INPUT OFFSET VOLTAGE

THE OP-AMP OUTPUT VOLTAGE MAY NOT BE ZERO WHEN THE VOLTAGE ACROSS INPUT IS ZERO.

INPUT OFFSET CURRENT

OFFSET CURRENT MAY BE REQUIRED ACROSS THE INPUT TO MAKE OUTPUT VOLTAGE TO BECOME ZERO.

INPUT BIAS CURRENT

THE AVERAGE OF THE TWO INPUT CURRENTS REQUIRED TO DRIVE THE OUTPUT VOLTAGE TO ZERO.

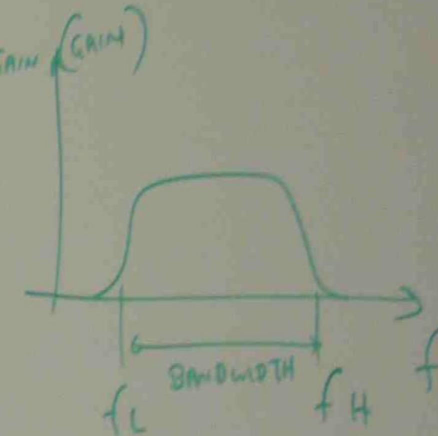
SLEW RATE

IF A VOLTAGE IS SUDDENLY APPLIED TO THE INPUT OF AN OP-AMP, THE OUTPUT WILL SATURATE TO THE MAXIMUM. THE SLEW RATE IS THE RATE AT WHICH THE OUTPUT VOLTAGE CHANGES TO THE SATURATION VALUE

UNITY GAIN FREQUENCY BANDWIDTH

THE FREQUENCY RESPONSE OF AN OP-AMP IS TYPICALLY DEFINED BY A GRAPH OF OPEN LOOP VOLTAGE GAIN VERSUS FREQUENCY

$\frac{V_O}{V_{IN}}$ = GAIN

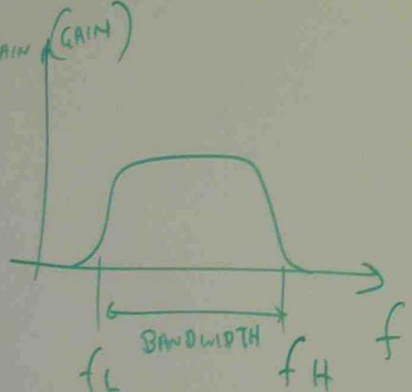


$BW = f_H - f_L$

UNITY GAIN FREQUENCY BANDWIDTH

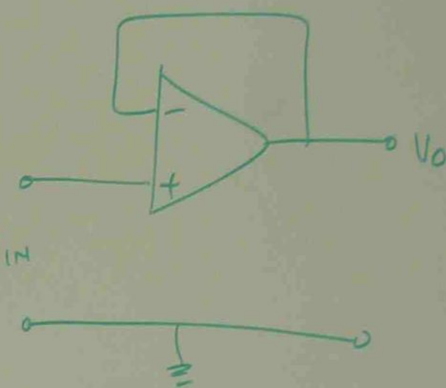
THE FREQUENCY RESPONSE OF AN OP-AMP IS TYPICALLY DEFINED BY A GRAPH OF OPEN LOOP VOLTAGE GAIN VERSUS FREQUENCY.

