① $f_0 = 200\ MHz$
$f_s = 48\ MHz$
$t_{ADRMS} = 0,1\ ps$
$SNR \geq 70\ dB$

t_{jRMS} → APSOLUTNO PODRHTAVANJE

$\frac{t_{jRMS}}{T}$ → RELATIVNO PODRHTAVANJE

$$SNR = 20 \log_{10} \frac{U_m/\sqrt{2}}{U_m 2\pi f t_{jRMS}} = 20 \log_{10}(2\sqrt{2}\pi f t_{jRMS})$$

$$10^{\frac{70}{20}} \frac{1}{2\sqrt{2}\pi f} = t_{jRMS}$$

$$t_{jRMS} \leq 1,78 \cdot 10^{-13}$$

$$t_{jRMS} = \sqrt{t_{ADRMS}^2 + t_{cRMS}^2} = 1,78 \cdot 10^{-13}$$

$$t_{cRMS} < 0,147183\ ps$$

$$\frac{t_{cRMS}}{T_s} = t_{cRMS} f_s < 7,06479\ \mu s$$

② $n = 12$
$U_6 = \pm 1,5\ V$
$f_s = 60\ MHz$
$f_{ul} = 500\ MHz$

$u^2 = 1,225 \cdot 10^{-7}\ V^2/Hz$

$$N_a = \frac{f_{ul}}{f_s/2} = 16,67 \Rightarrow \text{ne zaokružuje se}$$

$$P_{n1} = U_n^2 \frac{f_s}{2} = 3,675 \cdot 10^{-10}\ W$$

$$P_n = P_{n1} \cdot N_a = 6,13\ mW \Rightarrow \text{ekvivalentna snaga}$$

$$U_{nIN} = \sqrt{P_n} = 7,827 \cdot 10^{-5}\ V \Rightarrow \text{efektivni napon šuma}$$

$$U_{nINLSB} \frac{U_{nIN}}{U_{LSB}} = U_{nIN} \cdot \frac{2^{12}}{\$5} = 0,2\ LSB$$

③ $n = 12$

$f_{s\,max} = 50\,MHz$

$U_{m,LSB\,RMS} = 0{,}2\,LSB = U_{mIN,LSB}$

$\epsilon = 0{,}5\,LSB$ } AD

$t_{j\,RMS\,AD} = 1{,}2\,ps$

$t_{j\,RMS\,CLK} = 0{,}8\,ps$

$f_{ul} = 20\,MHz$

$$t_{j\,RMS} = \sqrt{t_{j\,RMS\,AD}^2 + t_{j\,RMS\,C}^2} = 1{,}44\,ps$$

$$SNR = -20 \log_{10} \sqrt{(2\sqrt{2} f\, t_{j\,RMS})^2 + \left(\frac{\sqrt{2}(1+\epsilon)}{2^N \sqrt{3}}\right)^2 + \left(\frac{\sqrt{2}\, U_{mIN,LSB}}{2^N}\right)^2}$$

$$= 68{,}67\,dB$$

$\epsilon \Rightarrow$ tipična vrijednost srednje DNL

$U_{mIN,LSB} \Rightarrow$ efektivna vrijednost izlaznog šuma

④ $n = 14$

$SNR_{AD} = 72\,dB$

$U_0 = \pm 1{,}5\,V$

$f_s = 100\,MHz$

$B = 3\,kHz$

a) $SNR = SNR_{AD} + PG$

$$PG = 10 \log_{10}\left(\frac{f_s}{2B}\right) = 42{,}21\,dB$$

$SNR = 114{,}21\,dB$

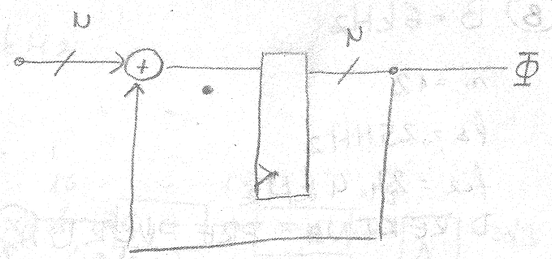
$$SN = 10 \log_{10}\left(\frac{U_m^2}{2U_n^2}\right) \Rightarrow U_n = 2{,}0637\,\mu V$$

$$SNR_{min} = -20 \log \frac{\sqrt{2}\, U_m}{U_m} =$$

$$U_m = 6{,}526\sqrt{2}\,\mu V$$

⑥ $N = 28$

$f_s = 50\,MHz$



$$f_{max} = \frac{f_s}{2} = 25\,MHz$$

$$f_{min} = \frac{f_s}{N} = 0{,}1826\,Hz$$

$\omega_0 = 9{,}7^2\,MHz \Rightarrow$ frek na izlazu

razlučivost $\Rightarrow \Delta = \left\lfloor \frac{f_0}{f_s} 2^N + 0{,}5 \right\rfloor = \left\lfloor \frac{\omega_0}{\omega_s} 2^N + 0{,}5 \right\rfloor$

$$\Phi(n) = \frac{\Phi(n)}{\frac{2\pi}{2^N}} = \Phi(n)\frac{2^N}{2\pi}$$

$$\Delta = \Omega_0 \frac{2^N}{2\pi} \Rightarrow \boxed{\Omega_0 = 2\pi \frac{\omega_0}{\omega_s}}$$

$$\boxed{\Delta = 2^N \cdot \frac{\omega_0}{\omega_s}} = 5207678 = x"31A9FBE"$$

⑤ $x"5F2" = 0101\,1111\,0010$

$x"AOE" = 1010\,0000\,1110$

$0101\,1111\,0000$

$0101\,1111\,0000$

$1011\,1001\,1100$

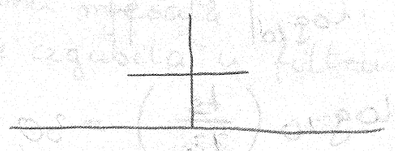
1522

-1520

⑦ $f_{s1} = 24\,kHz$

$f_{s2} = 14{,}4\,kHz$

$$R = \frac{3}{5} \quad \nearrow R \quad \searrow R$$



$$\omega_g = \min\left(\frac{\pi}{3}, \frac{\pi}{5}\right) = \frac{\pi}{5}$$

1) interpolacija s L

$$\omega_{g1} = \frac{\omega_c}{2} = \frac{0{,}3\pi}{2} = 0{,}1\pi$$

2) decimacija s R

$$\omega_g = \omega_{g1} \cdot R = 0{,}5\pi$$

(8) $B = 6\,kHz$

$m = 12$

$f_s = 25\,MHz$

$f_{iz} = 24.4\,kHz$

DIREKTNA PRETVORBA FREKVENCIJE, KOMPLEKSNA OBRADA

a) $|H(\omega)|_{CIC} \leq -100dB$

$$H(\omega) = \left(\frac{1}{R}\,\frac{1-z^{-R}}{1-z^{-1}}\right)^N \qquad R = \frac{25M}{24,4k} \approx 1024$$

