t)$?
- The input voltage change is 1/10 = 10%, what is the output change?

Hint: For Fig. 1(b), use the small-signal model.



(c)

Fig. 1

Solution:

For Fig. 1 (a):

$R_{23} = R_2||R_3 = 0.5\ K\Omega$ ---R_2 *and* R_3 are in parallel

- $V_{out}(t) = \frac{R_{23}}{R_1+R_{23}} V(t) = \frac{1}{3}[10 + \sin(2\pi f t)]$
- When input changes 10%, i.e., $V(t)$ changes from $V(t_1)$=10 V to $V(t_2)$ =11 V,

  $\rightarrow$ $V_{out}(t)$ changes from $V_{out}(t_1) = \frac{10}{3}$ V to $V_{out}(t_2) = \frac{11}{3}$ V

  $\rightarrow \frac{V_{out}(t_2) - V_{out}(t_1)}{V_{out}(t_1)} = 10\%$, i.e., the output also changes 10%.

For Fig. 1 (b):

Solution:

(c)

Fig. 1

For Fig. 1 (a):

$R_{23} = R_2||R_3 = 0.5\ K\Omega$ ---R_2 *and* R_3 are in parallel

- $V_{out}(t) = \frac{R_{23}}{R_1+R_{23}}V(t) = \frac{1}{3}[10 + \sin(2\pi f t)]$
- When input changes 10%, i.e., $V(t)$ changes from $V(t_1)$=10 V to $V(t_2)$ =11 V,

  ➔ $V_{out}(t)$ changes from $V_{out}(t_1) = \frac{10}{3}$ V to $V_{out}(t_2) = \frac{11}{3}$ V

  ➔$\frac{V_{out}(t_2)-V_{out}(t_1)}{V_{out}(t_1)} = 10\%$, i.e., the output also changes 10%.

For Fig. 1 (b):

Decompose the circuit into the DC biased circuit (top) and small-signal circuit(bottom) as in Fig.1 (c).

Do DC analysis to obtain I_{DQ} and r_d according to the DC biased circuit.

KVL: $V_Q = I_{R_1}R_1 + V_{DQ}$ ➔$I_{R_1} = \frac{V_Q-V_{DQ}}{R_1} = \frac{10-0.7}{1000} = 9.3$ mA

The voltage drop across R_3 is equal to $V_{DQ} = 0.7$ V ➔$I_{R_3} = \frac{V_{DQ}}{R_3} = \frac{0.7}{1000} = 0.7$ mA

KCL: $I_{R_1} = I_{DQ} + I_{R_3}$ ➔$I_{DQ} = I_{R_1} - I_{R_3} = 8.6$ mA

➔$r_d = \frac{V_T}{I_{DQ}} = \frac{26\ mV}{8.6\ mA} = \ 3.0\ \Omega$

According to the small-signal circuit:

as 3 Ω is so damn small

$R_{d,3} = r_d||R_3 \approx 3\ \Omega$ ---r_d *and* R_3 are in parallel

➔$v_d(t) = \frac{R_{d,3}}{R_{d,3}+R_1}v_s(t) = \frac{3}{1003}v_s(t)$

- $V_{out}(t) = V_{DQ} + v_d(t) = 0.7 + \frac{3}{1003}v_s(t)$
- When input changes 10%, i.e., $V(t)$ changes from $V(t_1)$=10 V to $V(t_2)$ =11 V ($v_d(t_2) = 1\ V$)

  ➔ $V_{out}(t)$ changes from $V_{out}(t_1)$ = 0.7 V to $V_{out}(t_2)$ =$(0.7 + \frac{3}{1003})$ V

  ➔$\frac{V_{out}(t_2)-V_{out}(t_1)}{V_{out}(t_1)} = 0.43\%$, i.e., the output also changes only 0.43%. The output voltage is insensitive to the input voltage changes.