$$\frac{V_O}{V_{IN}} = \text{GAIN}$$

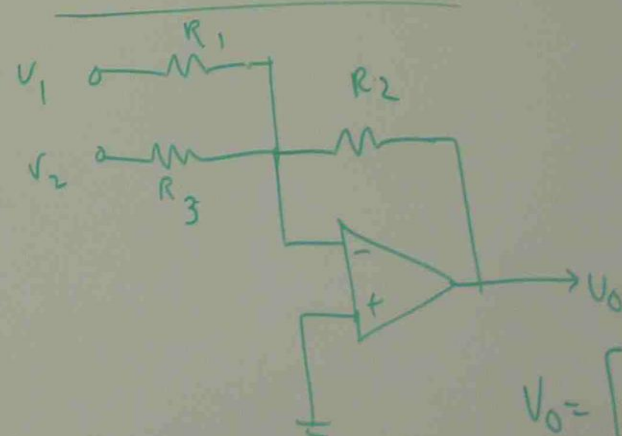


$$BW = f_H - f_L$$

VOLTAGE FOLLOWER



SUMMING AMPLIFIER



$$V_O = \left[\frac{R_2}{R_1} V_1 + \frac{R_2}{R_3} V_2\right]$$

pb/

DEVELOP AN O

PROVIDE AN O

RELATED TO

$V_{OUT} =$

V_{IN}

1k

5

3

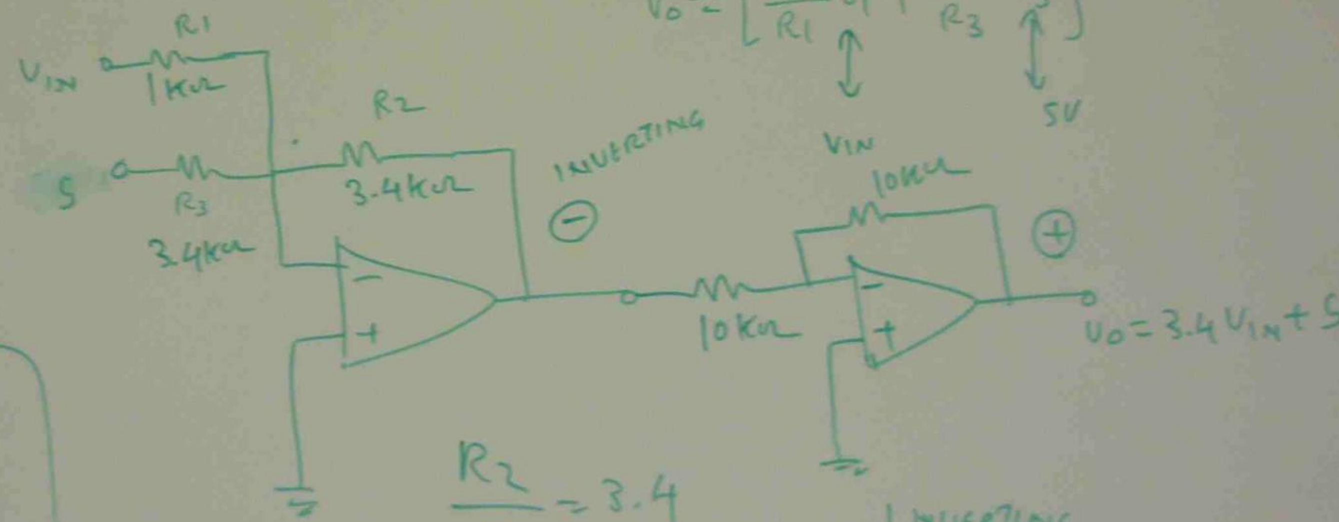
PD

DEVELOP AN OP-AMP CIRCUIT THAT CAN PROVIDE AN OUTPUT VOLTAGE THAT IS RELATED TO THE INPUT VOLTAGE BY

$$V_{OUT} = 3.4\,V_{IN} + 5 \quad \longleftarrow \text{COMPARE}$$

$$V_O = \left[\frac{R_2}{R_1} V_1 + \frac{R_2}{R_3} V_3\right]$$

$V_1 \leftrightarrow V_{IN}$ $\qquad$ $V_3 \leftrightarrow 5V$

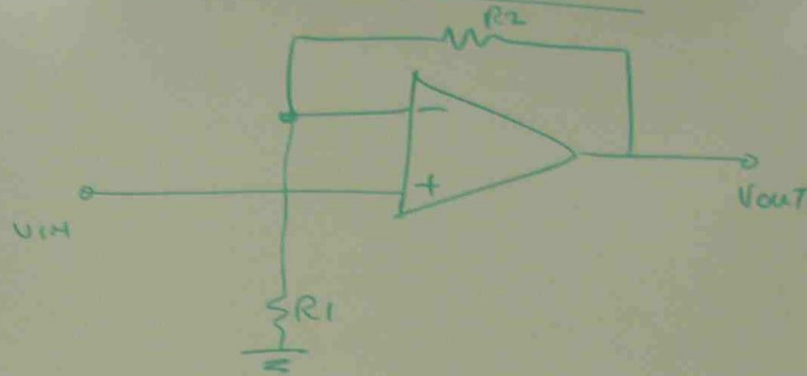


$$\frac{R_2}{R_1} = 3.4$$

$$\frac{R_2}{R_3} = 1$$

$$V_O = \left[\frac{R_2}{R_1} V_1 + \frac{R_2}{R_3} V_2\right]$$

NON INVERTING AMPLIFIER



$$V_{OUT} = \left[1 + \frac{R_2}{R_1}\right] V_{IN}$$

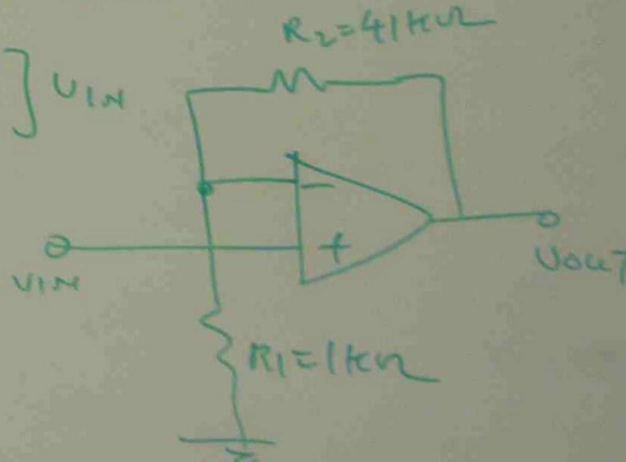
pb DESIGN A HIGH IMPEDANCE AMPLIFIER WITH A VOLTAGE GAIN OF 42.

$$V_{OUT} = \left[1 + \frac{R_2}{R_1}\right] V_{IN}$$

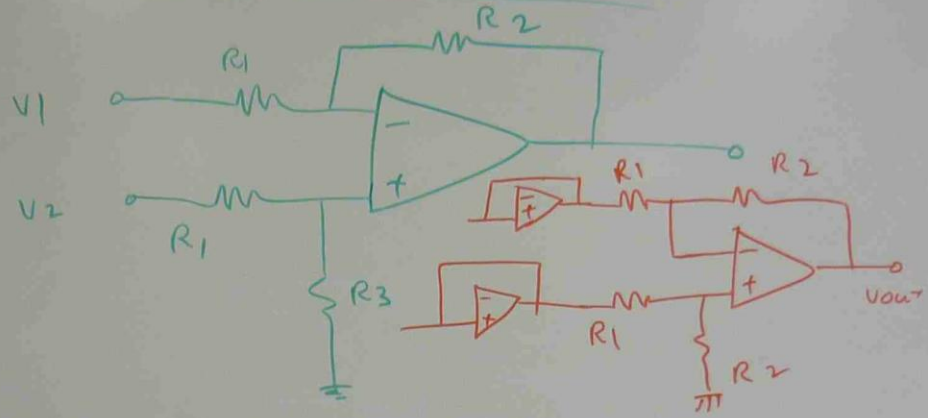
$$\frac{V_{OUT}}{V_{IN}} = 1 + \frac{R_2}{R_1}$$

$$42 = 1 + \frac{R_2}{R_1}$$

$$\frac{R_2}{R_1} = 41$$



DIFFERENTIAL AMPLIFIER



$$V_{OUT} = \frac{R_2}{R_1}\left(\underline{\underline{V_2}} - \underline{\underline{V_1}}\right)$$

