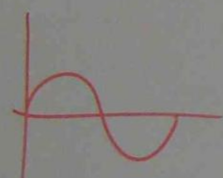
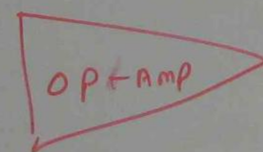
OPERATIONAL AMPLIFIER CHARACTERISTICS

FREQUENCY RESPONSE

FREQUENCY RESPONSE DESCRIBES HOW THE OUTPUT OF AN AMPLIFIER RESPONDS TO VARIOUS INPUT FREQUENCIES.



INPUT

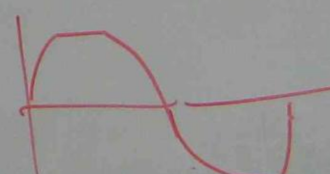


10KHZ → 100MHZ

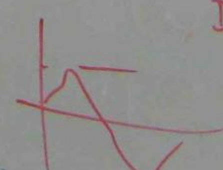
OPERATION FREQUENCY RANGE

OUTPUT

IF 200MHZ

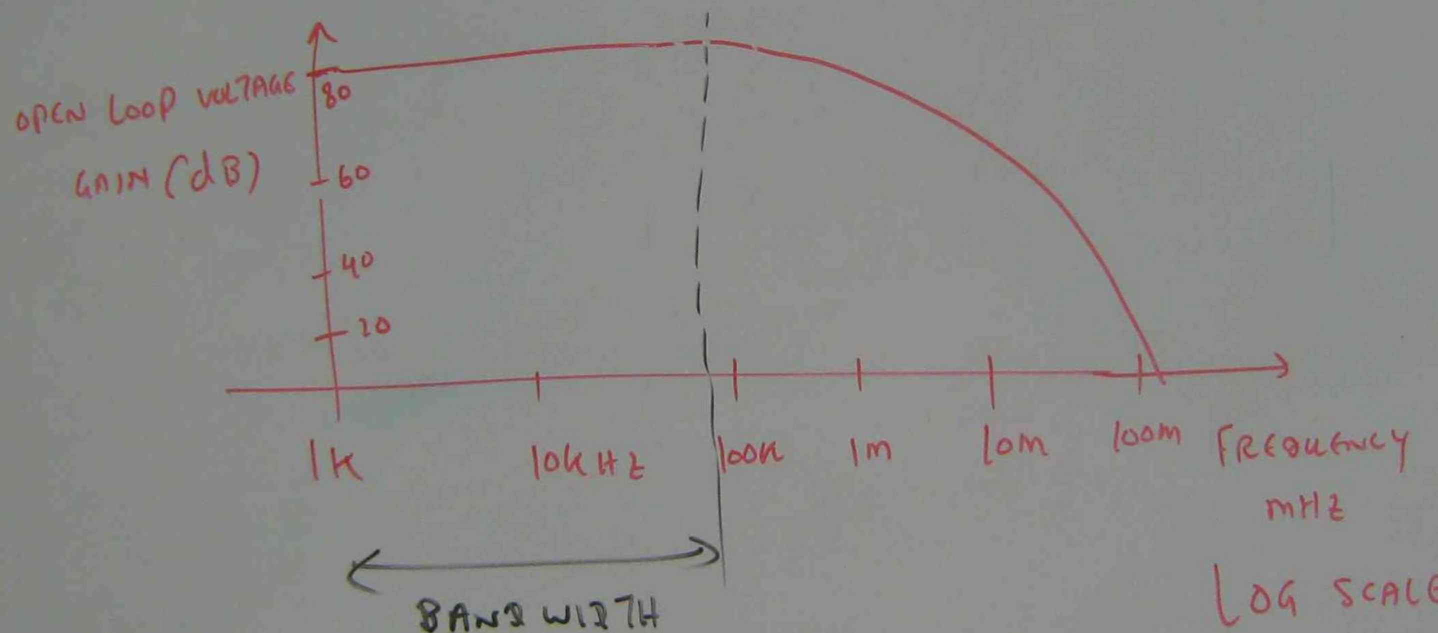


DISTORTED.