$$|H_{cic}(e^{j\omega})| = \left|\frac{1}{R}\,\frac{\sin\left(\frac{\omega_a R}{2}\right)}{\sin\left(\frac{\omega_a}{2}\right)}\right|^N$$

$$\omega_c = 2\pi\,\frac{B}{2f_s} = 7,5398\cdot 10^{-4}$$

$$\omega_a = \frac{2\pi}{R} - \omega_c = 5,3819\cdot 10^{-3}$$

$$20\log_{10}\left|\frac{1}{R}\,\frac{\sin\left(\frac{\omega_a R}{2}\right)}{\sin\left(\frac{\omega_a}{2}\right)}\right|^N \leq 100dB$$

$$N\log_{10}\left|\quad\right| = 5$$

$$N = \frac{5}{\log_{10}\left|\frac{N}{\quad}\right|} = 5,79 \Rightarrow \boxed{N=6}$$

b) $PG = 10\log_{10}\left(\frac{f_s}{f_{iz}}\right) = 30,1dB$ ⇒ CIC decimator

c) $\omega_c = 2\pi\,\frac{B}{2f_{iz}} = 0,246\pi\ rad$

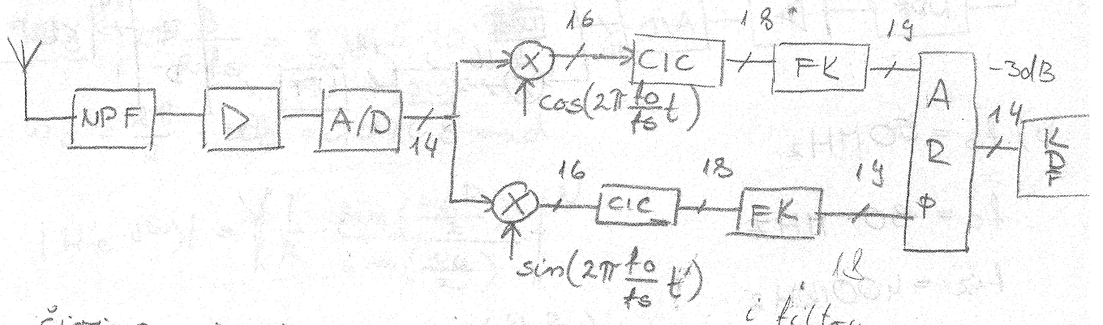
d) $PG = 10\log\left(\frac{24,4}{6}\right) = 6,09\,dB$

(9) $\Delta f = 100\,kHz$ $\quad f_{iz} = 200\,kHz$

$n = 14$

$f_s = 51,2\,MHz$

a)



b) širina signala se u CIC decimatoru smanjuje zbog PG

$$PG_{CIC} = 10\log_{10} R = 10\log_{10}\left(\frac{f_s}{f_{iz}}\right) = 24,08dB$$

$$N_{bit,CIC} = B_{in} + \frac{PG}{6dB} = 4$$

$N_{CIC} = 18$ bita

$$PG_{FK} = 10\log_{10}\left(\frac{f_s}{\Delta f}\right) = 27,09dB$$

$N_{FK} = 19$ bita

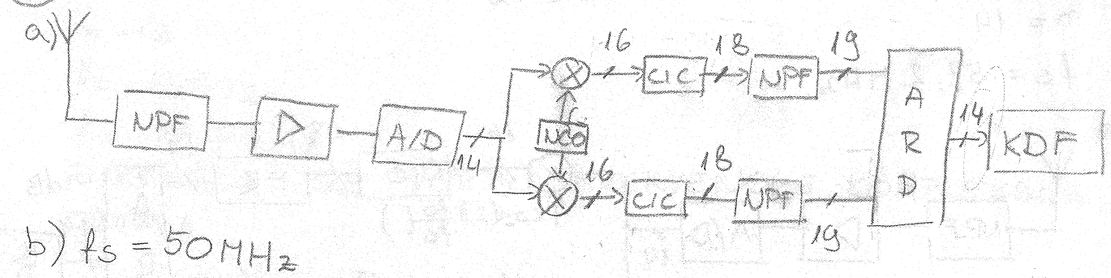
c) $SNR_{AD} = 6,02\,N + 1,76\,dB = 86,04dB$

$SNR = SNR_{AD} - 3dB + PG_{CIC} + PG_{FK} = 110,12\,dB$

d) 3dB SNR izgubljeno na miješalu
dodatna 3dB bi se izgubila u filtru kanala } -6dB

10

a)



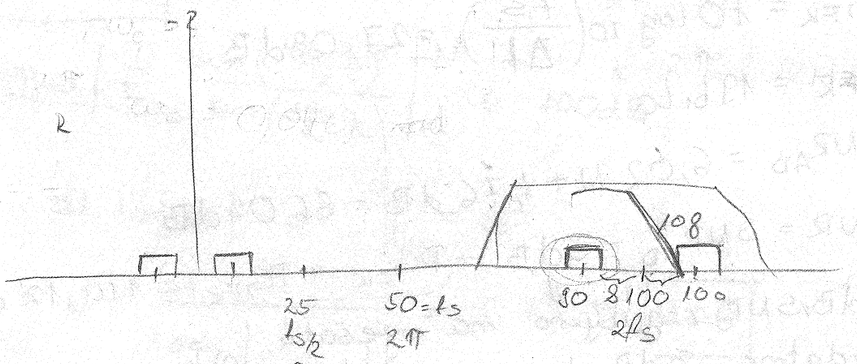
b) $f_s = 50\,MHz$

$f_c = 80\ MHz$

$f_{iz} = 400\,kHz$

$f_{osc} = 100MHz - 89,8\,MHz = 10,2\ MHz$

c) $\omega_{NCO} = 2\pi \frac{f_{osc}}{f_s} = 0,408\pi$



$f_a = 108\,MHz$

$f_c = 80MHz$

$|H_{PD}(\omega)| = \frac{1}{\sqrt{1+\left(\frac{\omega_a^2-\omega_c^2}{2\pi B\omega_a}\right)^{2N}}} =$

$20 \log_{10} \frac{1}{\sqrt{1+\left(\frac{\omega_a^2-\omega_c^2}{2\pi B\omega_a}\right)^{2N}}} = -80dB$

$N \log_{10}\left(1+\left(\frac{\omega_a^2-\omega_c^2}{2\pi B\omega_a}\right)\right) = 4$

$N = \frac{4}{\log_{10}\left(1+\left(\frac{\omega_a^2-\omega_c^2}{2\pi B\omega_a}\right)\right)} \rightarrow N = 5$

d)

