UNO

Poiché l'opamp satura a 5V e l'ampiezza di Vin è 1V, occorre che il modulo del guadagno sia minore di 5.

Il guadagno è del tipo -Z2/Z1:

```
k = 1000; n = 10^-9;
```

$$Z1 = 10\,k;\quad Z2 = 10\,k + \frac{90\,k\;\frac{1}{i\,2\pi f\,1\,n}}{90\,k + \frac{1}{i\,2\pi f\,1\,n}};\quad Av = -\frac{Z2}{Z1};\quad \text{Print["Av = ", Together[Av], " = ", Apart[Av]]}$$

$$Av = \frac{500000\,i - 9\,f\,\pi}{-50000\,i + 9\,f\,\pi} = -1 + \frac{450000\,i}{-50000\,i + 9\,f\,\pi}$$

```
Simplify[Av * Conjugate[Av], f ∈ Reals];
Flatten[Solve[% == 25, f]];
Last /@ %;
ff = Select[%, Positive];
Print["fmin = ", EngineeringForm[ff[[1]] / 1000., 3], "kHz"]
```

$$fmin = 3.13kHz$$

DUE

```
dati = {IS → 10^-15, VT → 25 / 1000, R1 → 20 k, R2 → 18 k, Rc → 1.2 k, Vcc → 1.5};
```

$$Veb := \frac{Vcc - Vin}{R1 + R2}\,R2;\quad Vbe := \frac{Vin + Vcc}{R1 + R2}\,R2;\quad Vout = Rc\left(IS\,e^{\frac{Veb}{VT}} - IS\,e^{\frac{Vbe}{VT}}\right);$$

$$Vout = Rc\,IS\left(e^{\frac{R2\,(Vcc-Vin)}{(R1+R2)\,VT}} - e^{\frac{R2\,(Vcc+Vin)}{(R1+R2)\,VT}}\right);\quad Vout = Rc\,IS\,e^{\frac{R2}{(R1+R2)}\frac{Vcc}{VT}}\left(e^{\frac{-Vin}{VT}\frac{R2}{(R1+R2)}} - e^{\frac{Vin}{VT}\frac{R2}{(R1+R2)}}\right);$$

$$Vout = -2\,Rc\,IS\,e^{\frac{R2}{(R1+R2)}\frac{Vcc}{VT}}\,Sinh\left[\frac{R2}{(R1+R2)}\frac{Vin}{VT}\right];$$

```
Print["Vout = ", EngineeringForm[Vout /. dati, 3]]
```

$$Vout = -5.29\,Sinh\left[\frac{360\,Vin}{19}\right]$$

```
Normal[Series[Vout /. dati, {Vin, 0, 1}]];
Print["vout/vin = ", EngineeringForm[% / Vin, 3]]
```

$$\frac{vout}{vin} = -100.$$

```
.options tnom = 16.96
.temp = 16.96
.model modn npn IS = 1 fA BF = 1000000
.model modp pnp IS = 1 fA BF = 1000000
Vin 1 0 dc 0 ac 1
R1p 1 2 20 k
R2p 2 3 18 k
R1n 1 4 20 k
R2n 4 5 18 k
Vcc 3 0 1.5
Vee 5 0 – 1.5
Qp 6 2 3 modp
Qn 6 4 5 modn
RL 6 0 1.2 k
```