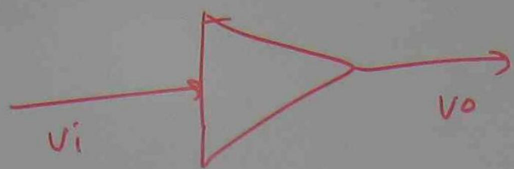


BAND WIDTH

THE RANGE OF FREQUENCIES AN AMPLIFIER CAN EFFECTIVELY AMPLIFY IS REFERRED TO AS THE BAND WIDTH



BETTER QUALITY → WIDER BANDWIDTH



$$\text{VOLTAGE GAIN } (A_V) = \frac{V_o}{V_i}$$

$$A_V \text{ (IN dB)} = 20 \log A_V = 20 \log_{10} A_V$$

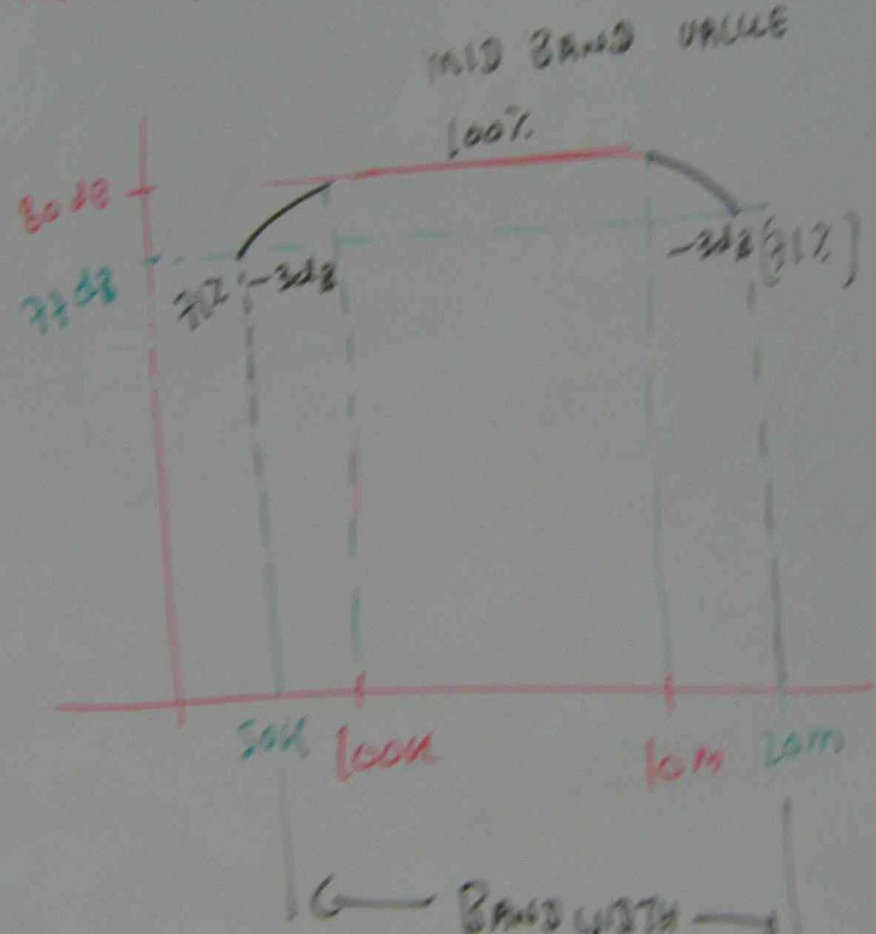
Pb
IF dB of AMPLIFIER IS 4, CALCULATE VOLTAGE GAIN

$$dB = 20 \log_{10} A_V$$

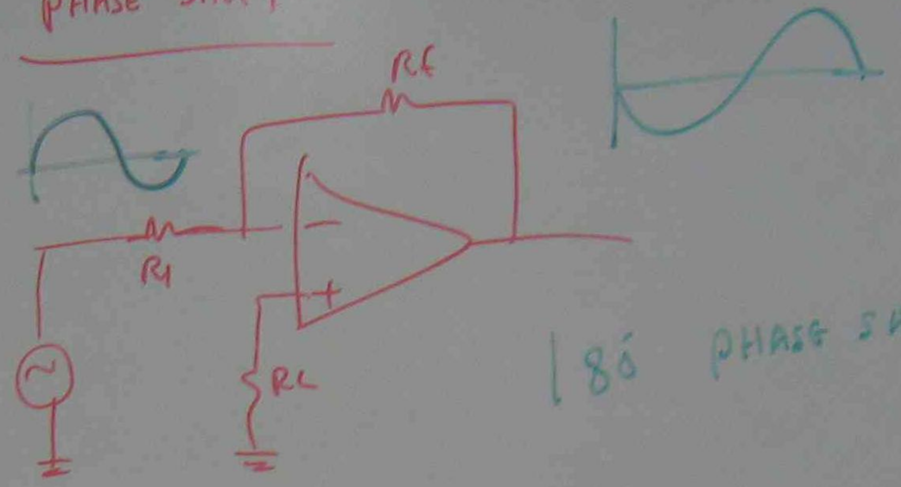
$$4 = 20 \log_{10} A_V$$

$$0.2 = \log_{10} A_V \longrightarrow A_V = 10^{0.2} = 1.58$$

* THE BANDWIDTH OF AN AMPLIFIER IS THAT RANGE OF FREQUENCIES BETWEEN - 3dB POINTS WHERE - 3dB EQUALS THE POINT WHERE THE OUT PUT HAS FALLEN TO 71 % OF IT'S MID BAND VALUE