$R = 125$

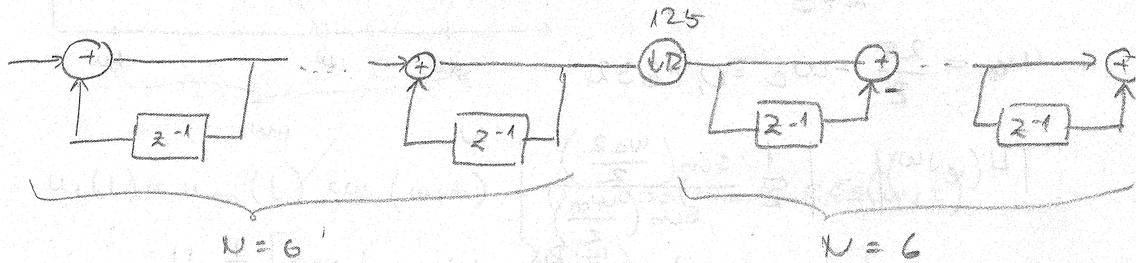
$\omega_c = 2\pi \frac{B}{2f_s} = 9,425 \cdot 10^{-3}$

$\omega_a = \frac{2\pi}{R} - \omega_c = 0,0408\ rad$

$|H(e^{j\omega})| = \left| \frac{1}{R} \frac{\sin\left(\frac{\omega_a R}{2}\right)}{\sin\left(\frac{\omega_a}{2}\right)} \right|^N$

$N \cdot 20 \log_{10} \left| \frac{1}{R} \frac{\sin\left(\frac{\omega_a R}{2}\right)}{\sin\left(\frac{\omega_a}{2}\right)} \right| = 80dB$

$N = \frac{4}{\log_{10}|\ |} = 6$



e) $PG_{CIC} = 10 \cdot \log_{10} R = 20,97dB$

$PG_{FK} = 10 \log_{10} \frac{f_s}{\Delta f} = 4,25\,dB$

$N_{bit\,CIC} \underset{\mu}{B_m} + \frac{20,97}{6dB} = 18\ bita$

$N_{bit\,FK} = 15\ bita$

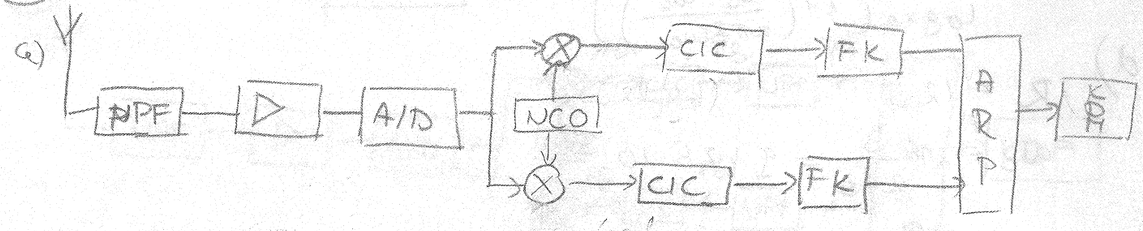
f) $SNR = SNR_{AD} - 3dB + PG_{FK} = 96,26dB$

18

PG_{CIC}

(11)

a)



b) $\omega_{NCO} = 2\pi \frac{f_{ocs}}{f_s}$

GPS

$$\frac{f_{ocs}}{NCO} = 6 f_s - \left(f_c \pm \frac{B}{2}\right)$$

$f_{NCO} = 100,8\ MHz$ $\quad \omega_{NCO} = 2\pi \frac{f_{NCO}}{f_s}$

$\Delta = 2^N \frac{f_{NCO}}{f_s} = 176\,160\,768\,0$

c)

$\omega_c = 2\pi \frac{B}{2 f_s} = 0,026$

$\omega_a = \frac{2\pi}{R} - \omega_c = 0,1832$

$$|H(e^{j\omega})| = \left| \frac{1}{R} \frac{\sin\left(\frac{\omega_a R}{2}\right)}{\sin\left(\frac{\omega_a}{2}\right)} \right|^N$$

$$N \log \left| \frac{1}{R} \frac{\sin\left(\frac{\omega_c R}{2}\right)}{\sin\left(\frac{\omega_a}{2}\right)} \right| = 13$$

$N = \frac{3}{2} \frac{1}{\log\left|\frac{1}{\quad}\right|} = 3, \quad \boxed{N = 4}$

d) prije kompenzacije

$$PROPAD = N\ 20 \log \left| \frac{1}{R} \frac{\sin\left(\frac{\omega_c R}{2}\right)}{\sin\left(\frac{\omega_c}{2}\right)} \right|$$

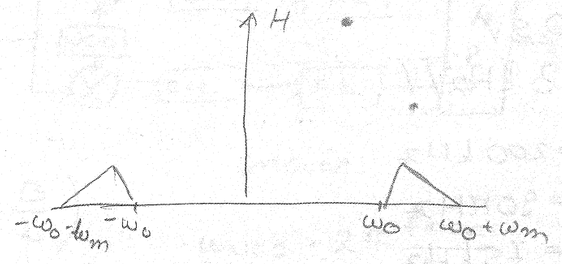
7

(1) USB - AM

$f_0 = 4kHz$

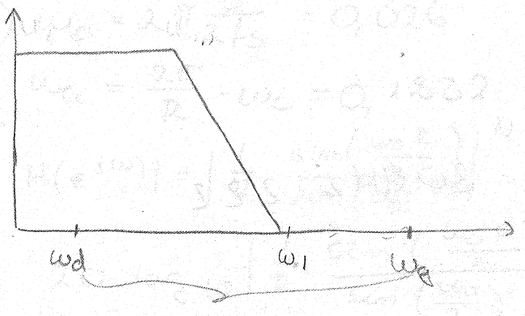
$M = \frac{SNR_0}{SNR_c}$

$SNR_0 =$



JIR 12/13

(1)



$u_1(t) = u_m(t) \cos(\omega_1 t) = U_m \cos(\omega_m t) \cos(\omega_1 t)$

$= U_m \frac{1}{2} \left[\cos(\omega_1 - \omega_m)t + \cos(\omega_1 + \omega_m)t\right]$

$u_2(t) = \frac{U_m}{2} \cos\left[(\omega_1 - \omega_m)t\right]$

$u_3(t) = \frac{U_m}{2} \cos\left[(\omega_1 - \omega_m)t\right] \cos(\omega_0 t)$

$= \frac{U_m}{4} \left[\cos\left[(\omega_1 - \omega_m - \omega_0)t\right] + \cos\left[(\omega_1 - \omega_m + \omega_0)t\right]\right]$

$u_4(t) = U_m \cos(\omega_m t) \sin(\omega_1 t) =$

$= \frac{U_m}{2} \left[\sin\left[(\omega_1 - \omega_m)t\right] + \sin\left[(\omega_1 + \omega_m)t\right]\right]$

$u_5(t) = \frac{U_m}{2} \sin\left[(\omega_1 - \omega_m)t\right]$

$u_6(t) = \frac{U_m}{2} \sin\left[(\omega_1 - \omega_m)t\right] \sin(\omega_0 t)$

$= \frac{U_m}{4} \left\{\cos\left[(\omega_1 - \omega_m - \omega_0)\right] + \cos\left[(\omega_1 - \omega_m + \omega_0)t\right]\right\}$