Pb A SENSOR OUTPUTS A RANGE OF 20 TO 250 mV AS A VARIABLE VARIES OVER ITS RANGE. DEVELOP SIGNAL CONDITIONING SO THAT THIS BECOMES 0 TO 5 V.

$$V_{OUT} = m V_{IN1} + V_{IN2}$$

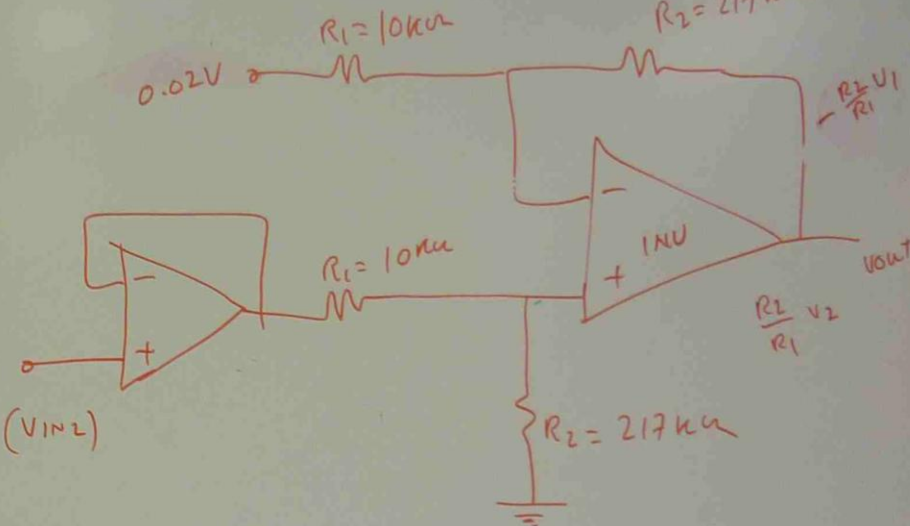
$$0 = m \times 0.02 + V_{IN2} \quad \text{--- (1)}$$

$$5 = m \times 0.25 + V_{IN2} \quad \text{--- (2)}$$

$$(2) - (1) \Rightarrow 5 = 0.23\, m$$

$$m = \frac{5}{0.23} = 21.7 = \frac{R_2}{R_1}$$

$$\frac{R_2}{R_1} = \frac{217}{10} = 21.7$$



$$5 = 0.25 \times 21.7 + V_{IN2}$$

$$V_{IN2} = 5 - 0.25 \times 21.7 = -0.434$$

V_{SAT} = OP-AMP SATURATION VOLTAGE

I_m = MAXIMUM CURRENT

$$V_{OUT} = m V_{IN1} + V_{IN2}$$

$$= 21.7\, V_{IN1} + (-0.434)$$

$$V_{OUT} = 21.7\, V_{IN1} - 0.434$$

2

N2 — 1

N2 — 2

$21.7 = \frac{R2}{R1}$

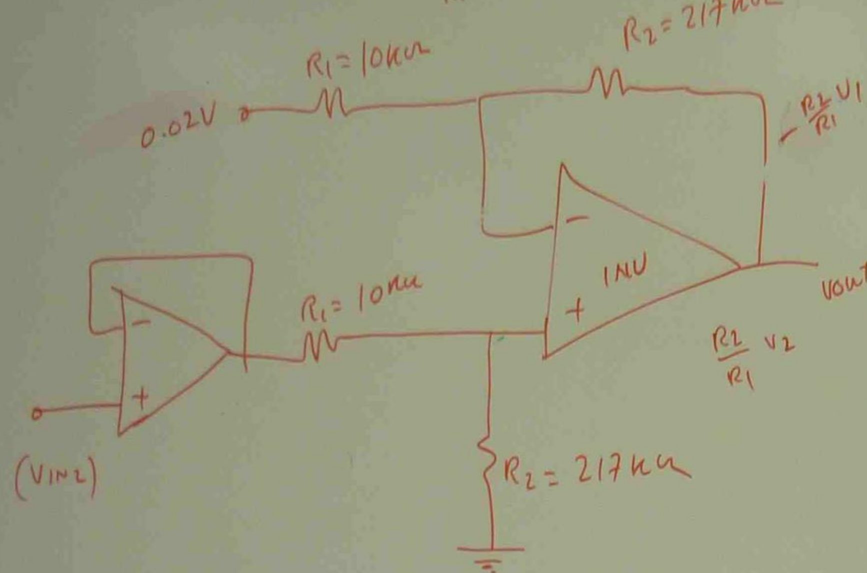
$= (-)\,0.434$

2

0.434)

4

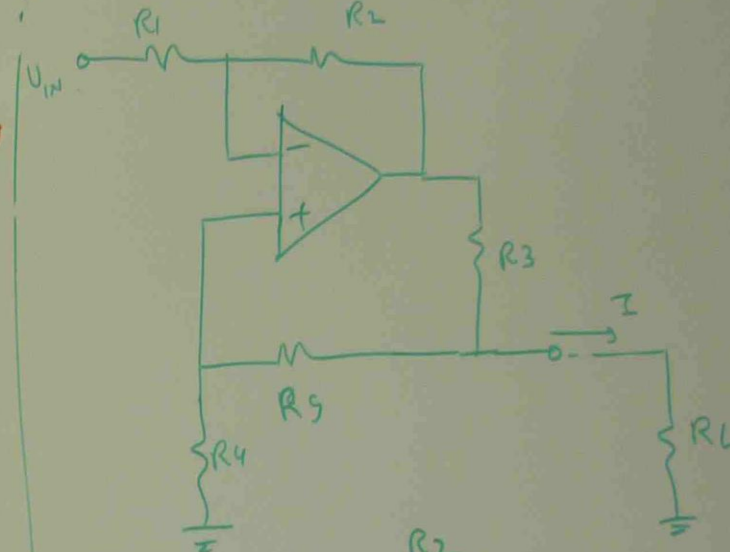
$\frac{R2}{R1} = \frac{217}{10} = 21.7$



V_{SAT} = OP-AMP SATURATION VOLTAGE

I_m = MAXIMUM CURRENT

VOLTAGE TO CURRENT CONVERTER

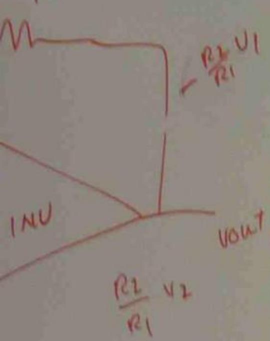


$$I = \frac{R_2}{R_1 R_3} V_{IN}$$

R_{mL} = MAXIMUM LOAD RESISTANCE

$$R_{mL} = \frac{(R_4 + R_5)\left[\frac{V_{SAT}}{I_m} - R_3\right]}{R_3 + R_4 + R_5}$$

