Basic Analog Electronic Circuits

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9-17-2014 Basic_Analog_Circuits.ppt

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OUTLINE

Introduction
Op Amp
Comparator
Bistable Multivibrator
RC Oscillator
RC Integrator
Peak Detector
Switched Capacitor Amplifier
Capacitors
Design Examples
References
Homework

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INTRODUCTION

Analog electronic circuits are different from digital circuits in that the signals are expected to have any value rather than two discrete values. Primitive analog components include the diode, mosfet, BJT, resistor, capacitor, etc,. Analog circuit building blocks include single stage amplifiers, differential amplifiers, constant current sources, voltage references, etc. Basic analog electronic ciruits include the operational amplifier, inverting amplifier, non-inverting amplifier, integrator, bistable multivibrator, peak detector, comparator, RC oscillator, etc. Mixed-mode analog integrated circuits include D-to-A, A-to-D, etc.

This document will introduce some Basic analog electronic circuits.

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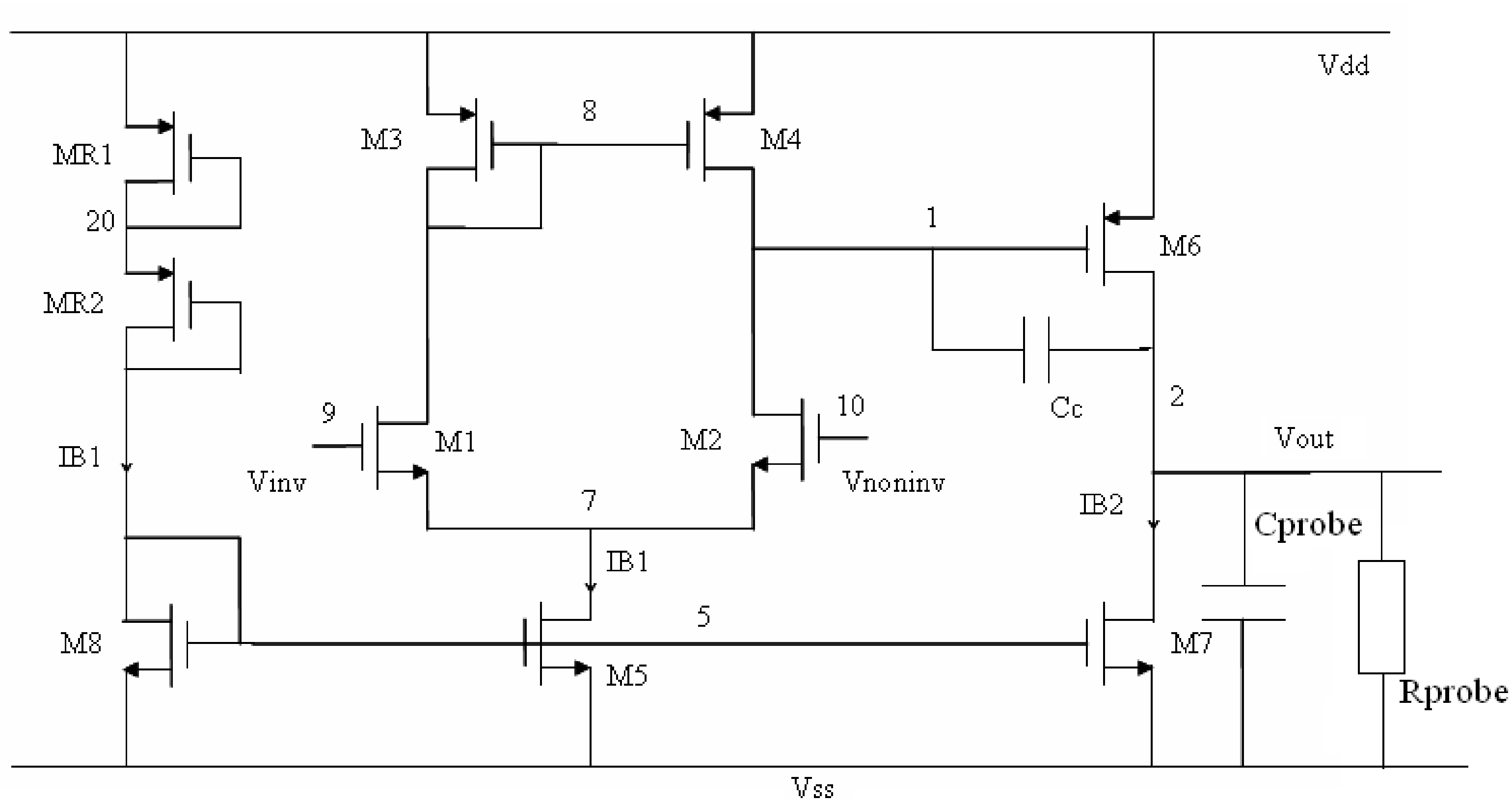
BASIC TWO STAGE OPERATIONAL AMPLIFIER



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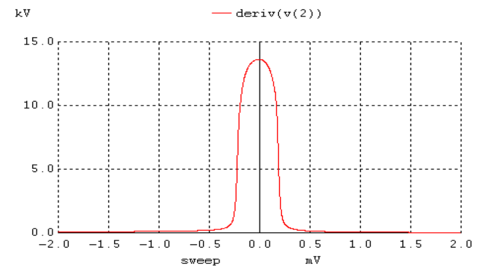
SPICE ANALYSIS OF OP AMP VERSION 2

```
.incl rit_sub_param.txt
m1 8 9 7 6 cmosn w=9u l=5u nrd=1 nrs=1 ad=45p pd=28u as=45p ps=28u
m2 1 10 7 6 cmosn w=9u l=5u nrd=1 nrs=1 ad=45p pd=28u as=45p ps=28u
m3 8 8 4 4 cmosp w=21u l=5u nrd=1 nrs=1 ad=102p pd=50u as=102p
    ps=50u
m4 1 8 4 4 cmosp w=21u l=5u nrd=1 nrs=1 ad=102p pd=50u as=102p
    ps=50u
m5 7 5 6 6 cmosn w=40u l=5u nrd=1 nrs=1 ad=205p pd=90u as=205p
    ps=90u
m6 2 1 4 4 cmosp w=190u l=5u nrd=1 nrs=1 ad=950p pd=400u as=950p
    ps=400u
m7 2 5 6 6 cmosn w=190u l=5u nrd=1 nrs=1 ad=950p pd=400u as=950p
    ps=400u
m8 5 5 6 6 cmosn w=40u l=5u nrd=1 nrs=1 ad=205p pd=90u as=205p
    ps=90u
vdd 4 0 3
vss 6 0 -3
cprobe 2 0 30p
Rprobe 2 0 1meg
cc 1 2 0.6p
mr1 20 20 4 4 cmosp w=6u l=10u nrd=1 nrs=1 ad=200p pd=60u as=200p
    ps=60u
mr2 5 5 20 4 cmosp w=6u l=10u nrd=1 nrs=1 ad=200p pd=60u as=200p
    ps=60u
***************
*************
```