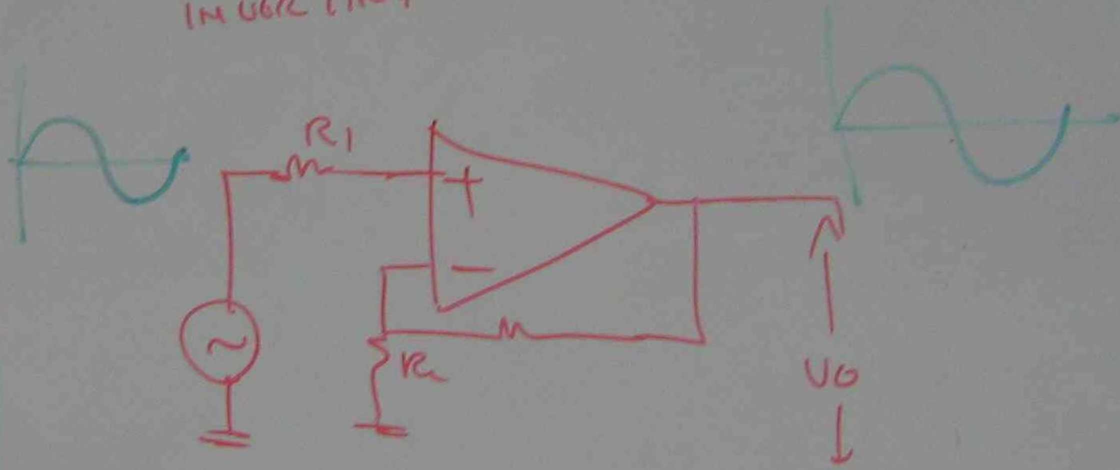


PHASE SHIFT



180° PHASE SHIFT

INVERTING



NON-INVERTING

0° PHASE SHIFT

ANOTHER IMPORTANT CONSIDERATION IS THE PHASE RELATIONSHIP BETWEEN THE INPUT AND OUTPUT VOLTAGES OF THE AMPLIFIER.

THE NORMAL PHASE DIFFERENCE IS EITHER 0° OR 180°

BUT AS FREQUENCY INCREASES, THE OTHER PHASE SHIFTS ANGLES CAN OCCUR AND THE CIRCUIT CAN BECOME UNSTABLE.

VERY STABLE BUT LIMITED SMALL SIGNAL BANDWIDTH

IF WIDER FREQUENCY IS TO BE APPLIED, EXTERNAL FREQUENCY COMPENSATION MUST BE PROVIDED.