21.7

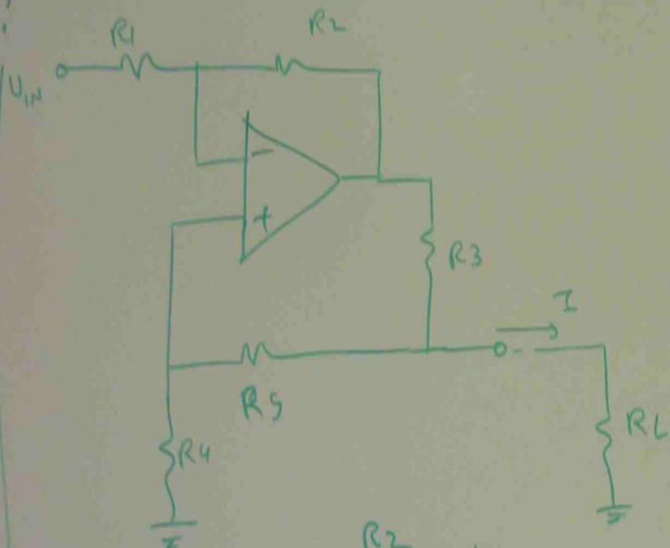


$17\,k\Omega$

AT = OP-AMP SATURATION VOLTAGE

m = MAXIMUM CURRENT

VOLTAGE TO CURRENT CONVERTER



$$I = \frac{R_2}{R_1 R_3} V_{IN}$$

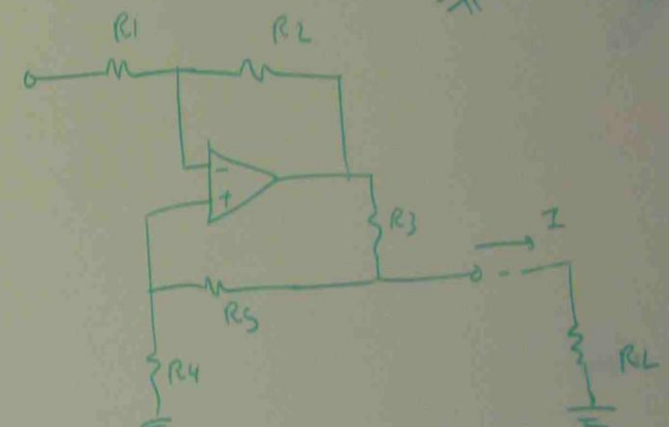
R_{mL} = MAXIMUM LOAD RESISTANCE

$$R_{mL} = \frac{(R_4 + R_5)\left[\frac{V_{SAT}}{I_m} - R_3\right]}{R_3 + R_4 + R_5}$$

pb A SENSOR OUTPUTS 0 TO 1 VOLT. DEVELOP A VO

SO THAT THIS BECOMES 0 TO 10 mA. SPECIFY TH

IF THE OP-AMP SATURATES AT 10V.



$$I = \frac{R_2}{R_1 R_3} V_{IN}$$

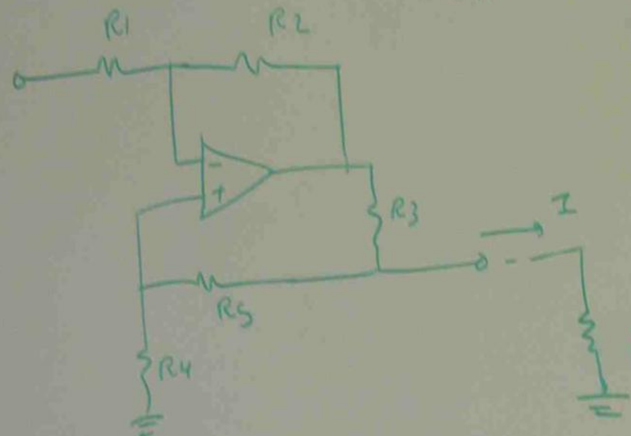
IN PRACTICAL DESIGN, SET $R_1 = R_2$ (ANY VALUE)

$$I = \frac{V_{IN}}{R_3}$$

pb

A SENSOR OUTPUTS 0 TO 1 VOLT. DEVELOP A VOLTAGE TO CURRENT CONVERTER SO THAT THIS BECOMES 0 TO 10mA. SPECIFY THE MAXIMUM LOAD RESISTANCE IF THE OP-AMP SATURATES AT 10V.