13.5kV/V gain

```
***dc open loop gain*********
vi1 9 0 0
vi2 10 0 0
*.dc vi2 -0.002 0.002 1u
.dc vi2 -1 1 0.1m
*****open loop frequency
    characteristics*****
*vi1 9 0 0
*vi2 10 0 dc 0 ac 1u
*.ac dec 100 10 1g
.end
```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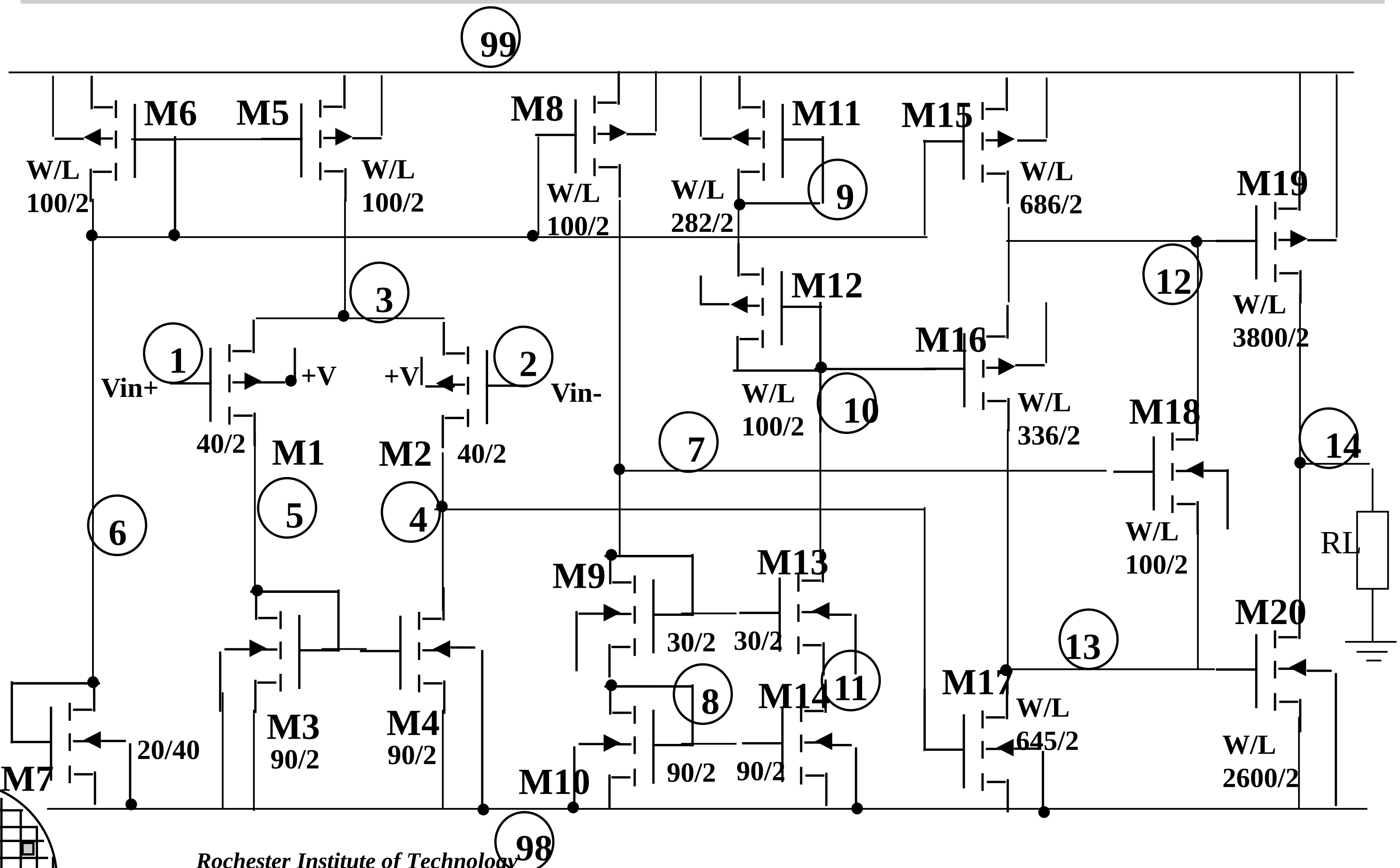
OPERATIONAL AMPLIFIER

RIT OP AMP WITH OUTPUT STAGE



W/L

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OPERATIONAL AMPLIFERS

The 741 Op Amp is a general purpose bipolar integrated circuit that has input bias current of 80nA, and input voltage of +/- 15 volts @ supply maximum of +/- 18 volts. The output voltage can not go all the way to the + and - supply voltage. At a minimum supply of +/- 5 volts the output voltage can go ~6 volts p-p.

The newer Op Amps have rail-rail output swing and supply voltages as low as +/- 1.5 volts. The MOSFET input bias currents are ~ 1pA. The NJU7031 is an example of this type of Op Amp.

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LOW VOLTAGE, RAIL-TO-RAIL OP AMP

JRC **NJU7031/32/34**

LOW VOLTAGE C-MOS OPERATIONAL AMPLIFIER

■ GENERAL DESCRIPTION

The NJU7031/32/34 are single, dual and quad single supply, low offset, output full swing C-MOS Operational Amplifiers.

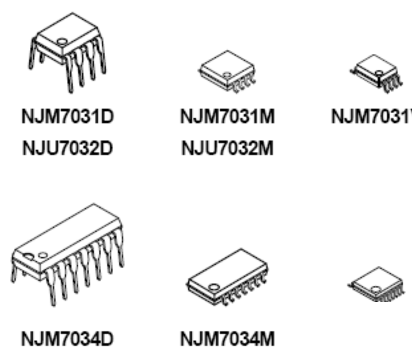
The wide operating voltage 3V to 16V, High slew rate 3.5V/µs and output full swing are suitable for fast signal processing amplifiers. Additionally, low input bias current 1pA, and single supply operation offer amplification of the very small signal around the ground level.

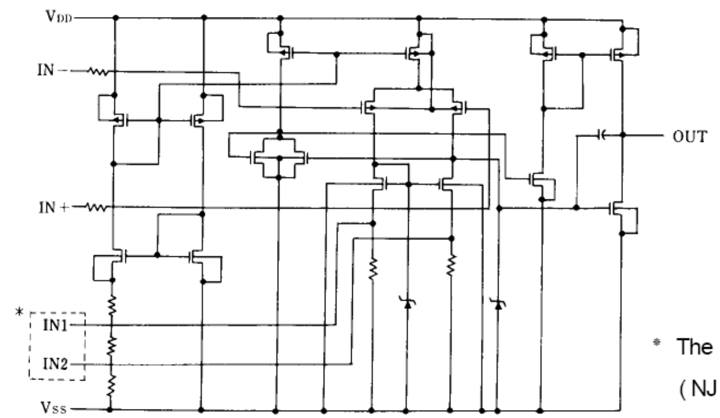
The NJU7031 has external offset null function.

■ FEATURES

- High Slew Rate 3.5V/µs
- Wide Operating Voltage +3V to +16V
- Output Voltage with full Swing V_{OM}=9.98V typ. (@V_{DD}=10V)
- Input Common Mode Voltage Range V_{ICM}=0V to 9V (@V_{DD}=10V)
- Low Bias Current I_B=1pA typ.
- Input Common Mode Voltage range includes ground.
- External Offset Null Adjustment (Only NJU7031)
- C-MOS Technology
- Package Outline NJU7031 (single) DIP8, DMP8, SSOP8
  NJU7032 (dual) DIP8, DMP8
  NJU7034 (quad) DIP14, DMP14, SSOP14