$u_7(t) = \frac{U_m}{2} \cos\left[(\omega_1 - \omega_m - \omega_0)t\right]$ SSB modulator

② $f_g = 15\,kHz$

$V = 0{,}5\,V$

$K_f = 3\,kHz/V$

$f_m = 200\,kHz$

$f_0 = 90\,MHz$

$\Delta f_{iz} = 75\,kHz$

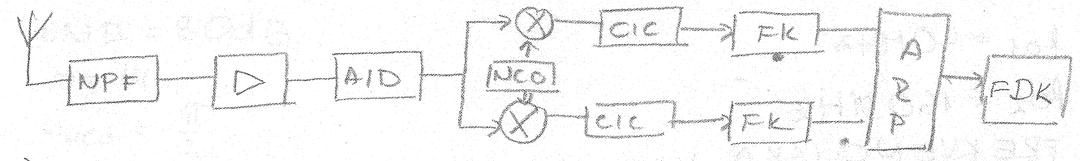
$\Delta f_{wl} = 1{,}5\,kHz$

$$N = \frac{\Delta f_{iz}}{\Delta f_{wl}} = 50$$

$f_0' = N \cdot f_m = 10\,MHz$

$f_{osc} = 90\,MHz - 10\,MHz = 80\,MHz$ ¿¿¿

③ a)



b) GPS

$f_{NCO} = 6 f_s - \left(f_c \pm \frac{B}{2}\right)$

$\omega_{NCO} = 2\pi \frac{f_{NCO}}{f_s}$

incide

$\omega_{NCO} = 2\pi \frac{f_{osc}}{f_s}$

$f_{NCO} = 100{,}86\,MHz \quad \omega_{NCO} = 0{,}8208\pi$.

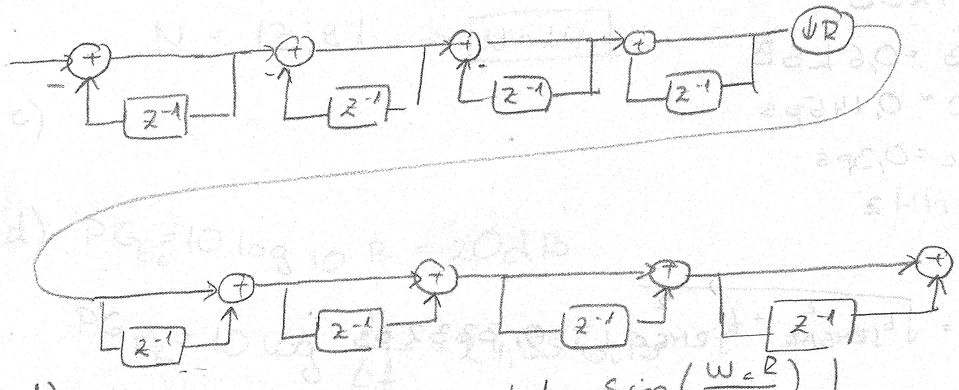
c) $\omega_c = 2\pi \frac{B}{2f_s} = 0{,}026$

$\omega_a = \frac{2\pi}{R} - \omega_c = 0{,}1832$

$$|H(e^{j\omega})| = \left| \frac{1}{R} \frac{\sin\left(\frac{\omega_a R}{2}\right)}{\sin\left(\frac{\omega_a}{2}\right)} \right|^N$$

$$20 \log_{10} \left| \frac{1}{R} \frac{\sin\left(\frac{\omega_a R}{2}\right)}{\sin\left(\frac{\omega_a}{2}\right)} \right|^N = 60\,dB$$

$$N = \frac{3}{\log_{10} \left| \frac{1}{\quad} \right|} = 3{,}51 \qquad \boxed{N = 4}$$



d) $PROPAD = N\,20 \log \left| \frac{1}{R} \frac{\sin\left(\frac{\omega_c R}{2}\right)}{\sin\left(\frac{\omega_c}{2}\right)} \right|$

e) $PG_{CIC} = 10 \log R = 14{,}77\,dB$

PG

21 15 16

① $f_{o1} = 40\,MHz$

$f_{o2} = 160\,MHz$

FREKVENCIJSKA MODULACIJA

$M = M_{AWGN}\,\frac{N_H}{N_T}$

$N_H = S_N\left(\frac{f_m}{2}\right) \quad N_T = S_N\left(\frac{f_o}{2}\right)$

$M_1 = M_2$

$M_{AWGN1}\,\frac{N_H}{N_{T1}} = M_{AWGN2}\,\frac{N_H}{N_{T2}}$

$\frac{3}{2}(m_{FM1})^2\,\frac{1}{N_{T1}} = \frac{3}{2}(m_{FM2})\,\frac{1}{N_{T2}}$

$\frac{m_{FM2}}{m_{FM1}} = \sqrt{\frac{N_{T2}}{N_{T1}}} = \sqrt{\frac{S_N\left(\frac{f_{o2}}{2}\right)}{S_N\left(\frac{f_{o1}}{1}\right)}} = 2$

② $\varepsilon = 1,4\,LSB$

$U_{min\,LSB} = 0,6\,LSB$

$t_{jRMSAD} = 0,145\,ps$

$t_{jRMS\,C} = 0,3\,ps$

$f = 50\,MHz$

$N = 14$

$t_{jRMS} = \sqrt{t_{jRMSAD}^2 + t_{jRMSC}^2} = 0,3332\,ps$

$SNR_{sin} = -20\log_{10}\sqrt{\quad}$

$= 77,1652\,dB$

③ $f_{max} = 25\,MHz \qquad t_{osc} = 10,7\,s$

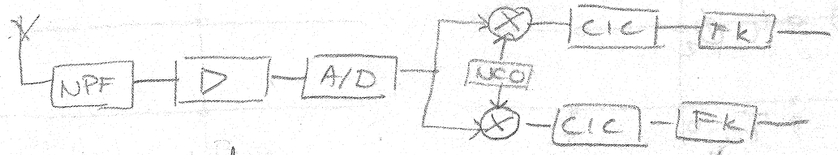
$SNR = 80\,dB$

$n = 14$

$\omega_{NCO} = \frac{\pi}{2}$

$f_{PPF} = 10,7\,MHz$

a)



b) $\omega_{NCO} = 2\pi\,\frac{f_{osc}}{f_s} \Rightarrow f_s = 2\pi\,\frac{f_{osc}}{\frac{\pi}{2}} = 4\,f_{osc}$

$f_s = 42,8\,MHz$

$R = 100$

$\omega_c = 2\pi\,\frac{B}{2f_s} = 0,022$

$\omega_a = 0,0408$

$N \cdot 20\log_{10}\left|\frac{1}{R}\,\frac{\sin\left(\frac{\omega_a R}{2}\right)}{\sin\left(\frac{\omega_a}{2}\right)}\right| = 100\,dB$