#



$$I = \frac{R_2}{R_1 R_3} V_{IN}$$

IN PRACTICAL DESIGN, SET $R_1 = R_2$ (ANY VALUE)

$$I = \frac{V_{IN}}{R_3}$$

$I = 10mA$, $V_{IN} = 1V$ $R_3 = ?$

$$10 \times 10^{-3} = \frac{1}{R_3}$$

$$R_3 = \frac{1}{10^{-2}} = 10^{2} = 100\Omega$$

IN PRACTICAL DESIGN

SET $R_3 = R_4$

$\therefore R_3 = R_4 = 100\Omega$

IN PRACTICAL $R_5 \simeq 0$

$$R_{mL} = \frac{(R_4 + R_5)\left[\frac{V_{SAT}}{I_m} - R_3\right]}{R_3 + R_4 + R_5}$$

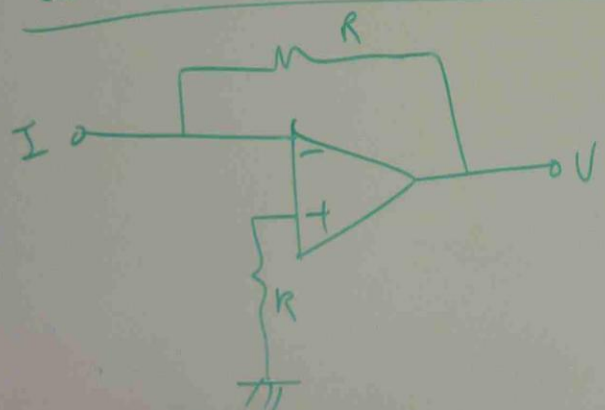
$$R_{mL} = \frac{(100+0)\left[\frac{10}{10\times10^{-3}} - 100\right]}{100+100+0}$$

$$= \frac{100 \times \left[1000 - 100\right]}{200}$$

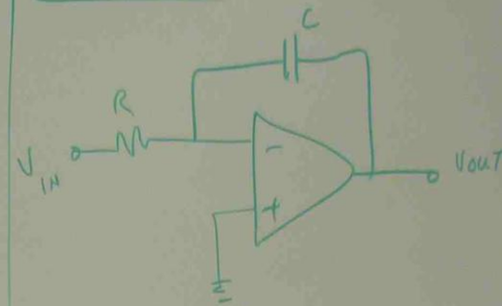
$$= \frac{900}{2}$$

$$= 450\Omega$$

CURRENT TO VOLTAGE CONVERTER



INTEGRATOR



$$V_{OUT} = -\frac{1}{RC}\int V_{IN}\,dt$$

$$V_{OUT} = \frac{K}{RC}t$$

IF $V_{IN} = K$

PD) USE AN INTEGRATOR TO PRODUCE LINEAR RAMP VOLTAGE RISING AT 10 V PER ms.

$$V_{OUT} = \frac{V_{IN}}{RC}t$$

$$10 = \frac{V_{IN}}{RC}\times10^{-3}$$

$$\frac{10}{10^{-3}} = \frac{V_{IN}}{RC}$$

$$10^{4} = \frac{V_{IN}}{RC}$$

IF $V_{IN} = 1V$

R = ?

C = ?

$$RC = \frac{1}{10^{4}} = 10^{-}$$

$] \left[\frac{10}{10\times10^{-3}} - 100 \right]$

$00 + 0$

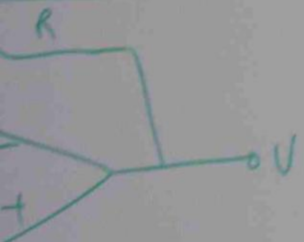
$\times \left[1000 - 100 \right]$

200

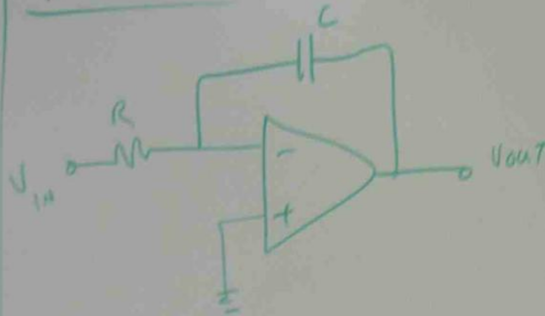
0

Ω

LTAGE CONVERTER



INTEGRATOR



$$V_{OUT} = -\frac{1}{RC} \int V_{IN} \, dt$$

$$V_{OUT} = \frac{K}{RC} t$$

IF $V_{IN} = K$

pb) USE AN INTEGRATOR TO PRODUCE A LINEAR RAMP VOLTAGE RISING AT 10V PER ms.