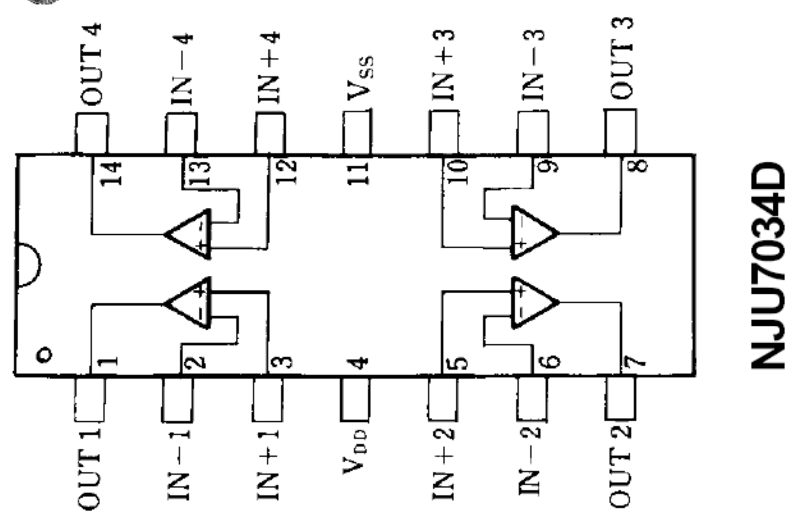
■ PACKAGE OUTLINE





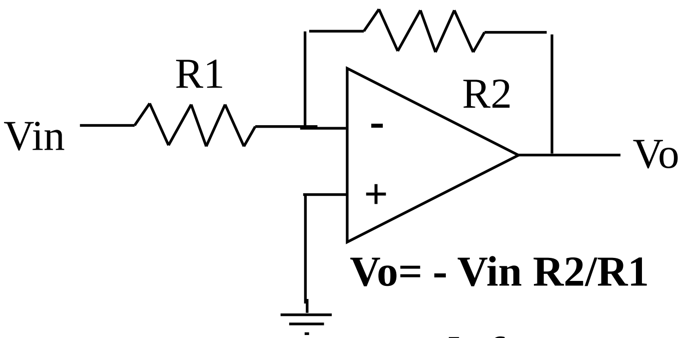
* The
(NJ

New Japan Radio Co.,Ltd



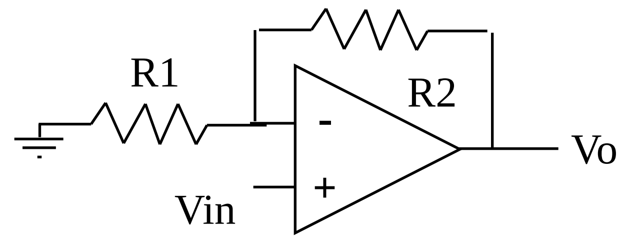
SOME BASIC ANALOG ELECTRONIC CIRCUITS

These circuits should be familiar:



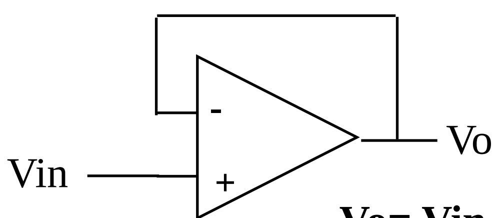
Vo= - Vin R2/R1

Inverting Amplifier



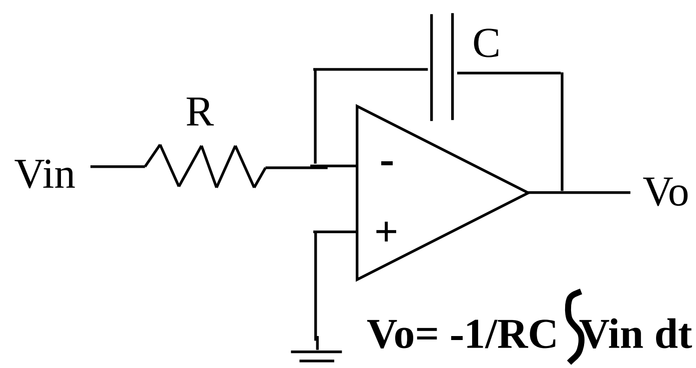
Vo= Vin (1 + R2/R1)

Non-Inverting Amplifier



Vo= Vin

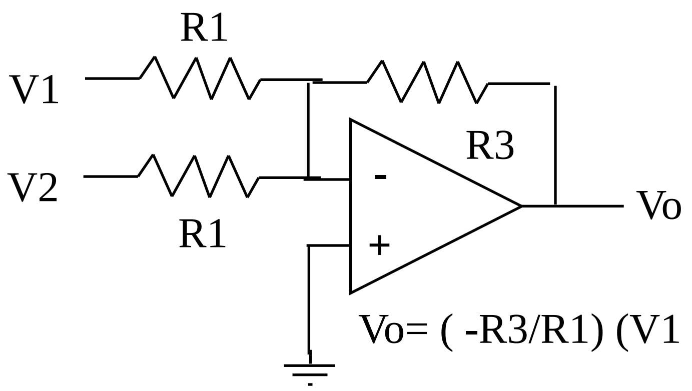
Unity Gain Buffer



Vo= -1/RC ∫Vin dt

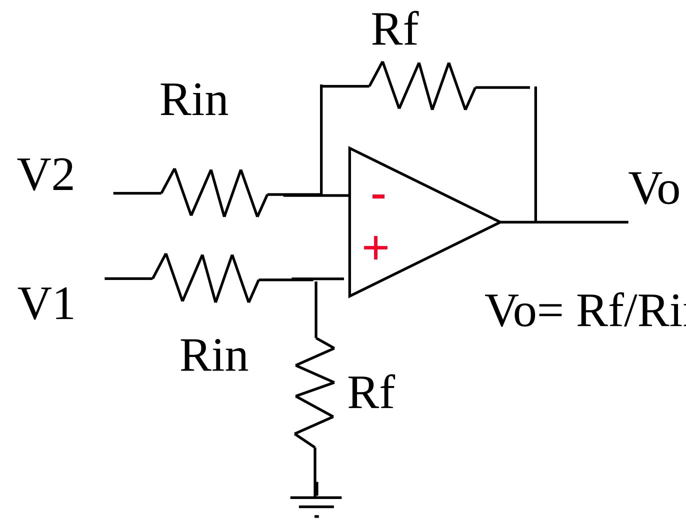
Integrator

SOME BASIC ANALOG ELECTRONIC CIRCUITS



Vo= (-R3/R1) (V1 + V2)