COMPENSATION → INTERNAL FREQUENCY COMPENSATION

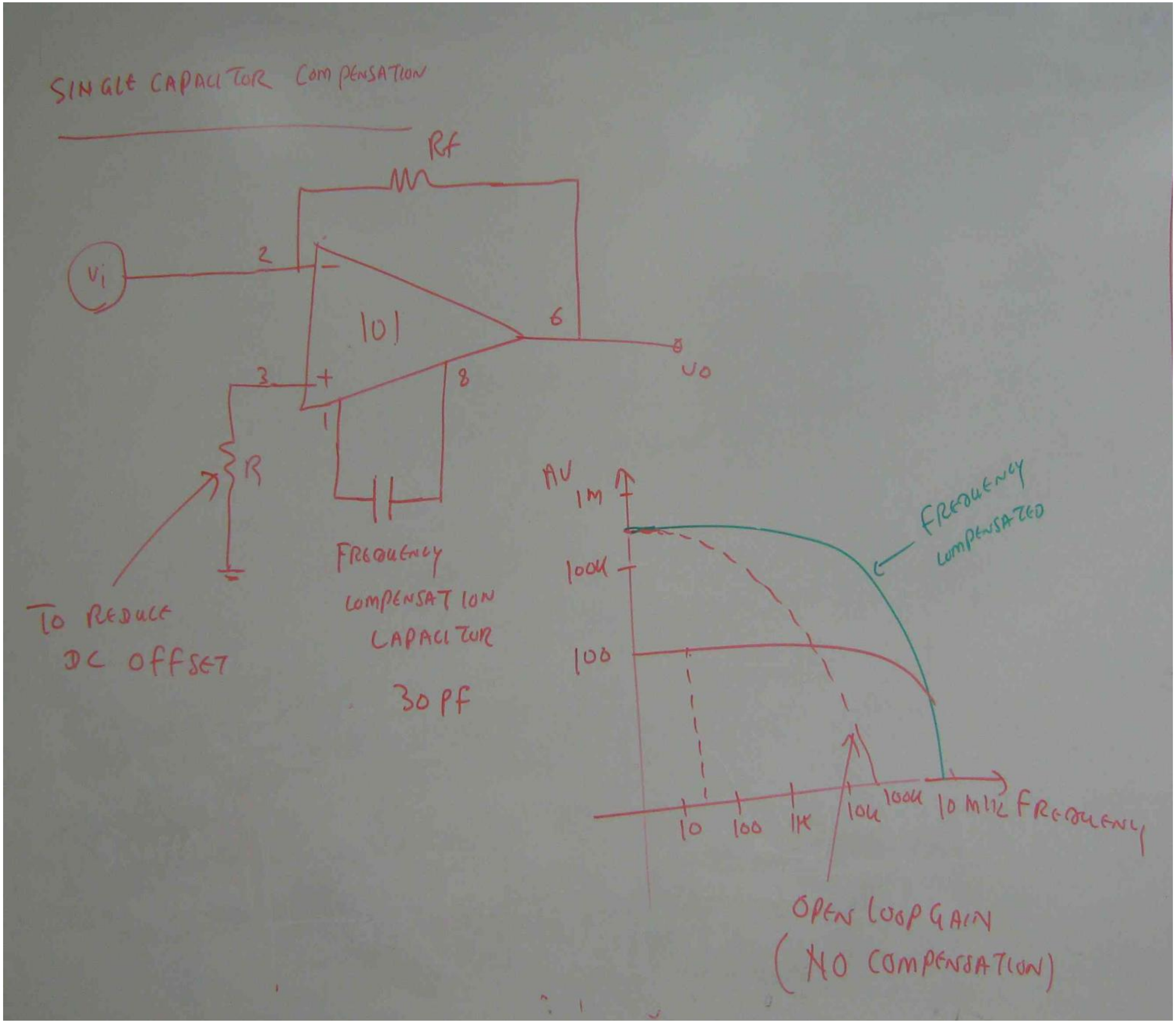
741, TL071, TL081, LF411

COMPENSATION → EXTERNAL FREQUENCY COMPENSATION

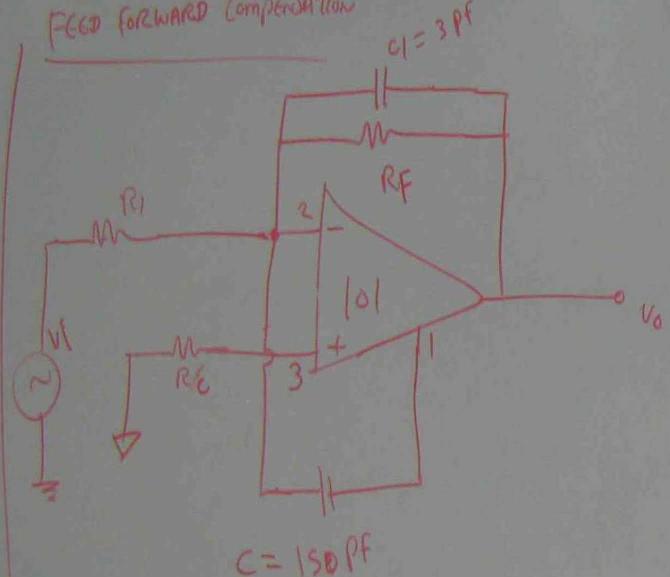
EXTERNAL FREQUENCY COMPENSATION → SINGLE CAPACITOR COMPENSATION

EXTERNAL FREQUENCY COMPENSATION → FEED FORWARD COMPENSATION

$$X_c = \frac{1}{2\pi f c} \rightarrow f = \frac{1}{2\pi X_c \times C}$$


SINGLE CAPACITOR COMPENSATION
Rf
Vi
2
3
101
6
8
1
Vo
R
TO REDUCE DC OFFSET
FREQUENCY COMPENSATION CAPACITOR
30 pF
AV
1M
100K
100
10
100
1K
10K
100K
10 MHz
FREQUENCY
FREQUENCY COMPENSATED
OPEN LOOP GAIN
(NO COMPENSATION)

FEED FORWARD COMPENSATION



THE BANDWITH CAN BE INCREASED BY FEED FORWARD COMPENSATION

GAIN BANDWIDTH PRODUCT (GBP)