$N = 13,91 \Rightarrow \boxed{N = 14}$

c)

d) $PG_{CIC} = 10\log_{10} R = 20\,dB$

$PG_{FK} = 10\log\frac{f_s}{\Delta f} = 24,554\,dB$

$SNR = SNR_{AD} - 3dB + PG_{FK} = 101,55\,dB$

④ $\phi_1 = 1 \qquad 0 < t < T_b$

$$s_1(t) = \begin{cases} 3 & 0 < t < 1 \\ 0 & 1 < t < 2 \end{cases}$$

$s_2(t) = k\phi_1 + g$

$s_2(t) = -4\phi_1 + g$

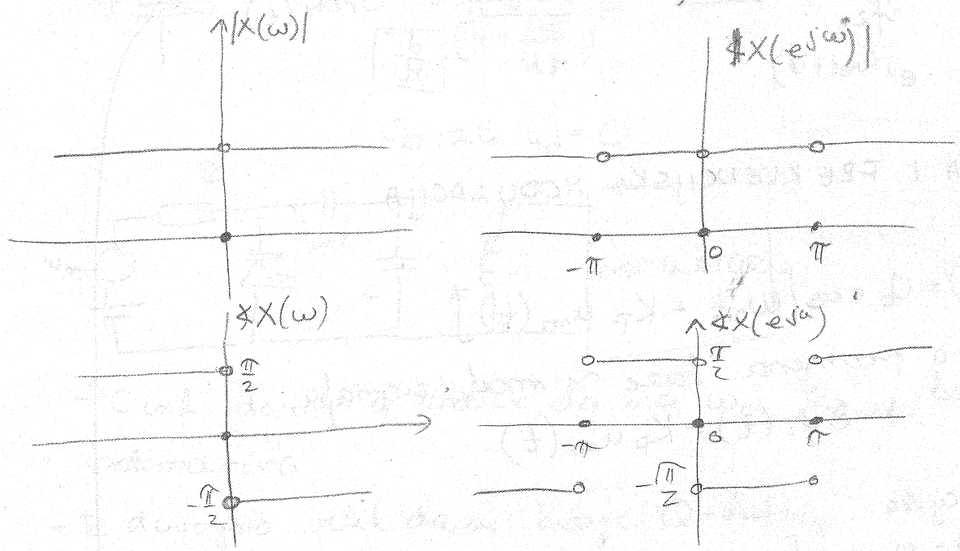
$g(t) = -4 \cdot \phi_2$

$\phi_2 = 1 \qquad T$

HI 15/16

① $x(n) = \delta(n) - 2\delta(n-1) + \delta(n+2)$

$X(\omega) \Longrightarrow X(e^{j\omega})$



$$h_{HT}(n) = \frac{1}{2\pi} \int_{-\pi}^{\pi} (-j\,\mathrm{sgn}(\omega))\, e^{j\omega n}\, d\omega$$

$$= -\frac{j}{2\pi} \int_{-\pi}^{\pi} \left(\mathrm{sgn}(\omega)\cos(\omega n) + j\,\mathrm{sgn}(\omega)\sin(\omega n) \right)$$

$$= \frac{1}{2\pi} 2 \int_{0} \sin(\omega n)\, d\omega = -\frac{1}{\pi n}\left[\cos(\pi n) - 1\right]$$

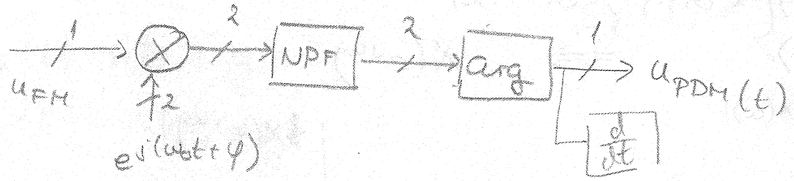
$$= \frac{1}{n\pi} 2 \sin^2\left(\frac{\pi n}{2}\right)$$

② $\Delta = \frac{f_s}{N} \qquad N = \frac{f_s}{\Delta}$

$f_{\tau_E} = 2{,}35 \frac{f_s}{N} = 2{,}35 \cdot 0{,}2\,MHz = 0{,}47\,MHz$

$f_{\tau,n} = \frac{2\pi}{N} = 0{,}0125\,rad$

BLOK SHEMA KUTNOG DEMODULATORA.



(40) FAZNA I FREKVENCIJSKA MODULACIJA

FAZNA

$$u_{PM}(t) = U_0 \cos[\omega_0 t + K_p u_m(t)]$$

- trenutna promjena faze ~ mod. signala

$$\delta\varphi_i(t) = K_p u_m(t)$$

Frekvencijska

$$u_{FM}(t) = U_0 \cos\left[\omega_0 t + K_\omega \int_0^t u_m(t)dt\right]$$

$$\delta\omega_i(t) = K_\omega u_m(t)$$

$$u_{PM}(t) = U_0 \cos[\omega_0 t + K_p U_m \cos(\omega_m t)]$$

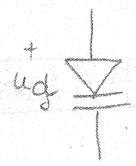
$$K_p U_m = m$$

$$u_{FM}(t) = U_0 \cos\left[\omega_0 t + K_\omega \frac{U_m}{\omega_m} \sin(\omega_m t)\right]$$

$$K_\omega \frac{U_m}{\omega_m} = m$$

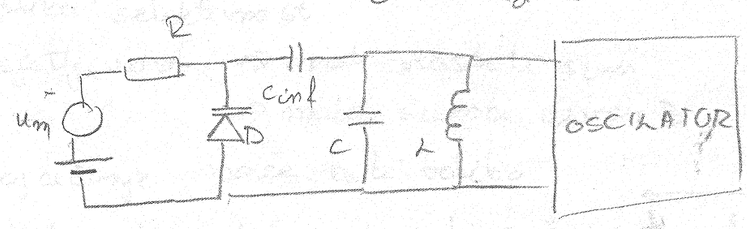
(43)