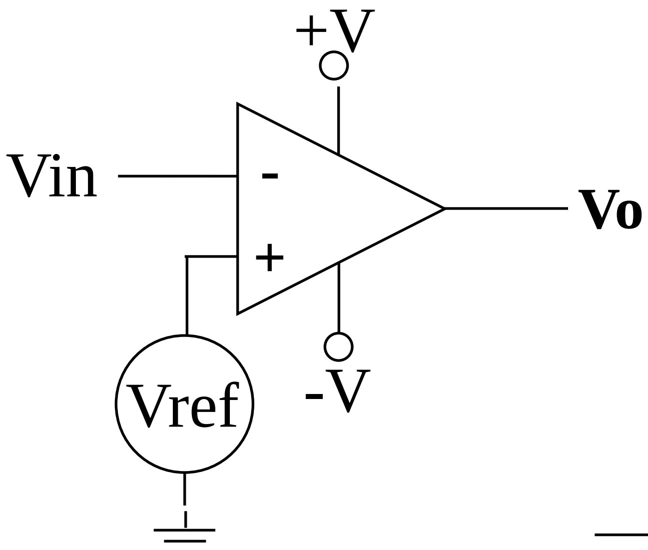
Inverting Summer

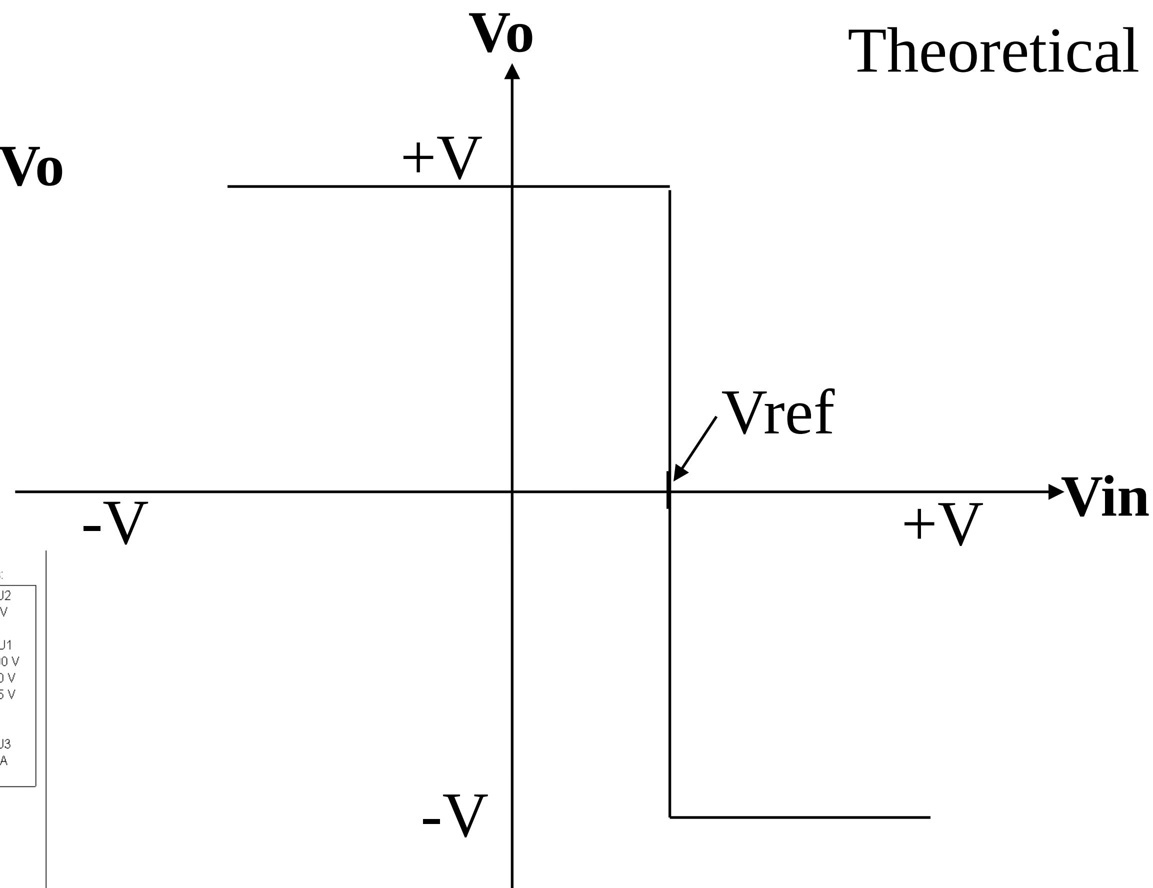


Vo= Rf/Rin (V1-V2)