GBP = AV (CLOSED LOOP) X BW = UNITY GAIN (UGB) BANDWIDTH

↑

BANDWIDTH OF INTERNALLY COMPENSATED OP-AMP

pb THE UGB FOR 741 OP-AMP IS 1MHZ AND 4MHZ FOR LF411. IF CLOSED LOOP VOLTAGE GAIN IS 100, CALCULATE BANDWIDTH

LF411

$AV \times BW = UGB$

$100 \times BW = 4000\,kHz$

$BW = \frac{4000}{100} = 40\,kHz$

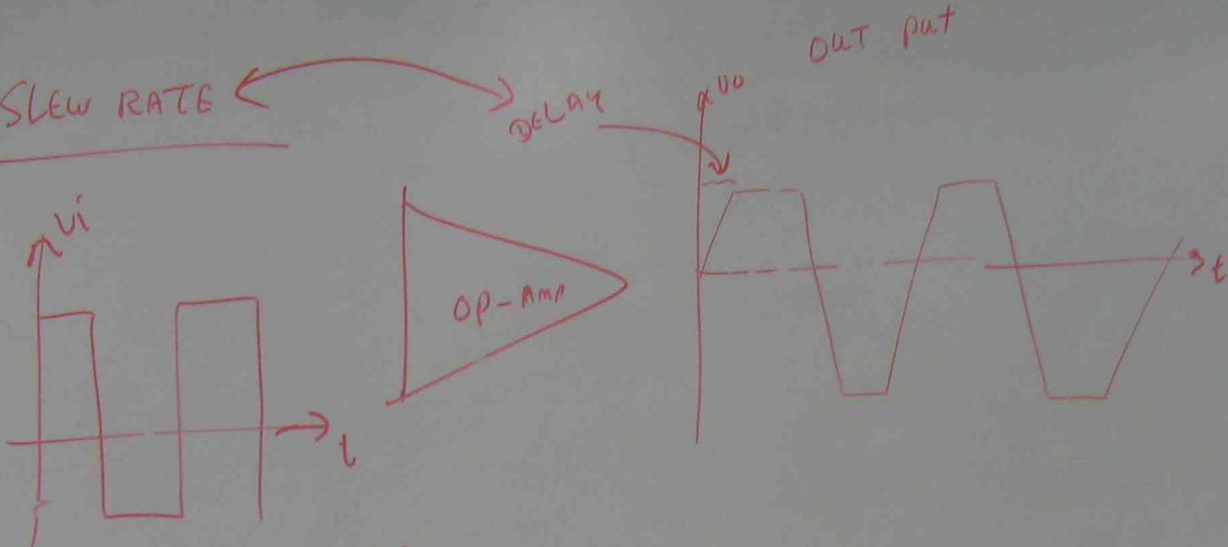
741

$100 \times BW = 1\,MHz$

$BW = \frac{1000\,kHz}{100}$

$= 10\,kHz$

SLEW RATE



INPUT SQUARE WAVE
STEP CHANGE IN INPUT

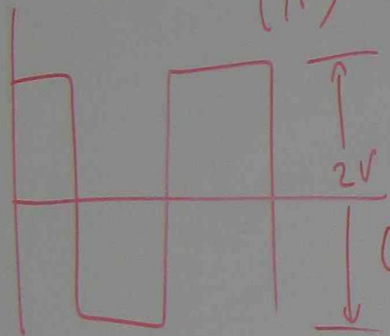
THE SLEW RATE SPECIFICATION OF AN OP-AMP SHOWS HOW FAST THE OUTPUT VOLTAGE OF OP-AMP CAN CHANGE FOR A STEP CHANGE AT INPUT.

$$\text{SLEW RATE} = \frac{\text{MAXIMUM CHANGE IN } V_O}{\text{CHANGE IN TIME}}$$

pb/ If 2 V_{p-p} square wave at a frequency of 50 KHz is applied to a voltage follower with a slew rate of 0.5 V/µs

calculate (i) period of wave form

(ii) time taken to change by 2V.



$$f = 50\,\text{KHz}$$

(i)

$$T = \frac{1}{f} = \frac{1}{50\times10^{3}} = \frac{10^{6}}{50\times10^{3}}\,\mu s$$

