Operational Amplifier

Jiwook Kim

1 The input voltage to an op amp is a large voltage step. The output is an exponential waveform that changes 2.0 V in 0.4 μs. What is the slew rate of the op amp?

Δ V_{out} = 2V
Δ t = 0.4 μs

S_R = (Δ V_{out}) / (Δ t) = 5 V/μs

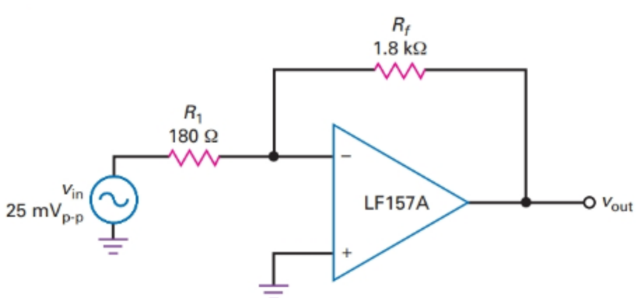
2 Use Eq. (16-2) to calculate the power bandwidth for each of the following:
a. S_R = 0.5 V/μs and V_p = 1 V

f_{max} = S_R/(2*π*V_p) = 0.5 V/μs/(2*π*1V) = 80khZ

b. S_R = 3 V/μs and V_p = 5 V
f_{max} = S_R/(2*π*V_p) = 3 V/μs/(2*π*5V) = 95.5khZ
c. S_R = 15 V/μs and V_p = 10V

f_{max} = S_R/(2*π*V_p) = 15 V/μs/(2*π*10V) = 238.7khZ

3 What are the closed-loop voltage gain and bandwidth in Fig. 16-30? What is the output voltage at 1 kHz? At 10 MHz? Draw the ideal Bode plot of closed-loop voltage gain.



Inverting Amplifier
A = -R_f /R_1 = -1.8kΩ/180Ω = - 10

Calculate the bandwidth
f_2 = unity gain frequency/(A_V) = 1Mhz/10 = 100Khz

$A_{vcl(db)} = 20 * log(A_{VCL})$ = 20 log 10 = 20db

at 1 Mhz A_V is = 0db

AT 1Khz

V_{out} = A_{VCL} * V_{in} = - 10 * 25mv = -250mV pp

Calculate the gain at 10MHZ

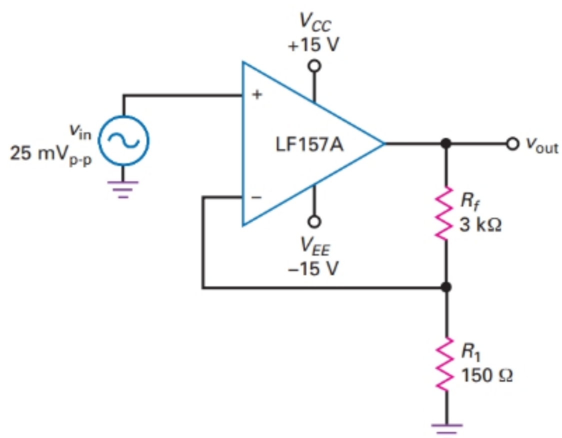
Slope is -20db/dec and $A_{VCL1mhz}$ is 0.

$A_{VCL10mhz(db)}$ = $A_{VCL1mhz}$ + -20* (log(10mhz/1mhz)
$A_{VCL10mhz(db)}$ = 0 - 20 * 1
$A_{VCL10mhz(db)}$ = - 20 db