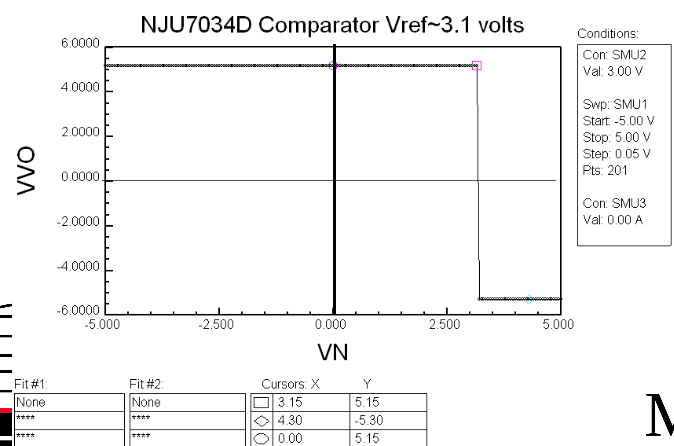
Difference Amplifier

COMPARATOR



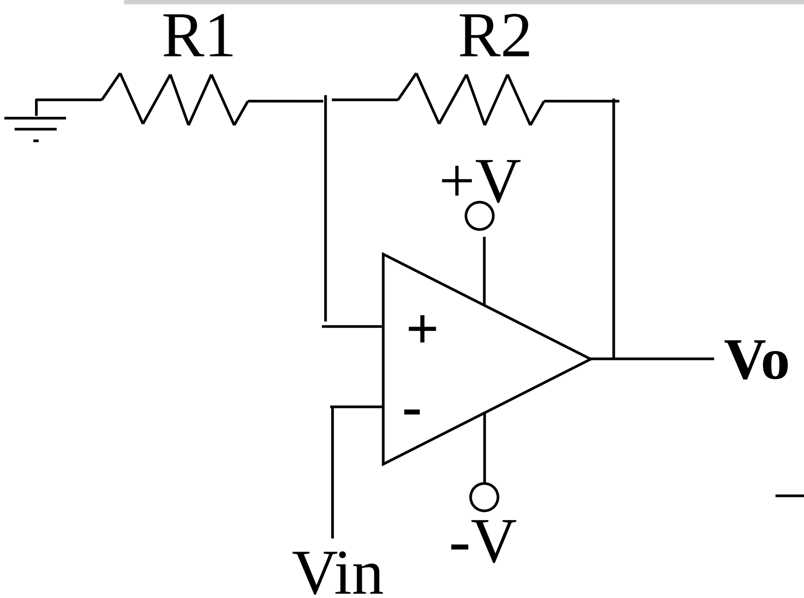


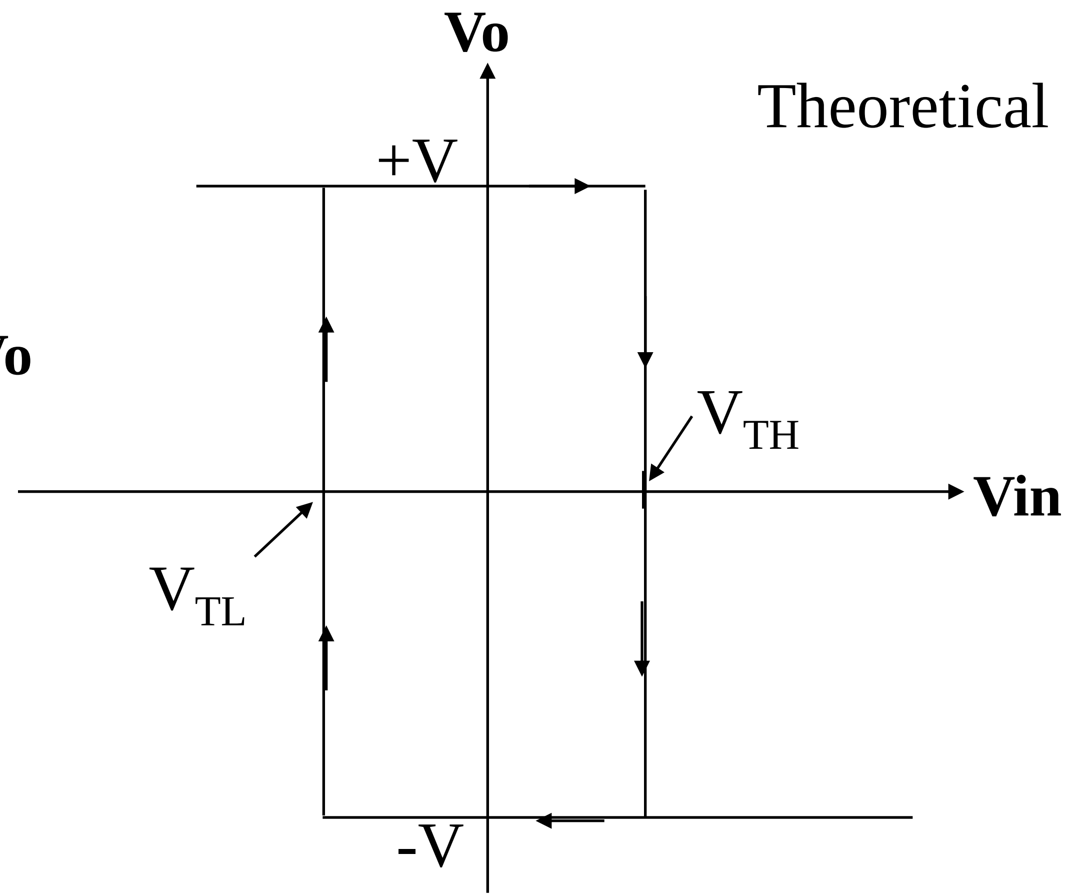
Theoretical



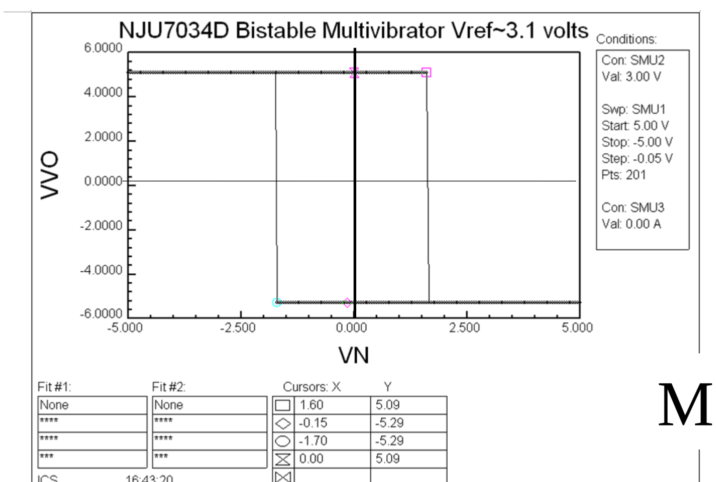
Measured

BISTABLE CIRCUIT WITH HYSTERESIS





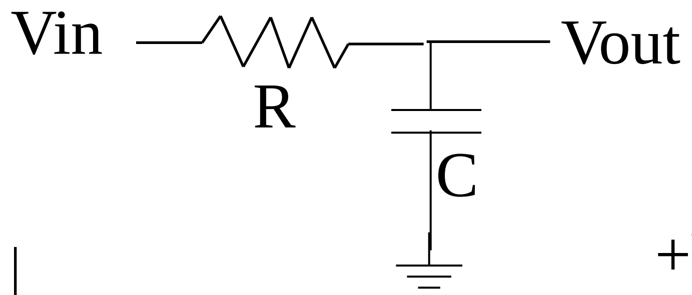
Theoretical

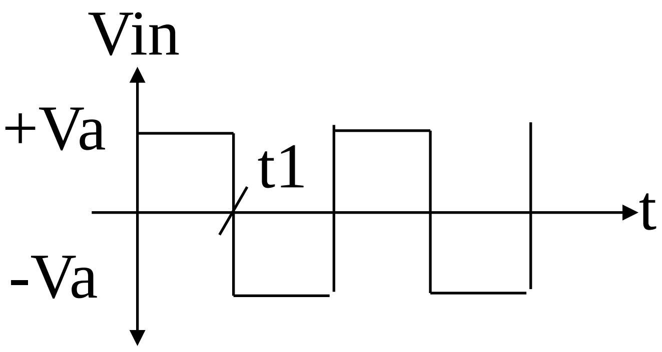


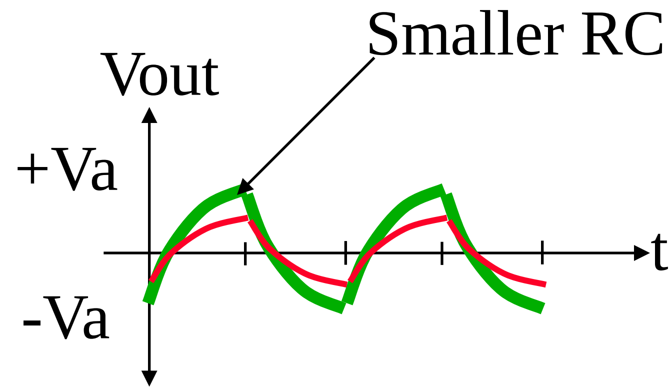
Measured

Sedra and Smith pg 1187

RC INTEGRATOR







$$Vout = (-Va) + [2Va(1-e^{-t/RC})] \quad \text{for } 0<t<t1$$

If R=1MEG and C=10pF find RC=10us
so t1 might be ~20us

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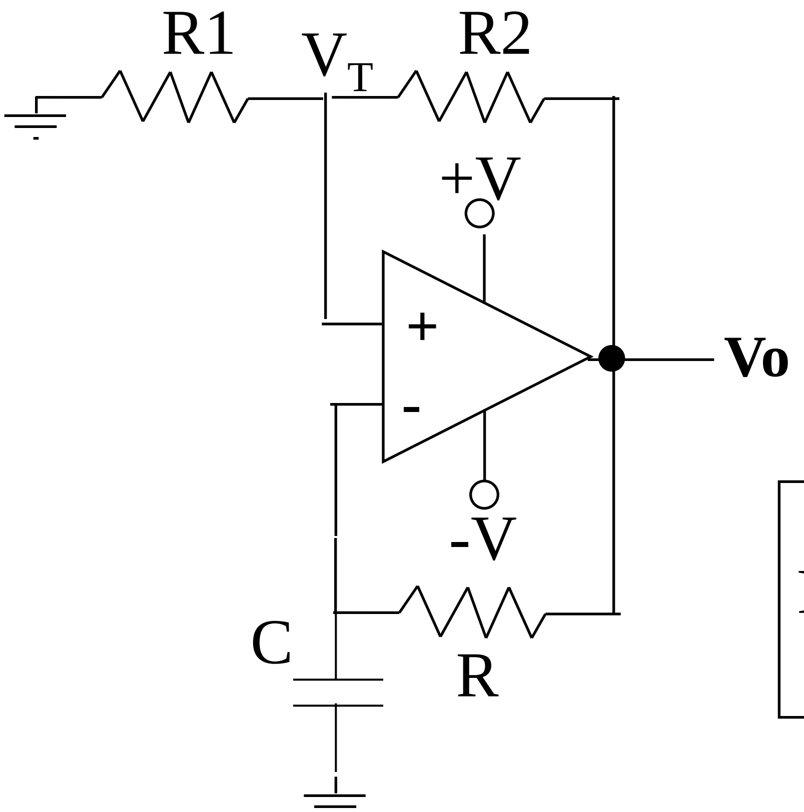
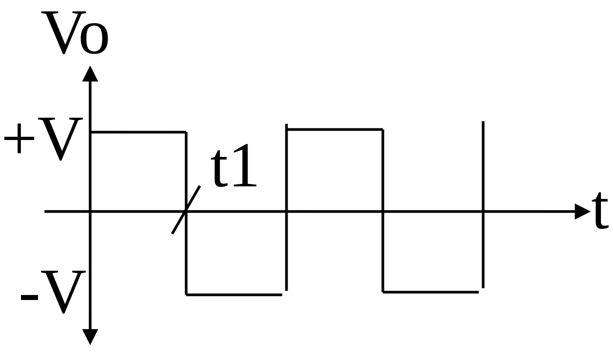
OSCILLATOR (MULTIVIBRATOR)