FM modulator s CAP diodom



$$C_j = \frac{C_0}{\left(1+\frac{u_d}{u_f}\right)^M}$$

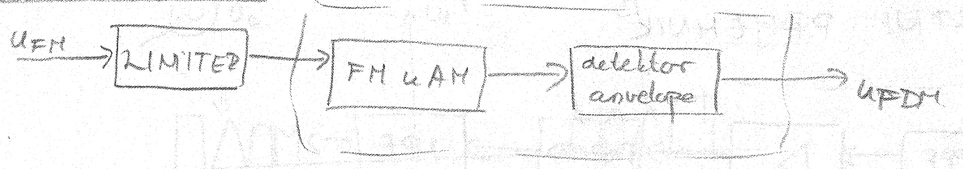
C_0 za $u_d = 0$



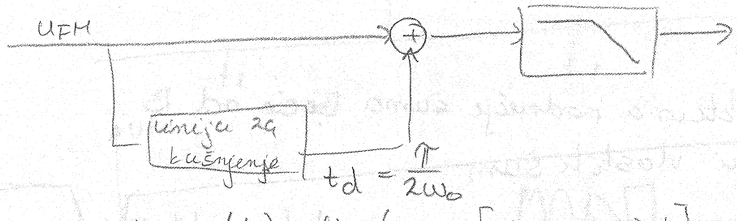
- C_{int} dovoljno velik da na ω_0 $2C_{int}$ bude zanemariva
- R dovoljno velik da ne kvari Q-faktor

$$U_B + u_m(t) > 0$$

Diskriminator



Kvadraturni detektor



$$u_{FM}(t) = U_0 \left(\cos\left[(\omega_0+\delta\omega)t\right] = U_0 \cos(\omega_1 t)\right.$$

$$u_{FM}(t) = U_0 \cos\left[\omega_0 t + K_\omega \int_0^t u_m(t)dt\right)$$

$$u_L(t) = e^{j(\omega_0 t+\varphi)}$$

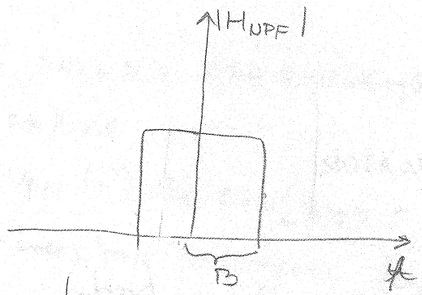
$$u(t) = u_{FM}(t) \cdot u_L(t)$$

- fitriranje $2\omega_0$

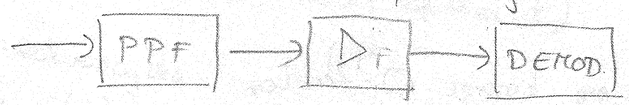
arg pa $\frac{d}{dt}$

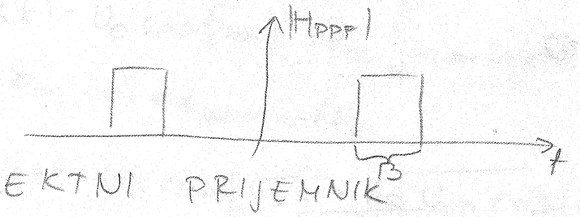
IDEALNI PRIJEMNIK

- u osnovnom području

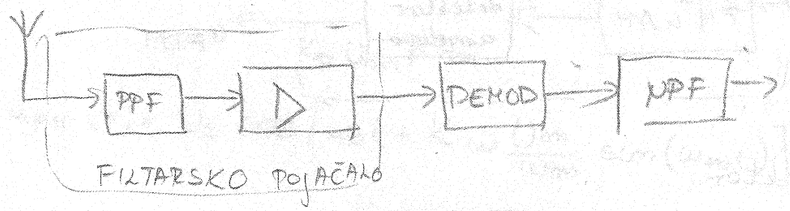


- u transponiranom području



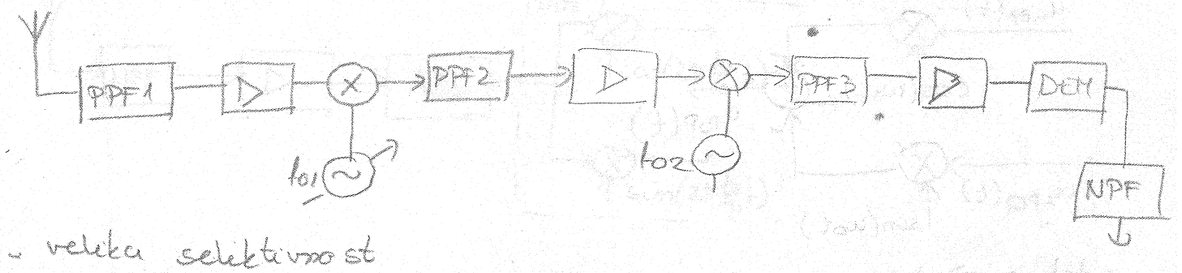


DIREKTNI PRIJEMNIK



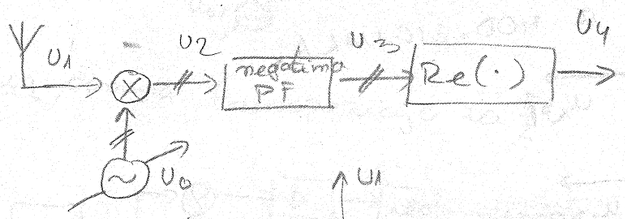
- mala selektivnost
- osjetljivost ⇒ efektivno područje šuma šire od B
  ⇒ veliki vlastiti šum
- pojačanje filtarskog pojačala ne može biti velika
  ⇒ moguće osciliranje
- odabir kanala samo ako PPF ima promjenjivu ω_C
- primjena ⇒ jednostavni žični kom. sustavi

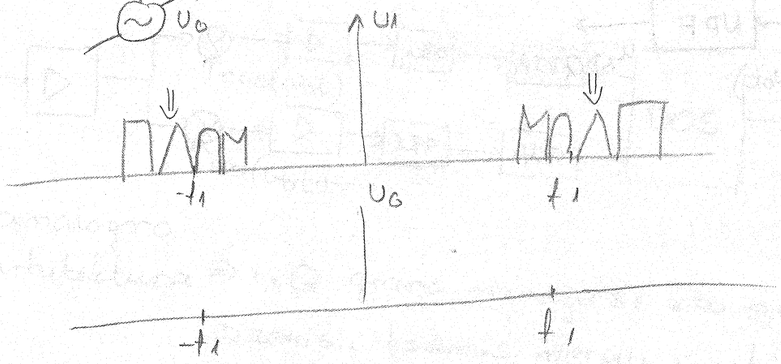
PRIJAMNIK S DVOSTRUKOM TRANSPOZICIJOM

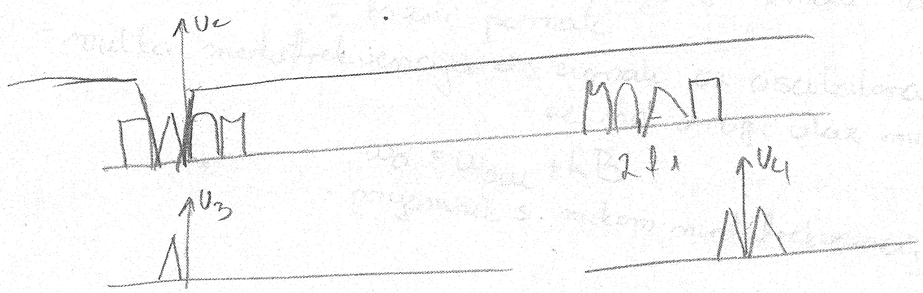


- velika selektivnost
- osjetljivost ⇒ mali vlastiti šum
  ⇒ malo šuma izvan B
- pojačanje može biti velika
- odabir kanala se izvodi promjenom frekvencije f_{o1}
- primjena ⇒ analogni kom. prijemnici