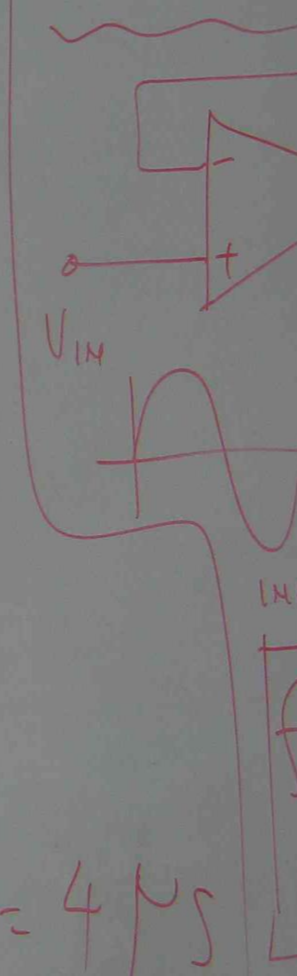
$$= 20\,\mu s$$

$$\text{(ii) SLEW RATE} = \frac{\Delta V_0}{\Delta t}$$

$$0.5 = \frac{2}{\Delta t} \longrightarrow \Delta t = \frac{2}{0.5} = 4\,\mu s$$

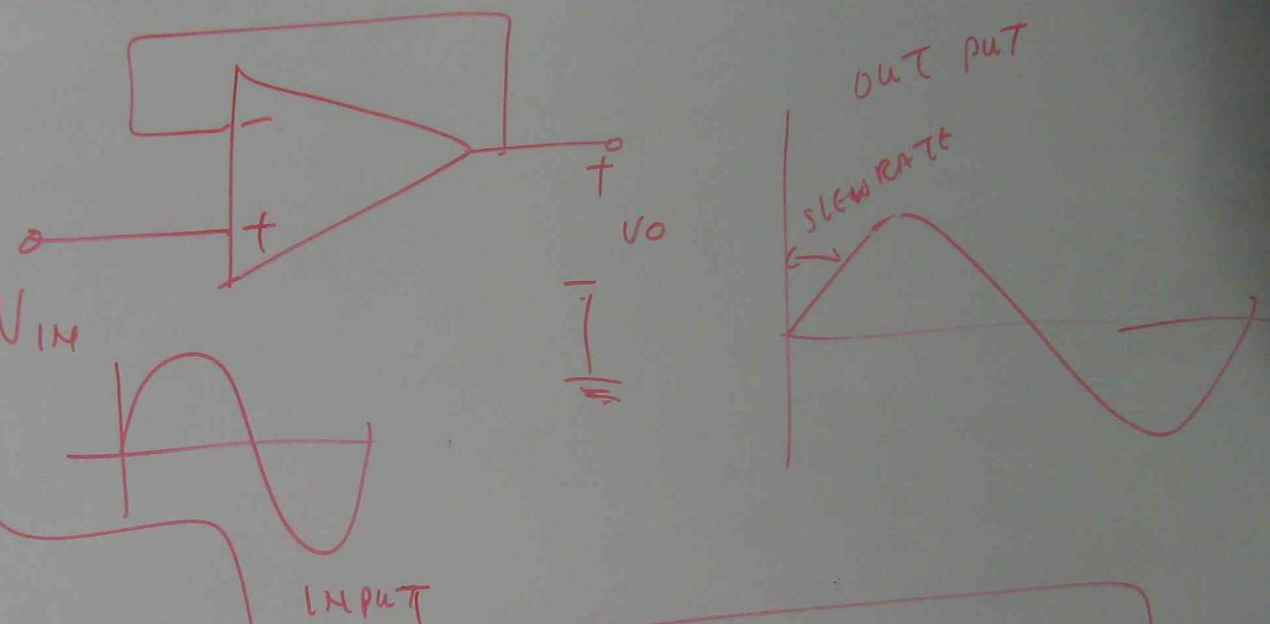
SLEW RATE

SINE WAVES



INPU

SLEW RATE LIMITING OF SINE WAVES



$$\boxed{f_{max} = \frac{\text{SLEW RATE}}{2\pi V_{o\,max}}}$$

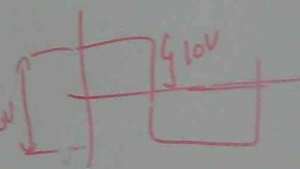
$= 4\,\mu s$

pb ①

THE SLEW RATE OF A 741 IS 0.5 V/μs. IT IS CONFIGURED AS A VOLTAGE FOLLOWER. DETERMINE THE MAXIMUM FREQUENCY THAT CAN BE OBTAINED FROM THE CIRCUIT FOR THE FOLLOWING VOLTAGES

(a) A 20 V_{p-p} SINE WAVE

(b) A 2 V_{p-p} SINE WAVE

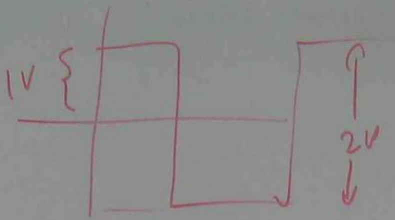


(a) $$f_{max} = \frac{\text{SLEW RATE}}{2\pi V_{o\,max}} = \frac{0.5}{2 \times 3.1416 \times 10 \times 1\mu s}$$

$$= \frac{0.5 \times 10^{6}}{2 \times 3.1416 \times 10}\ \text{Hz}$$

$$= \frac{0.5 \times 10^{3}}{2 \times 3.1416 \times 10}\ \text{kHz}$$

$$= 7.96\ \text{kHz}$$



(b) $f_{max} = \dfrac{0.5}{2 \times 3.1416 \times 1 \times 1\mu s}$

$= \dfrac{0.5 \times 10^{6}}{2 \times 3.1416 \times 1}$ Hz

$= \dfrac{0.5 \times 10^{3}}{2 \times 3.1416 \times 1}$ kHz

$= 79.6$ kHz

Pb2

DETERMINE THE BANDWIDTH OF AN INVERTING AMPLIFIER WITH A CLOSED LOOP GAIN OF (−) 150. THAT IS CONSTRUCTED WITH AN INTERNALLY COMPENSATED OP AMP THAT HAS A UNITY GAIN BANDWIDTH OF 2 MHZ.