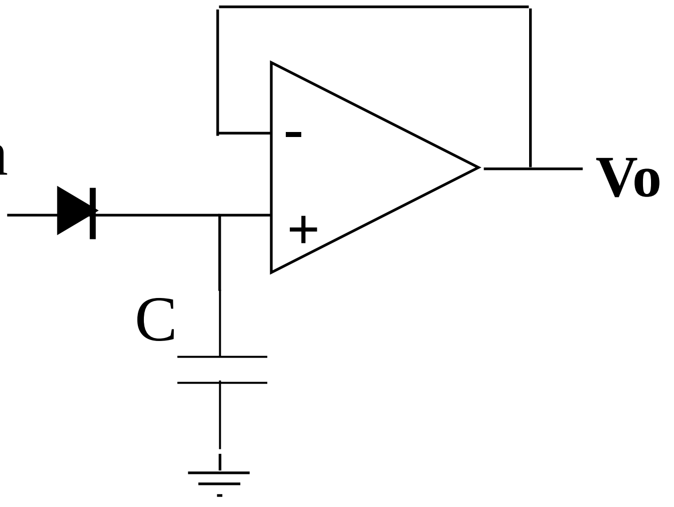


$$\text{Period} = T = 2RC \ln \left(\frac{1+Vt/V}{1-Vt/V} \right)$$

Bistable Circuit with Hysteresis and RC Integrator

PEAK DETECTOR

Variable Vin

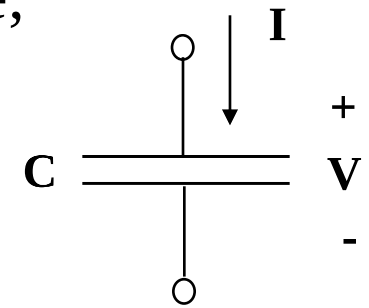


Diode reverse leakage current ~100nA

CAPACITORS

Capacitor - a two terminal device whose current is proportional to the time rate of change of the applied voltage;

$$I = C\ dV/dt$$



a capacitor C is constructed of any two conductors separated by an insulator. The capacitance of such a structure is:

$C = \varepsilon o\ \varepsilon r\ Area/d$ where εo is the permitivitty of free space

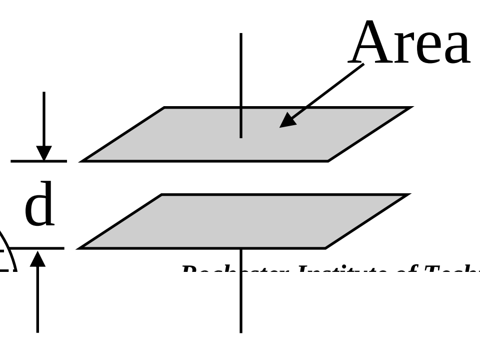
εr is the relative permitivitty

Area is the overlap area of the two conductor separated by distance d

$\varepsilon o = 8.85E\text{-}14$ F/cm

εr air = 1

$\varepsilon r\ SiO_2 = 3.9$



DIELECTRIC CONSTANT OF SELECTED MATERIALS

Vacuum	1
Air	1.00059
Acetone	20
Barium strontium titanate	500
Benzene	2.284
Conjugated Polymers	6 to 100,000
Ethanol	24.3
Glycerin	42.5
Glass	5-10

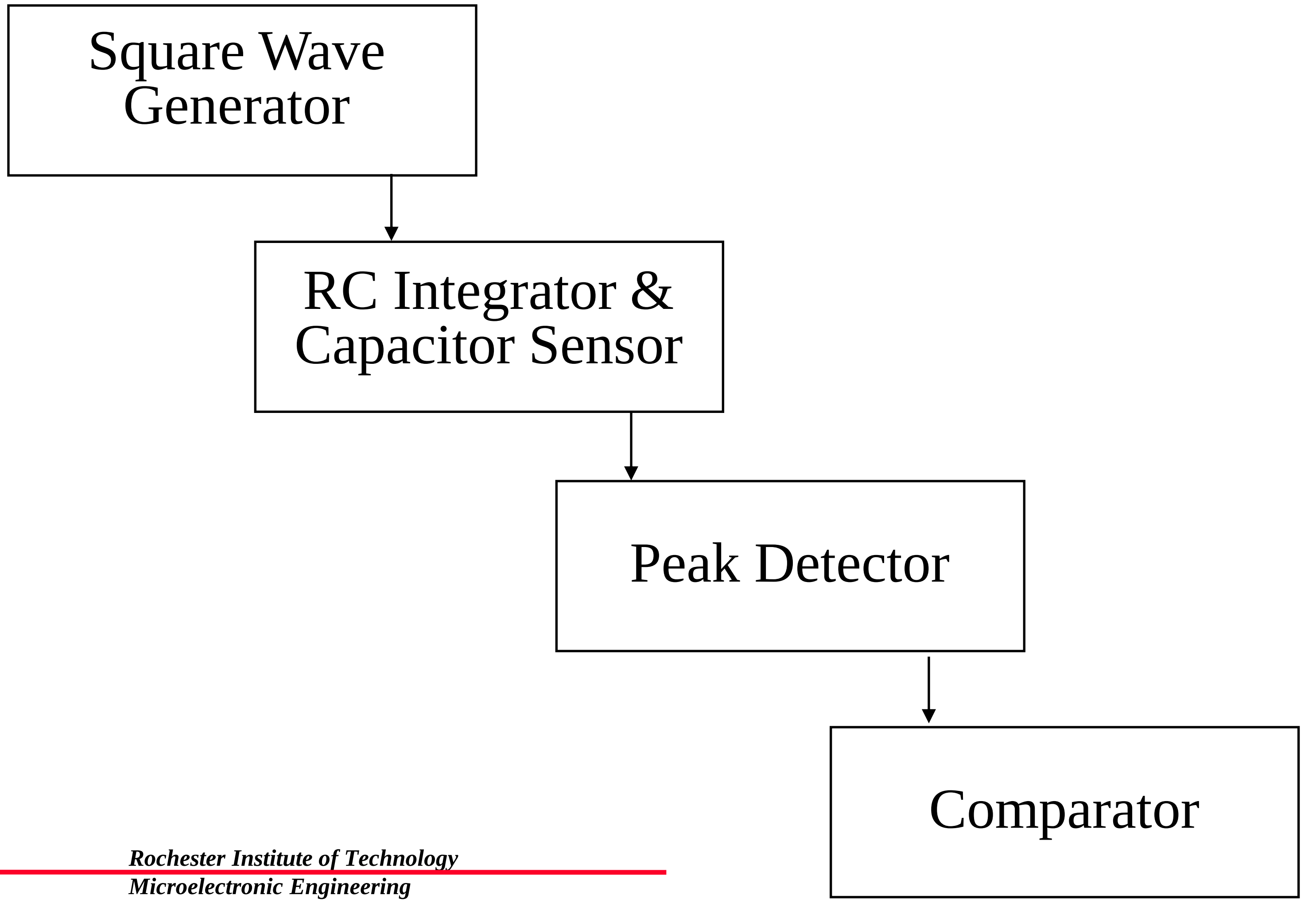
Methanol	30
Photoresist	3
Plexiglass	3.4
Polyimide	2.8
Rubber	3
Silicon	11.7
Silicon dioxide	3.9
Silicon Nitride	7.5
Teflon	2.1
Water	80-88

http://www.asiinstruments.com/technical/Dielectric%20Constants.htm

CALCULATIONS

	A	B	C	D	E	F	G	H	I
1	**Rochester Institute of Technology**								8-Apr-08
2	Dr. Lynn Fuller		Microelectronic Engineering, 82 Lomb Memorial Dr., Rochester, NY 14623						
3									
4	To use this spread sheet enter values in the white boxes. The rest of the sheet is protected and should not be								
5	changed unless you are sure of the consequences. The results are displayed in the purple boxes.								
6									
7	**Capacitance of Two Parallel Plates**								
8	**Capacitance = eoer Area/d**					C =	8.85E-12	F	
9				eo = Permitivitty of free space			8.85E-14	F/cm	
10				er = relative permitivitty =			1		
11						Area =	1.00E-02	cm2	
12				number of pairs of plates, N =			1		
13				distance between plates, d =			1	µm	
14				If round plates, Diameter =			0	µm	
15				If rectangular plates, length =			1000	µm	
16				If rectangular plates, width =			1000	µm	
17	**Force Between Two Parallel Plates**					Force =	4.43E-04	N	
18	**Electrostatic Force= eoer Area $V^2/2d^2$**				Applied Voltage, V =		10	volts	
19									
20	**Capacitance for very Thick Interdigitated Fingers**								
21		**C = (N-1) eoer L h/s**			Capacitance, C =		1.77E-13	F	
22				Number of Fingers, N =			101		