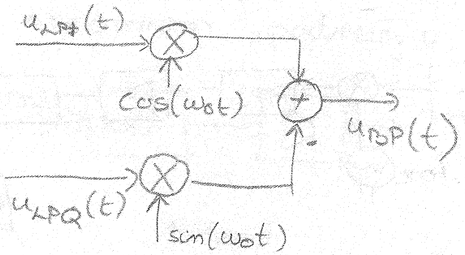
PRIJEMNIK S KOMPLEKSNIM MIJEŠANJEM





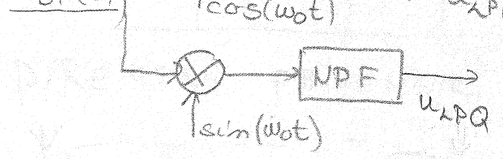


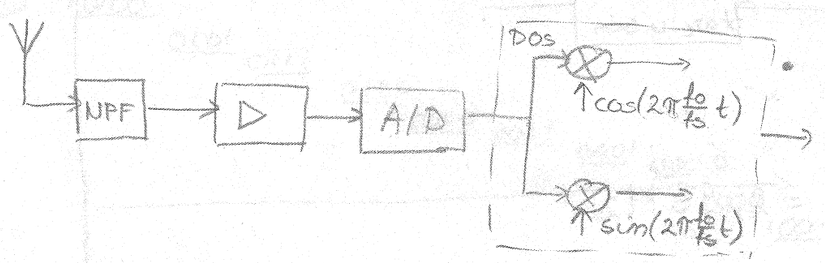
MODULIRANI SIGNAL IZ KOMPLEKSNE OVOJNICE



- dobro ⇒ dobivanje kompleksne ovojnice može biti složeno ovisno o modulacijskom postupku
  ⇒ na frek. nosioca rade jedino miješala i generator kvadraturnih komponenata nosioca
- loše ⇒ množila u I i Q grani moraju se dobro podudarati

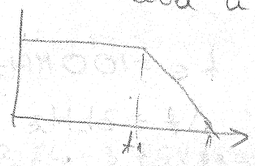
KOMPLEKSNA OVOJNICA IZ MOD. SIGNALA

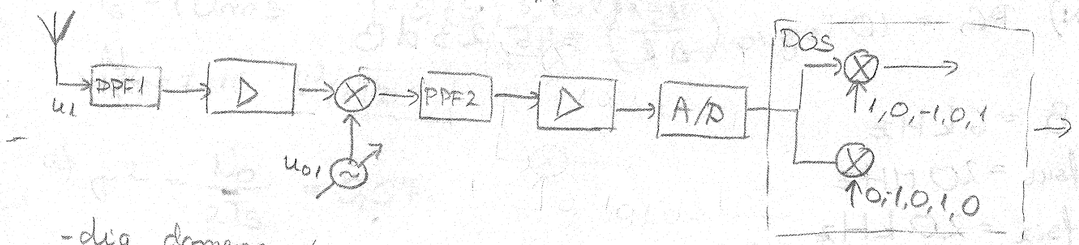




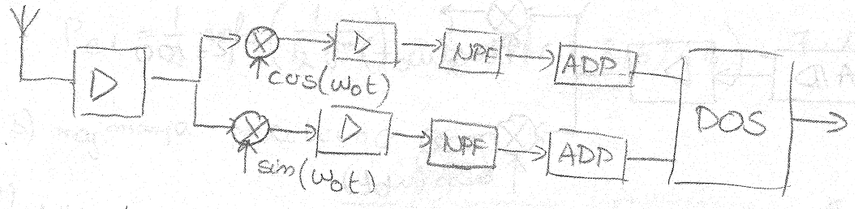
- kompleksna ovojnica se dobiva u dig. domeni

$f_s = f_1 + f_2$





- dig domena, transpozicija za $\frac{\pi}{2}$

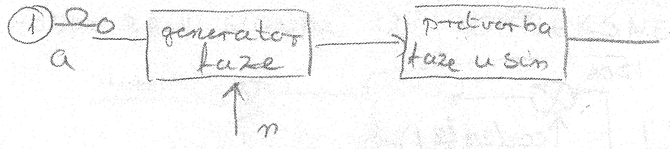


- analogna
- arhitektura ⇒ I,i Q grana moraju se što manje razlikovati
  ⇒ sinus i kosinus moraju imati točne amplitude i fazni pomak
- multa međufrekvencija ⇒ signali iz oscilatora preslušavaju se na drugi ulaz miješala

$\omega_0 = \omega_{out} + kB$

- prijemnik s niskom međufrekvencijom

NCO s DDS

① 

b) $f_{o_{min}} = \frac{f_s}{2^N} = 2,98\,Hz$

c) $\Delta = \frac{f_o}{f_s} 2^N = 335544$

② $SNR_{AD} = 72\,dB$ $\quad f_s = 100\,MHz$

$U_m = 1,5\,V$ $\quad \Delta f = 3\,kHz$

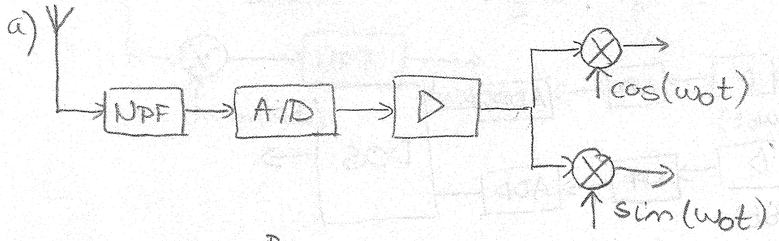
a) $PG = 10 \log_{10}\left(\frac{f_s}{\Delta f}\right) = 45,23\,dB$

③ $B = 6\,kHz$

$f_{sul} = 20\,MHz$

$f_{siz} = 20\,kHz$

a)



$R = 100$

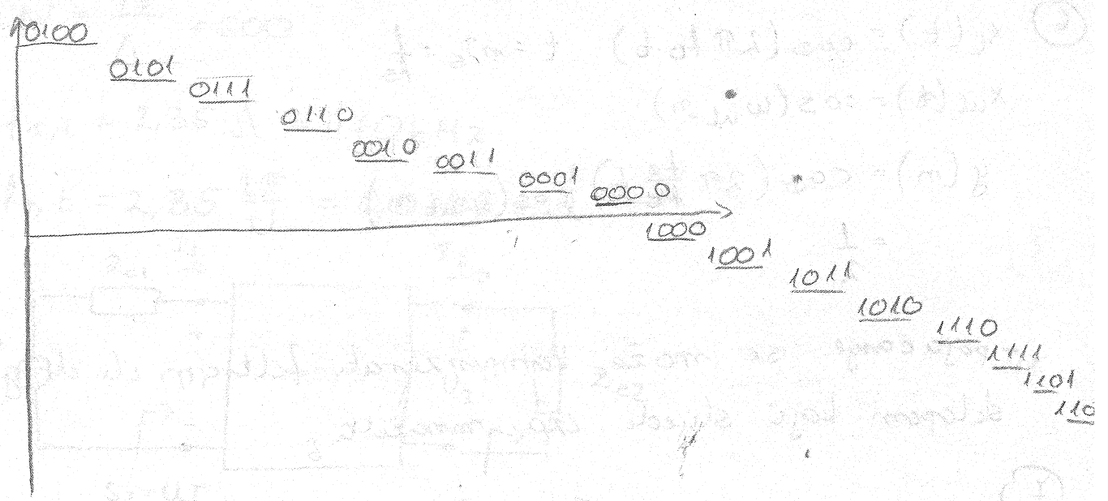
b) $\omega_c = 2\pi \frac{B}{2f} = 1,885 \cdot 10^{-3}$