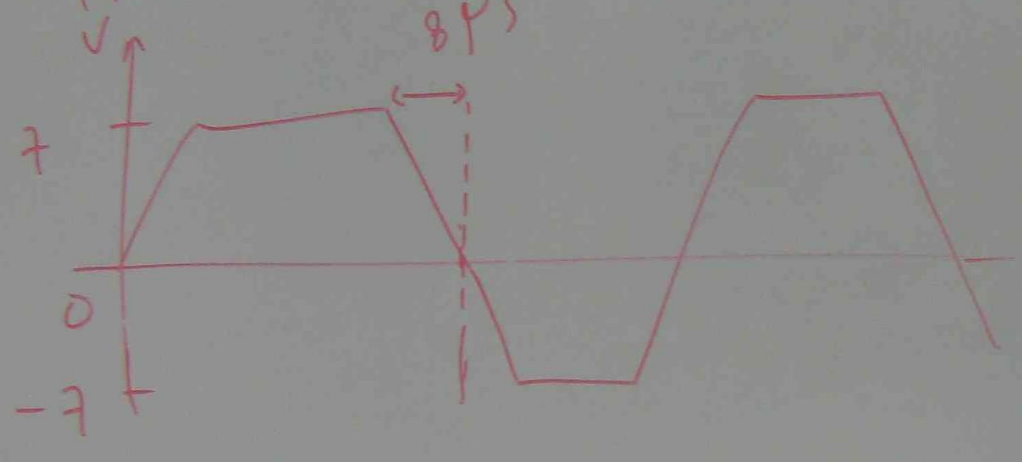
A_V (closed loop) $\times$ BW = UGB

$150 \times BW = 2$ MHz

$BW = \dfrac{2000 \text{ kHz}}{150} = 13.33$ kHz

Pb 3

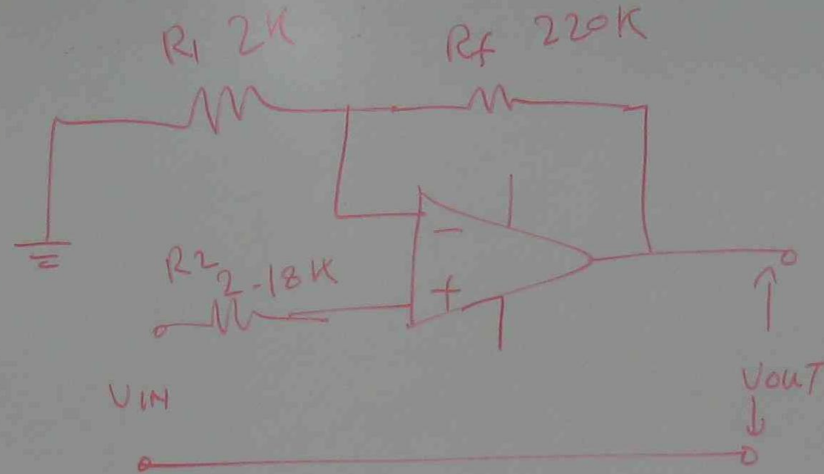
DETERMINE THE SLEW RATE OF THE OP-AMP WHOSE OUTPUT RESPONSE TO A SQUARE WAVE IS SHOWN IN FIGURE



$$\text{SLEW RATE} = \frac{\text{MAX CHANGE IN } V_O}{\text{CHANGE IN TIME}} = \frac{7}{8\,\mu s}$$

$$= 0.875\ V/\mu s$$

pb 4



THE ABOVE CIRCUIT IS A NON-INVERTING AMPLIFIER CONSTRUCTED WITH A 741 OP-AMP. SLEW RATE IS 0.5 V/μs. UNITY GAIN BANDWIDTH IS 1 MHz

DETERMINE (a) THE BANDWIDTH OF THE CIRCUIT

(b) MAXIMUM PEAK TO PEAK OUTPUT VOLTAGE.

$$A_v \times BW = UGB$$

$$? \times BW = 1\,MHz$$

(a) $V_0 = \frac{R_f}{R_1} V_1$

$V_0 = \frac{220}{2} \times V_1$

$\frac{V_0}{V_1} = A_V = 110$

$110 \times BW = 1 \times 10^3 \text{ kHz}$

$BW = \frac{1000}{110} \text{ kHz} = 9.09 \text{ kHz}$

(b) $\text{SLEW RATE} = \frac{V_0}{\text{CHANGE IN TIME}} \Rightarrow 0.5 \text{ V}/\mu s = \frac{V_0}{1 \mu s}$

$V_0 = 0.5 \text{ V}$

$T = \frac{1}{f} = \frac{1}{10^6} = 1 \mu s$

$$N = \frac{120f}{P}$$

N = MOTOR SPEED

f = FREQUENCY

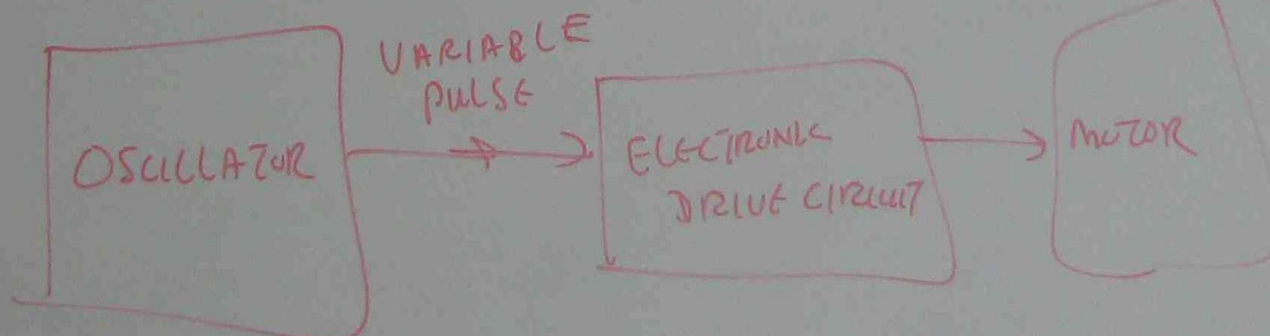
P = NO. OF POLES.