DESIGN EXAMPLE



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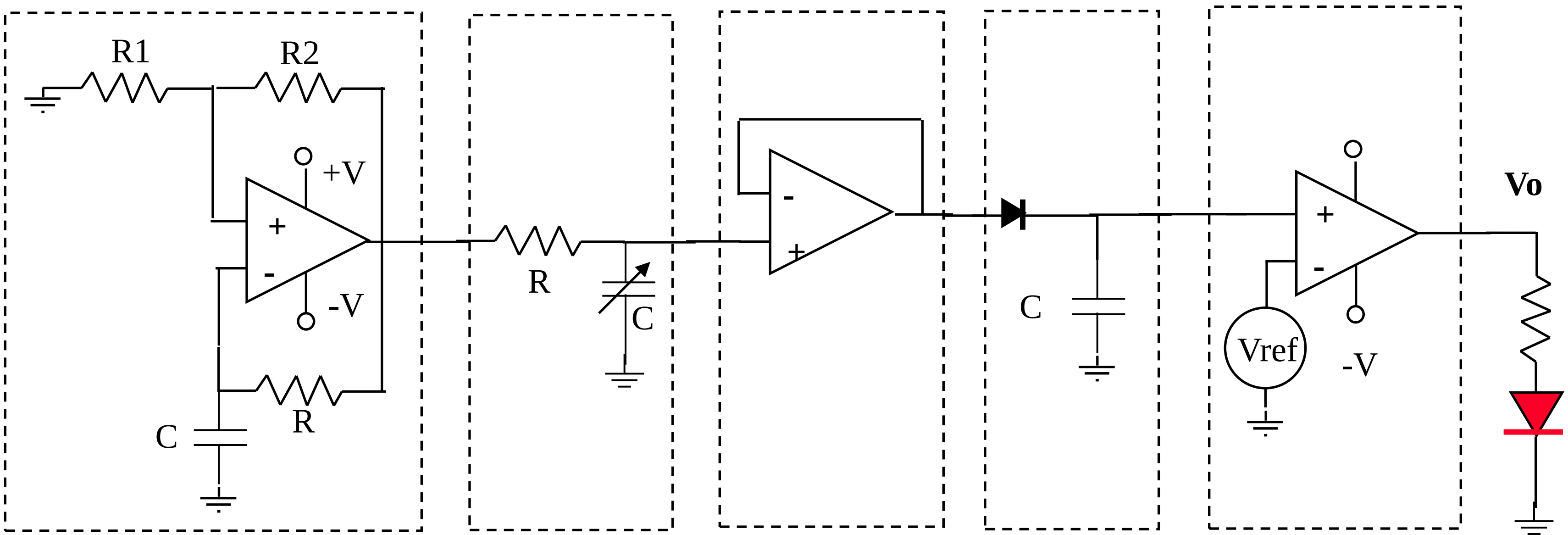
DESIGN EXAMPLE – CAPACITOR SENSOR



Square Wave Generator | RC Integrator & Capacitor Sensor | Buffer | Peak Detector | Comparator | Display

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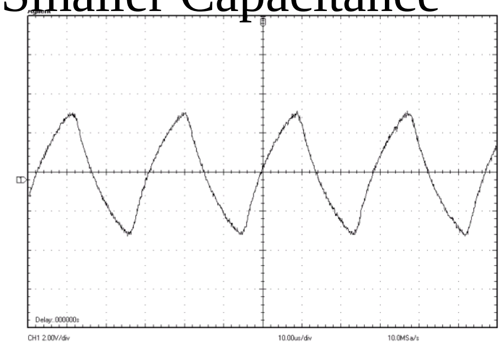
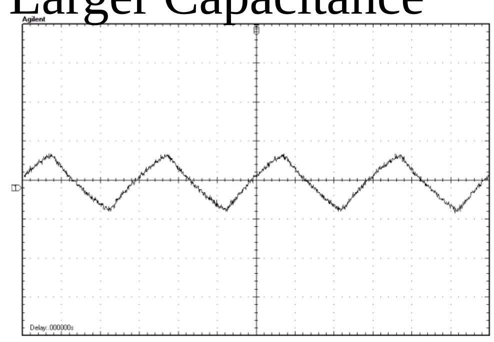
EXAMPLE LABORATORY RESULTS

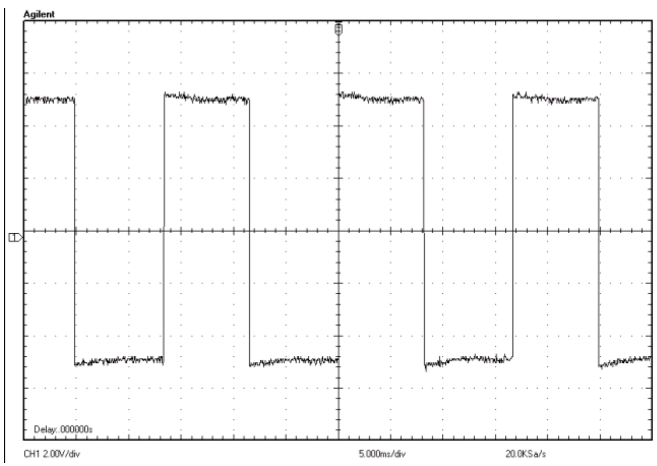
Smaller Capacitance



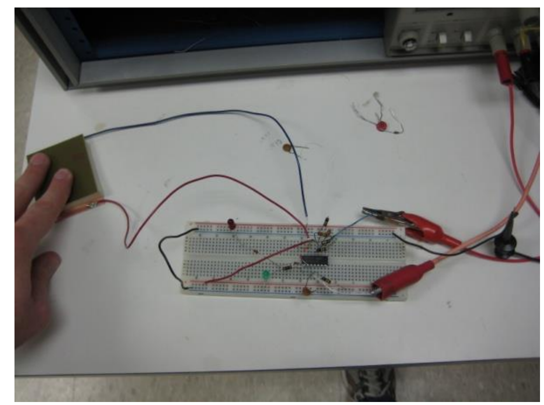
Larger Capacitance



Buffer
Output



Square Wave
Generator
Output



Display

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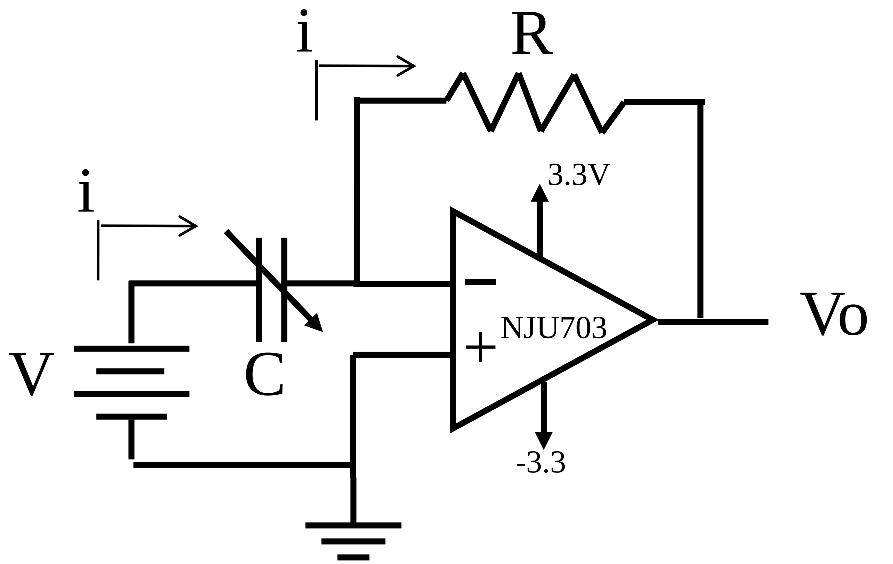
CAPACITOR MICROPHONE PLUS AMPLIFIER