$\omega_a = 0,0609$

$$N \cdot 20 \log \left| \frac{1}{R} \frac{\sin\left(\frac{\omega_a R}{2}\right)}{\sin\left(\frac{\omega_a}{2}\right)} \right| \leq -100$$

$N =$

④



$T_s = 10\,ms$ $\quad [-3,75; 3,75V]$ $n = 16$

$\frac{N_0}{2} = 7 \cdot 10^{-4}\,V^2/Hz$

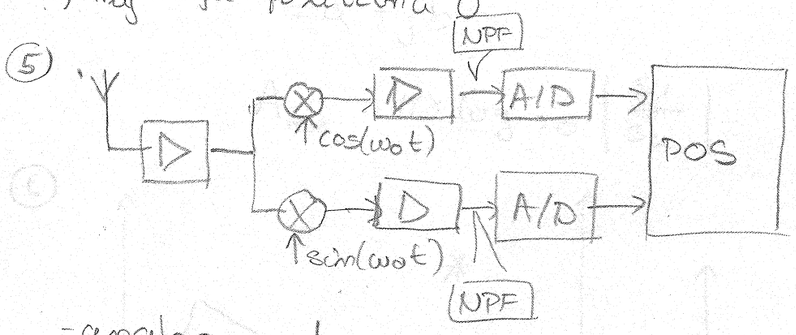
a) $\sigma^2 = \frac{N_0}{2T_s} = 0,07$

$\sigma = 0,2646$

$P_{e1} = \frac{1}{2} erfc\left(\frac{1}{\sqrt{2}\sigma}\right) = \frac{1}{2} erfc\left(2,6726\right) = 7 \cdot 10^{-3}$

b) najmanja pozitivna 0

⑤



- analogna domena
- posljedica arhitekture ⇒ I i Q grane moraju se što manje razlikovati
  ⇒ izvori sin i cos moraju imati točne amplitude i faze
- posljedica multe međufrekvencije ⇒ signali iz oscilatora preslušavaju se na drugi ulaz miješala

⑥ $x_L(t) = \cos(2\pi f_0 t) \quad t = nT_s = \frac{n}{f_s}$

$x_{uL}(n) = \cos(\omega_{uL} n)$

$y(n) = \cos\left(2\pi \frac{f_0}{f_s} t\right) \cos(\omega_{uL} n)$

$= \frac{1}{2}$

- pojačanje se može kompenzirati filtrom ili drugim sklopom koji slijedi iza množila

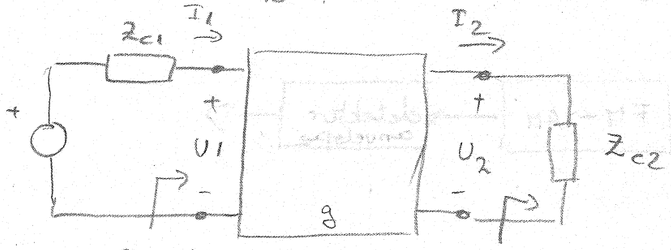
⑦

② $N = \frac{f_s}{\Delta} = 500$

$f_{r,t} = 2{,}35\,\Delta = 470\,kHz$

$f_{n,t} = 2{,}35 \frac{2\pi}{N} = 0{,}0295\ rad$

⑤



$S_1 = U_1 I_1$ $\qquad S_2 = U_2 I_2$

$\sqrt{\frac{z_{c1}}{z_{c2}}} e^{g} = \frac{U_1}{U_2}$ $\qquad \sqrt{\frac{z_{c2}}{z_{c1}}} e^{g} = \frac{I_1}{I_2}$

$\frac{U_1 I_1}{U_2 I_2} = e^{2g} \Rightarrow g = \frac{1}{2} \ln \frac{S_1}{S_2}$

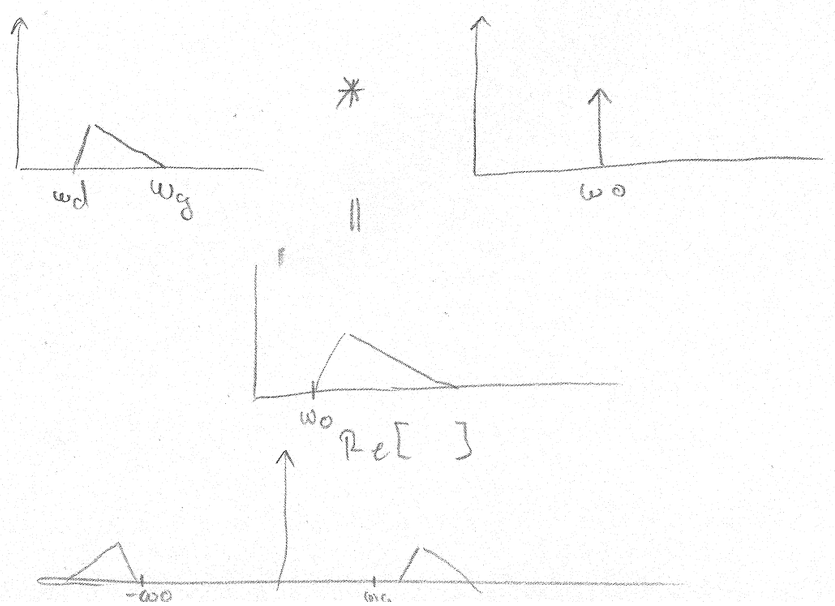
$\ln x = \ln|x| + j \arg x$

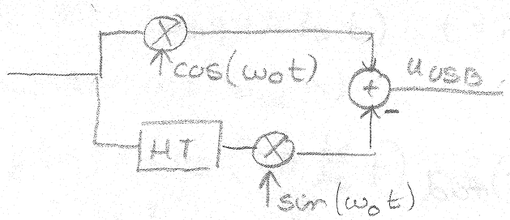
$g = \frac{1}{2} \ln\left|\frac{S_1}{S_2}\right| + j \arg(\varphi_1 - \varphi_2 + \phi_1 - \phi_2)$

$= a + jb$

$A_{real} = 10 \log_{10} \left|\frac{S_1}{S_2}\right|$

⑧





f)