$A_{VCL10mhz}$ = 10$^($A_{VCL10mhz(db)}$/20) = 0.1
voltage gain is 0.1

V_{out} = 0.1 (V_in) = 0.1 * 25mV = 2.5mV pp

4 In Fig. 16-32, what are the closed-loop voltage gain and bandwidth? The ac output volt-age at 100 kHz?



Non inverting amplifier. A = 1+R_f/R_1

A_{VCL} = 1 + 3kΩ/150Ω = 1 + 20 = 21

Unity gain frequency 1MHZ

f2 = unity gain frequency/(A_V) = 1Mhz/21 = 47Khz

$A_{VCLdb} = 20 log(A_{VCL})$ = 20 log 21 = 26.44dB

it is down 20db in 100khz, which means that it is 6.44db in 100khz

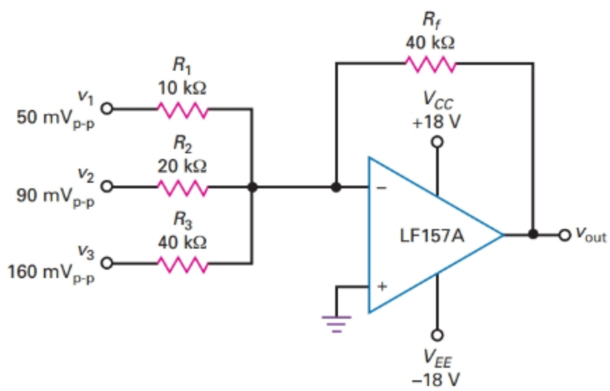
$A_{VCL100khz}$= 10$^($6.44/20) = 2.1

vout = 2.1 * vin

vout = 2.1 * 25mV pp = 52.5 mV pp

At 100 khZ vout is 52.5mV pp

5 In Fig. 16-33a, what is the ac output voltage? If a compensating resistor needs to be added to the non inverting input, what size should it be



(a)

inverting amplifier with summation

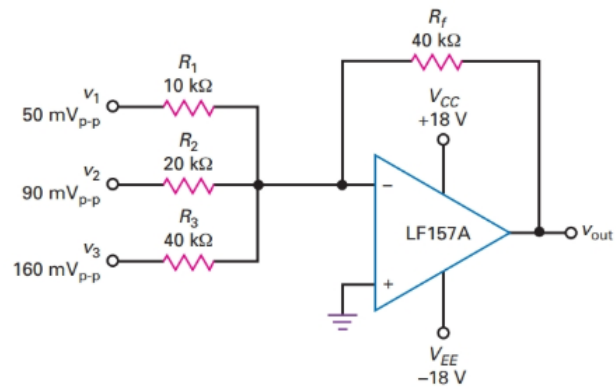
A1 = - rf/r1 = -40kΩ/R1 = -40kΩ/10Ω = -4
A2 = - rf/r1 = -40kΩ/R1 = -40kΩ/20kΩ = -2
A3 = - rf/r1 = -40kΩ/R1 = -40kΩ/40kΩ = -1

V_{out} = A1*50mV + A2*90mV + A3*160mV = -540mVPP

Compensating resistor

Rb2= 10kΩ$||20k\Omega||40k\Omega||40k\Omega$ = 5kΩ

6If the feedback resistor in Fig. 16-33a is changed to a 100kΩ variable resistor, what is the maximum output voltage? The minimum?



(a)

Mimimum resistance when Rf=0
the circuit act as voltage follower hence,

v_{out} = vin1 + vin2 + vin3 = 50mV + 90mV + 160mV = 300mV

When Rf=100kΩ

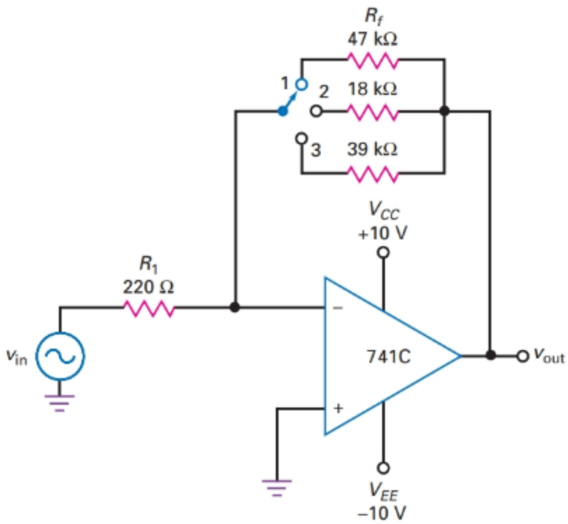
inverting amplifier with summation

A1 = - rf/r1 = -100kΩ/R1 = -100kΩ/10Ω = -10
A2 = - rf/r1 = -100kΩ/R1 = -100kΩ/20kΩ = -5
A3 = - rf/r1 = -100kΩ/R1 = -100kΩ/40kΩ = -2.5