$$V_{OUT} = \frac{V_{IN}}{RC} t$$

$$10 = \frac{V_{IN}}{RC} \times 10^{-3}$$

$$\frac{10}{10^{-3}} = \frac{V_{IN}}{RC}$$

$$10^4 = \frac{V_{IN}}{RC}$$

IF $V_{IN} = 1V$

$R = ?$

$C = ?$

$$RC = \frac{1}{10^4} = 10^{-4}$$

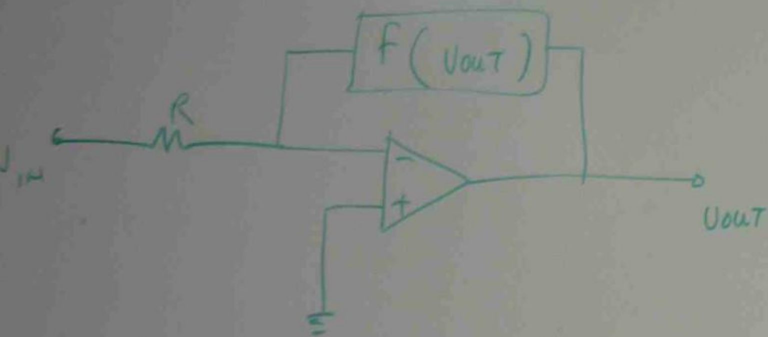
ANY COMBINATION

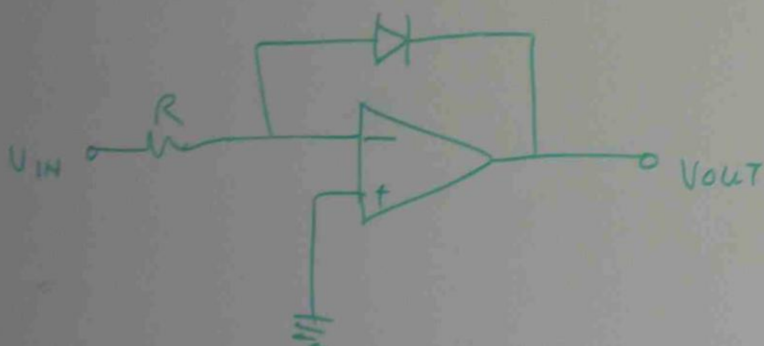
SAY

IF $R = 100\Omega$

THEN $C = 1\mu F$

LINEARIZATION





$$F(V_{OUT}) = F_0 e^{\alpha V_{OUT}}$$

F_0 = AMPLITUDE CONSTANT

α = EXPONENTIAL CONSTANT

$$V_{OUT} = \frac{1}{\alpha} \log_e V_{IN} - \frac{1}{\alpha} \log_e (F_0 R)$$

LOGARITHMIC AMPLIFIER CIRCUIT

SPECIAL INTEGRATED CIRCUITS (ICs)

1. HIGH GAIN DIFFERENTIAL INSTRUMENTATION AMPLIFIERS
2. CURRENT TO VOLTAGE CONVERTERS
3. MODULATOR / DEMODULATORS
4. BRIDGE AND NULL DETECTORS
5. PHASE SENSITIVE DETECTORS

$\log_e (F_0 R)$

CIRCUIT

s (ICs)