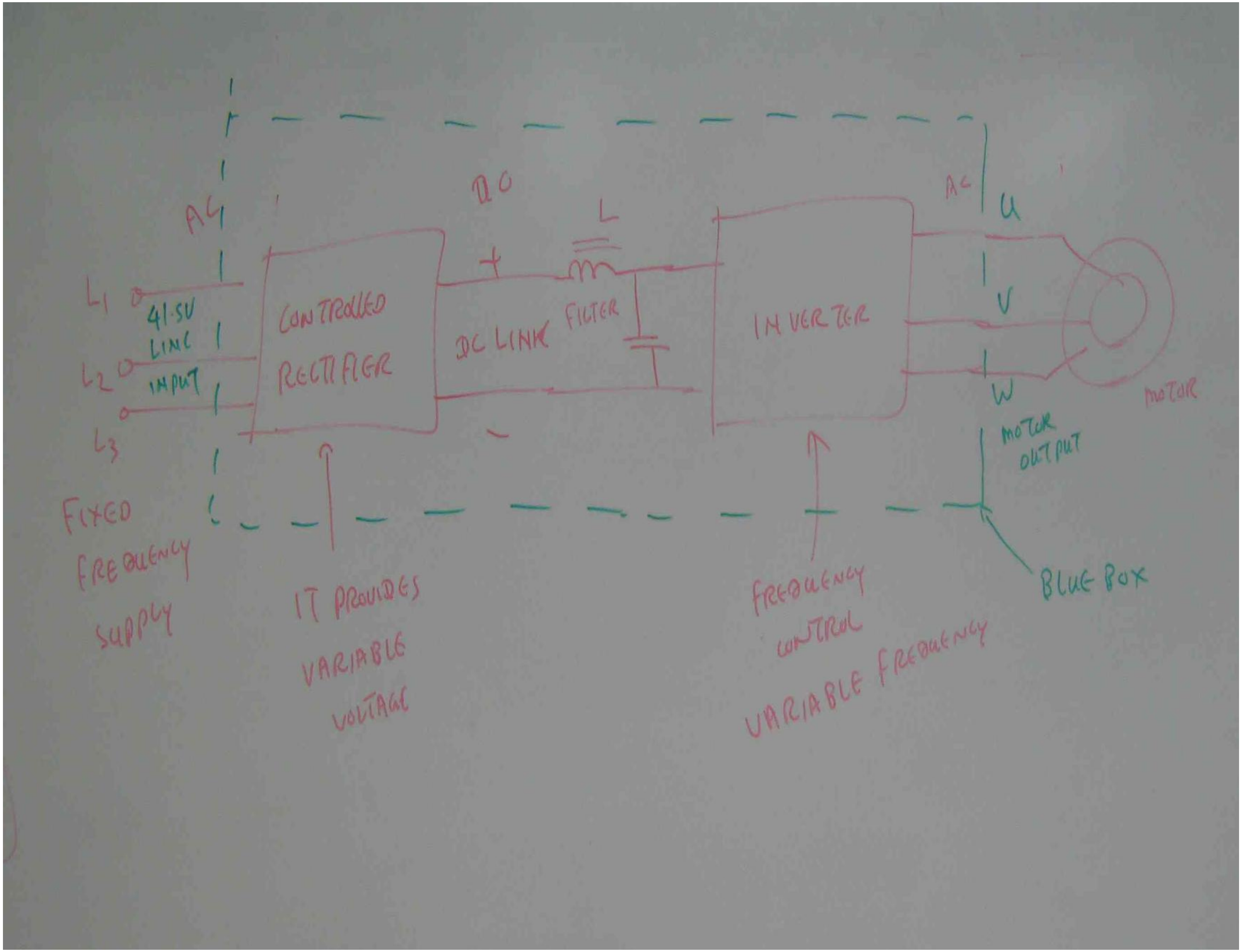
If $f = 50\,\text{Hz}$

$P = 4$ poles

$$N = \frac{120 \times 50}{4}$$

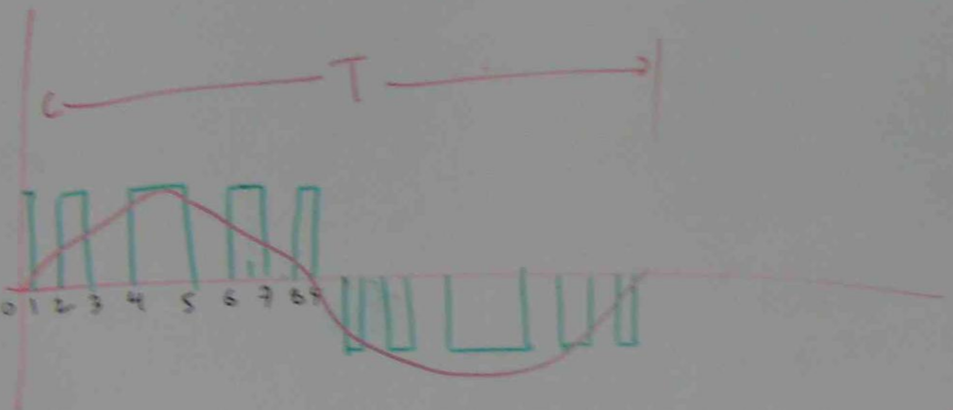
$= 1500$ RPM





AC
DC
L
AC
U
V
W
L1
L2
L3
415V
LINE
INPUT
CONTROLLED
RECTIFIER
+
-
DC LINK
FILTER
INVERTER
MOTOR
MOTOR
OUTPUT
FIXED
FREQUENCY
SUPPLY
IT PROVIDES
VARIABLE
VOLTAGE
FREQUENCY
CONTROL
VARIABLE FREQUENCY
BLUE BOX

PULSE WIDTH MODULATION SYSTEM → FREQUENCY / OUTPUT VOLTAGE CONTROL



SWITCHING CIRCUITS. THEIR SWITCHING RATES ARE DIFFERENENT

$0 \rightarrow 1 = 1\,\mu s$

$2 \rightarrow 3 = 2\,\mu s$

$4 \rightarrow 5 = 3\,\mu s$

$6 \rightarrow 7 = 2\,\mu s$

$8 \rightarrow 9 = 1\,\mu s$

BY SWITCHING RATE, SINUSOIDAL OUTPUT VOLTAGE IS CREATED.

T DEPENDS ON TOTAL SWITCHING TIMES OF ELECTRONIC DEVICES

$$f = \frac{1}{T}$$

BY ADJUSTING THE SWITCHING RATES OF ELECTRONIC DEVICES, THE OUTPUT FREQUENCY CAN BE CHANGED.