V_{out} = A1*50mV + A2*90mV + A3*160mV = -1.35V pp

V_{outmax} = -1.35V pp
V_{outmin} = 300mV pp

7 In Fig. 16-36, what is the closed-loop voltage gain for each switch position?

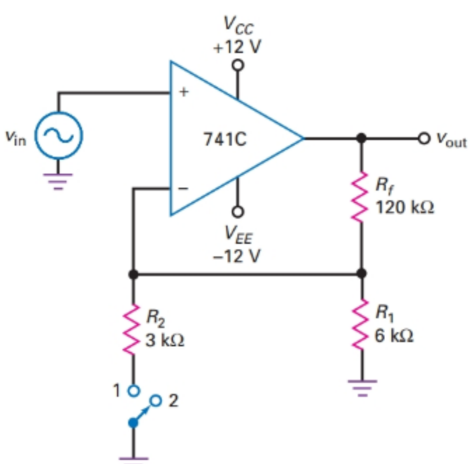


Inverting Amplifier

$A_{v(cl)}$ = -Rf/r1 = -Rf/220Ω

$A_{v(cl1)}$ = -47kΩ/220Ω = - 213.6
$A_{v(cl2)}$= -18kΩ/220Ω = -81.8
$A_{v(cl3)}$= -39kΩ/220Ω = -177.3

8 What is the closed-loop voltage gain for each switch position of Fig. 16-37? The bandwidth?



Closed loop voltage gain

$A_{v(cl)}$ = Rf/r1 + 1 = 120kΩ/6kΩ + 1 = 21

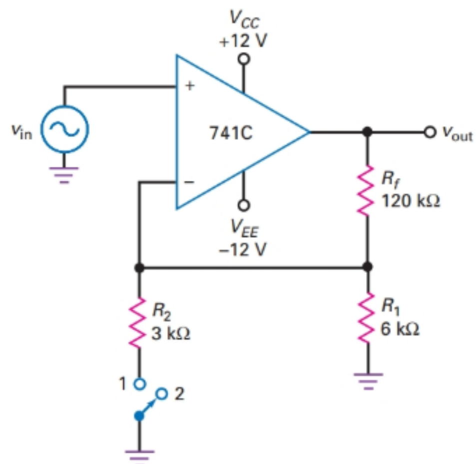
f_{unity} = 1Mhz
f_{2cl} = 1Mhz/$A_{v(cl)}$ = 47.6khz

When switch is on.
R1 = 3kΩ$||6k\Omega = 2k\Omega$

$A_{v(cl)}$ = Rf/r1 + 1 = 120kΩ/2kΩ + 1 = 61

f_{unity} = 1Mhz
f_{2cl} = 1Mhz/$A_{v(cl)}$ = 16.4khz

9 If the 120-kΩ resistor opens in Fig. 16-37, what is the output voltage most likely to do



This is non inverting amplifier

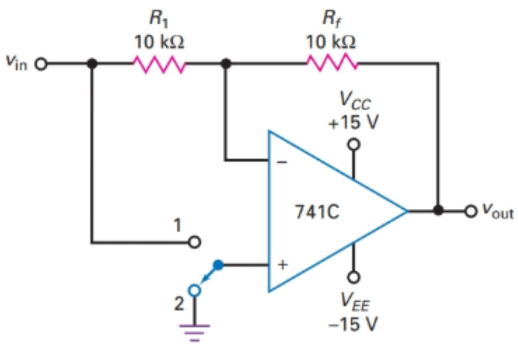
A_{Vcl} = Rf/r1 + 1

As Rf opens its infinity, thus, there is no feedback. So the output of the opamp keeps on increasing and goes to saturation with limit -12V to 12V

Thus the output voltage will go to positive or negative saturation.

10 What is the closed-loop voltage gain for each switch position of Fig. 16-38? The bandwidth?

Figure 16-38



if switch is connected to 1. vout = vin.
This is because current through R1 is zero. as node left and right voltage is equal to vin. This makes current through Rf is 0, thus, vout equals to vin
Thus, Av= 1

bandwidth is

f_{2cl} = f_{unity}/A_v = 1Mhz

If switch is connected to 0. This is inverting amplifier
A = -Rf/R1 = -1

f_{2cl} = $f_{unity}/(|A_v| + 1)$ = 1Mhz / (1+1) = 500Khz