INSTRUMENTATION

ERTERS

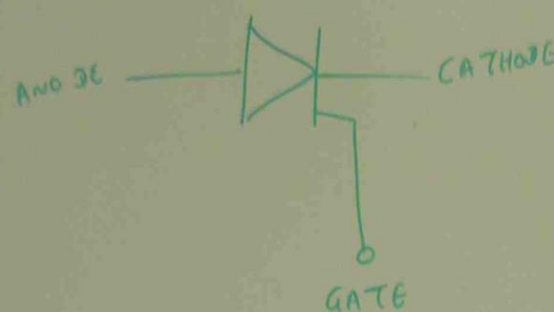
ATORS

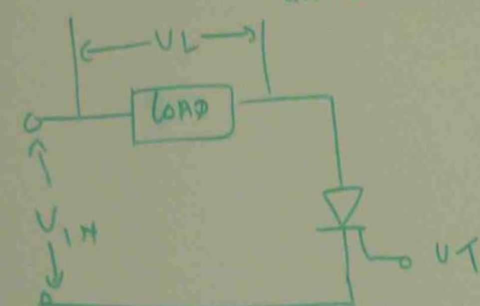
TECTORS

ECTORS

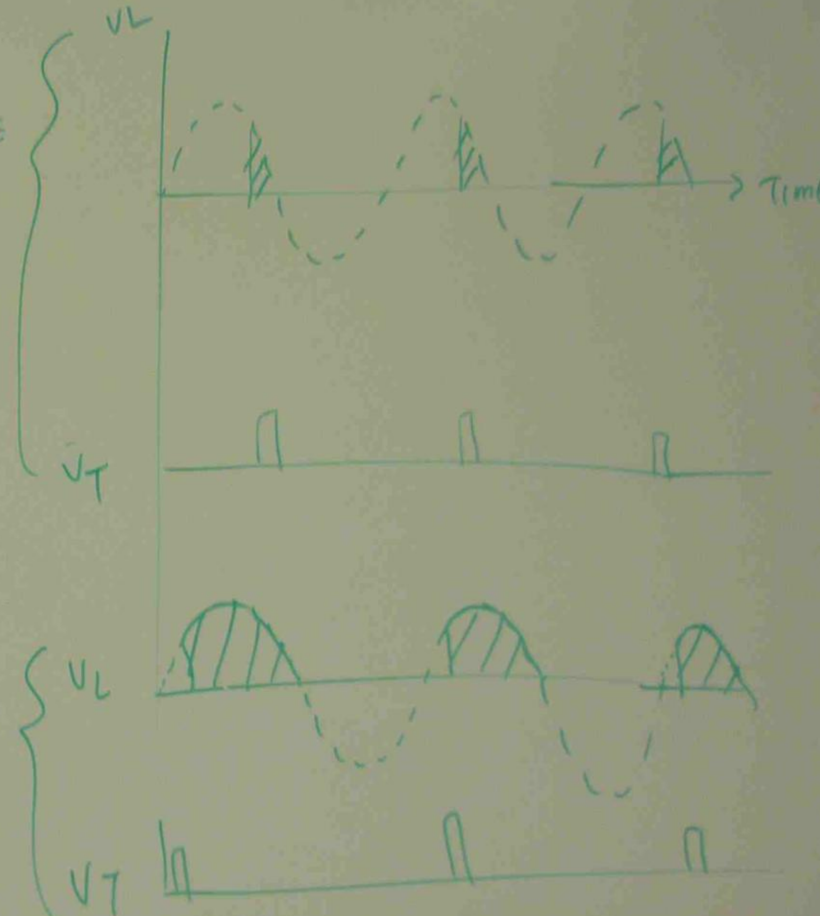
INDUSTRIAL ELECTRONICS

SILICON CONTROLLED RECTIFIERS





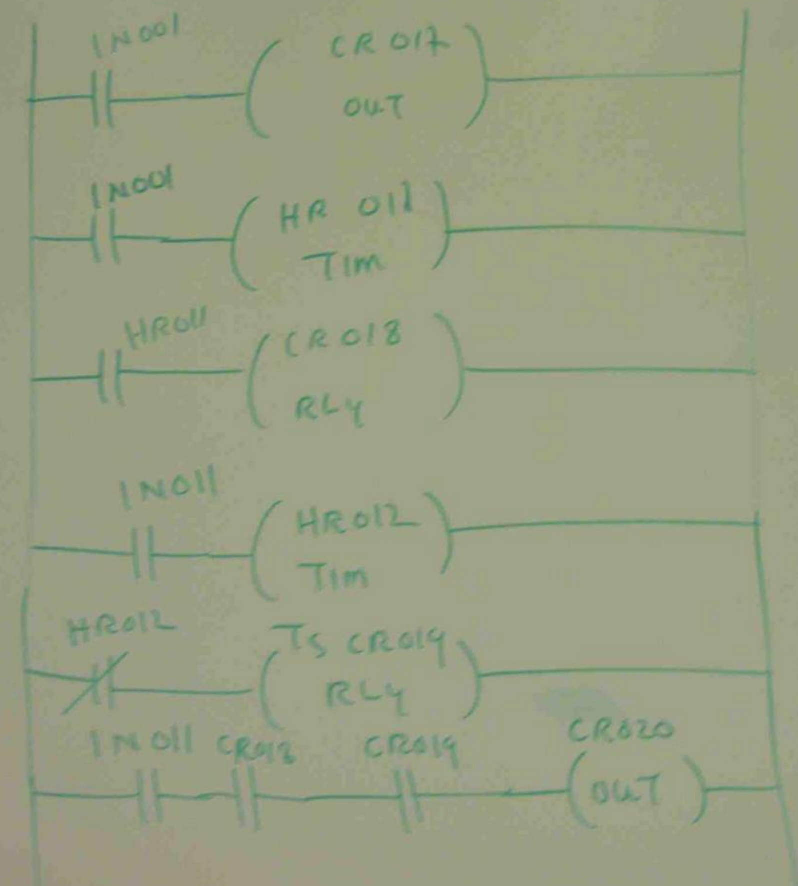
V_T = TRIGGERED VOLTAGE



PRACTICAL(1)

USE YOUR COMPUTER AND DESIGN THE FOLLOWING CONTROL SYSTEM

BY USING TL 31 PLC PROGRAM



INPUT

IN001

OUTPUT

CR020

CR017

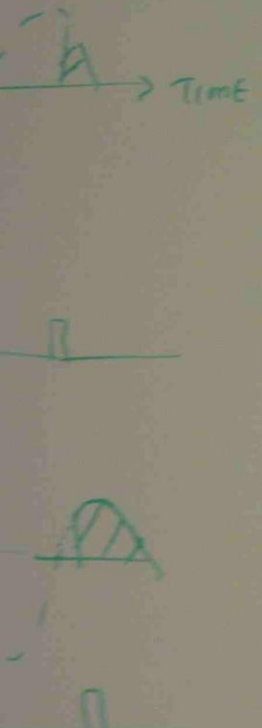
RELAY

CR018

CR019

TIMER

HR011	87 Sec
HR012	16 Sec



...NG CONTROL SYSTEM

INPUT

IN001

OUTPUT

CR020

CR017

RELAY

CR018

CR019

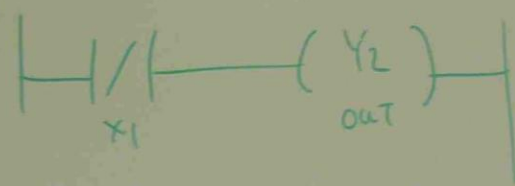
TIMER

HR011 87 Sec

HR012 16 Sec

pb

A NORMALLY CLOSED LIMIT SWITCH IS CONNECTED TO INPUT X_1. OUTPUT Y_2 MUST TURN ON WHEN THE LIMIT SWITCH OPENS WHEN THE OBJECT IS PRESENT



INPUT X_1

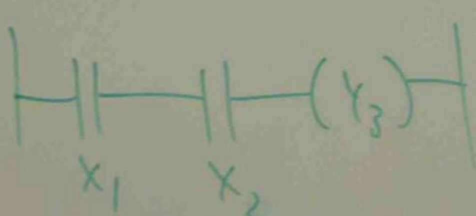
OUTPUT Y_2

pb

A NORMALLY OPEN PROXIMITY SWITCH IS CONNECTED TO INPUT X_1 AND A SECOND NORMALLY OPEN PROXIMITY SWITCH IS CONNECTED TO INPUT X_2. OUTPUT Y_3 MUST OPERATE WHEN BOTH SWITCHES ARE ACTUATED.

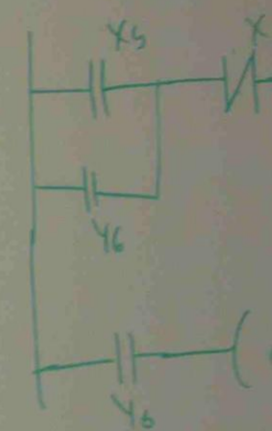
INPUT X_1, X_2

OUTPUT Y_3



pb

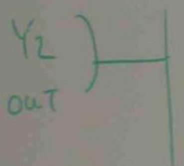
A NORMALLY CLOSE...
INPUT X_4 AND A N...
CONNECTED TO IN...
SWITCHES ARE TO BE...
OF OUTPUT Y_7.



...SED LIMIT SWITCH IS CONNECTED TO

...PUT Y_2 MUST TURN ON WHEN

...OPENS WHEN THE OBJECT IS PRESENT



INPUT X_1

OUTPUT Y_2

...EN PROXIMITY SWITCH IS

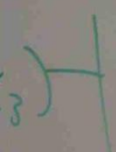
...PUT X_1 AND A SECOND NORMALLY

...TCH IS CONNECTED TO INPUT X_2.

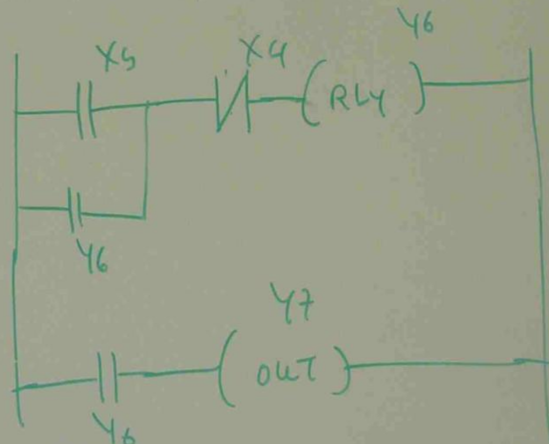
... OPERATE WHEN BOTH SWITCHES

INPUT X_1, X_2

OUTPUT Y_3

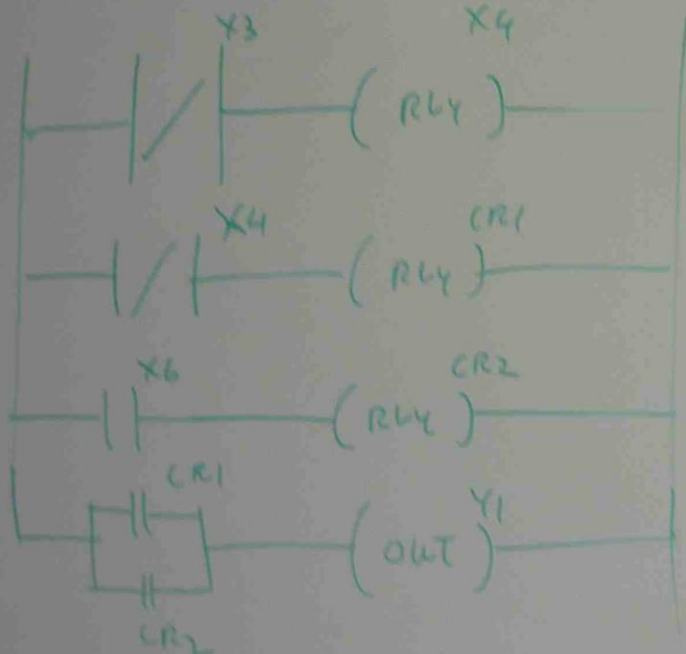


P1) A NORMALLY CLOSED PUSH BUTTON SWITCH IS CONNECTED TO INPUT X_4 AND A NORMALLY OPEN PUSH BUTTON SWITCH IS CONNECTED TO INPUT X_5. THESE TWO PUSH BUTTON SWITCHES ARE TO BE USED TO CONTROL THE OPERATION OF OUTPUT Y_7.



MOTOR STARTER CIRCUIT

PD A NORMALLY CLOSED LIMIT SWITCH IS CONNECTED TO INPUT X_3 AND A NORMALLY OPEN LIMIT SWITCH IS CONNECTED TO INPUT X_6. OUTPUT Y_1 OPERATES ONLY WHEN EITHER LIMIT SWITCH DETECTS AN OBJECT.



INPUT

X_3, X_6

OUTPUT

Y_1

RELAY

X_4, CR_1, CR_2

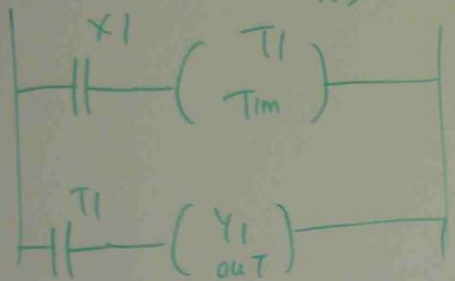
SIMULATION

IN	OUT
$X_3=0$ $X_6=0$	$Y_1=0$
$X_3=1$ $X_6=0$	$Y_1=1$
$X_3=0$ $X_6=1$	$Y_1=1$
$X_3=1$ $X_6=1$	$Y_1=1$

TIME DELAY LADDER

Pb) OUTPUT Y_1 OPERATES 0.5 SEC AFTER THE EXTERNAL SWITCH CONNECTED TO INPUT X_1 IS CLOSED.

K5

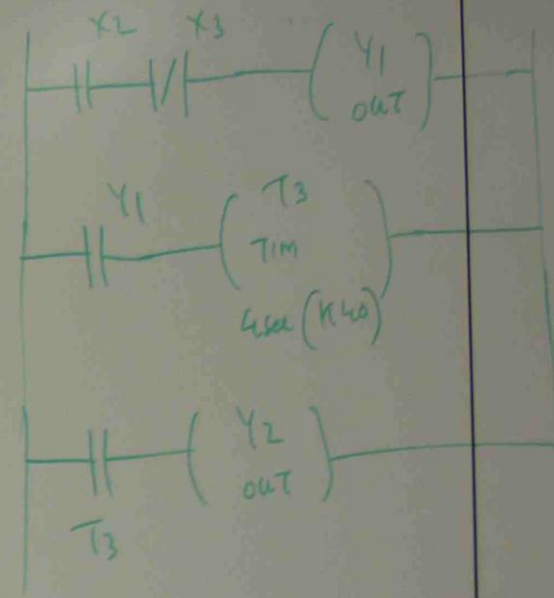


INPUT X1

OUTPUT Y1

IN	OUT
$X_1=0$	$Y=0$
$X_1=1$	$Y_1=1$

SIMULATION



INPUT X_2

X_3

OUTPUT Y_1

Y_2

TIMER T_3 4sec

Pb OUTPUT Y_1 OPERATES VIA A START BUTTON CONNECTED TO INPUT X_2 AND TURN OFF BY A STOP BUTTON CONNECTED TO INPUT X_3. Y_2 SHOULD OPERATE VIA TIMER T_3, 4 SEC AFTER Y_1 IS ENERGIZED. THE STOP BUTTON SHOULD TURN ALL OUTPUTS OFF.

.005)

TYPES

J, K, T, N, R, S, E

cion

OLE IS

TEMPERATURE

AND COLD

USED.

ATED IN mV/°C

), ALUMEL (NEGATIVE) - TYPE K

), CONSTANTAN (NEGATIVE) - TYPE J

THERMO PILES

THERMO PILES ARE CONSTRUCTED TO INCREASE THE OUTPUT LEVEL OF THERMOCOUPLE

JUNCTIONS ARE CONNECTED IN SERIES TO INCREASE OUTPUT