Vo = - i R

i = d (CV)/dt , V is constant C = Co + Cm sin (2πft)

i = V Cm 2 π f cos (2πft)

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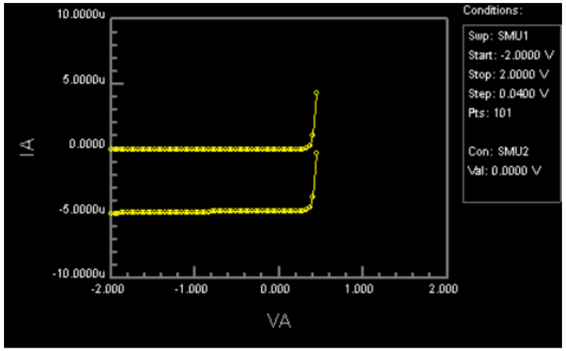
PHOTODIODE I TO V LINEAR AMPLIFIER



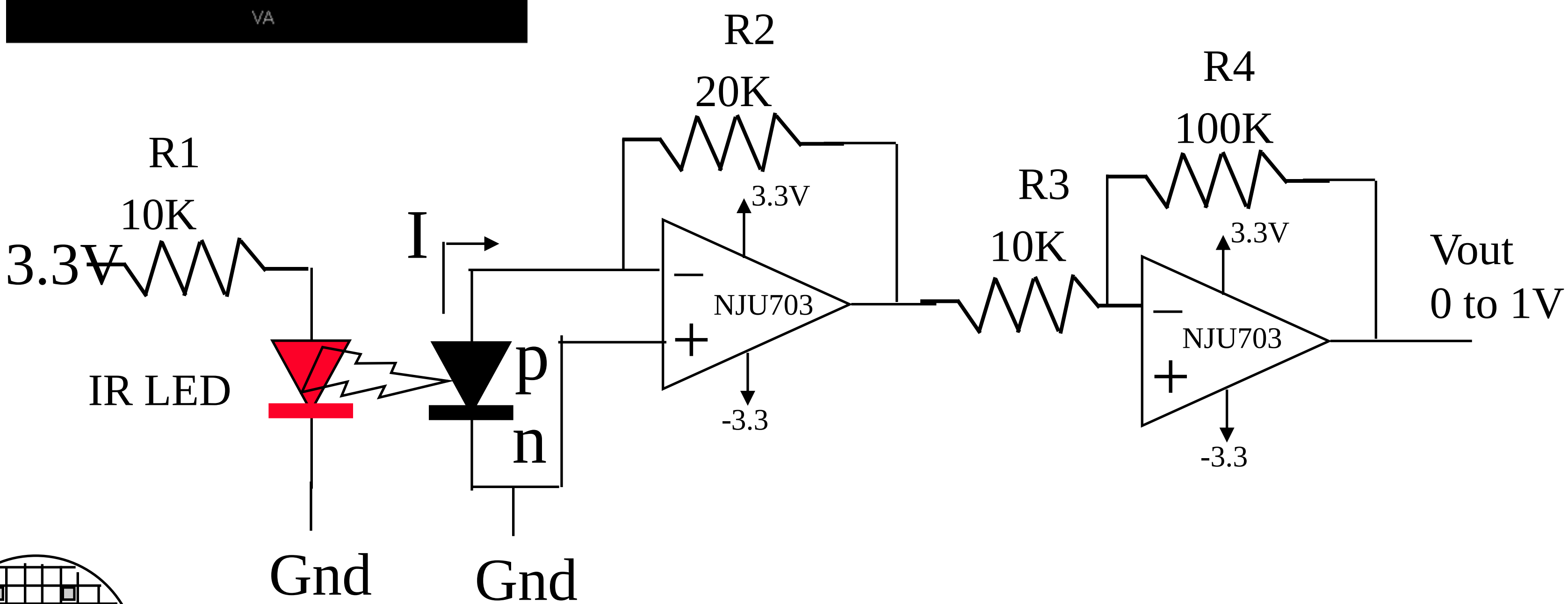


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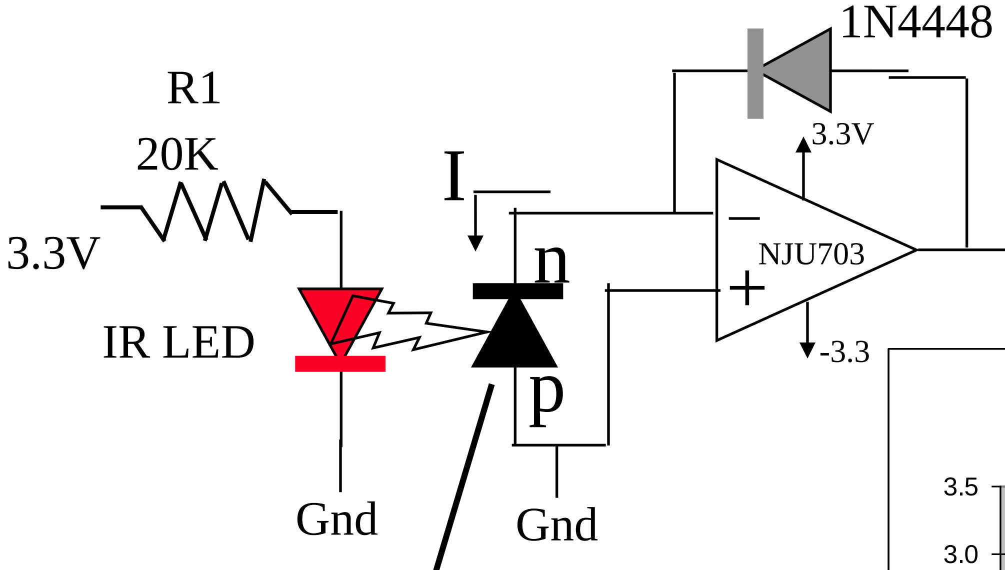
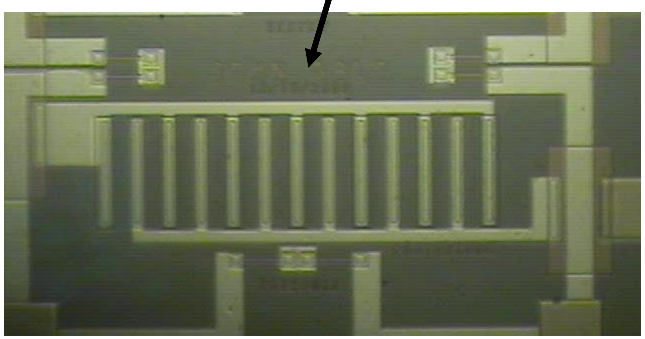
PHOTO DIODE I TO V LOG AMPLIFIER



Linear amplifier uses 100K ohm in place of the 1N4448



Photodiode

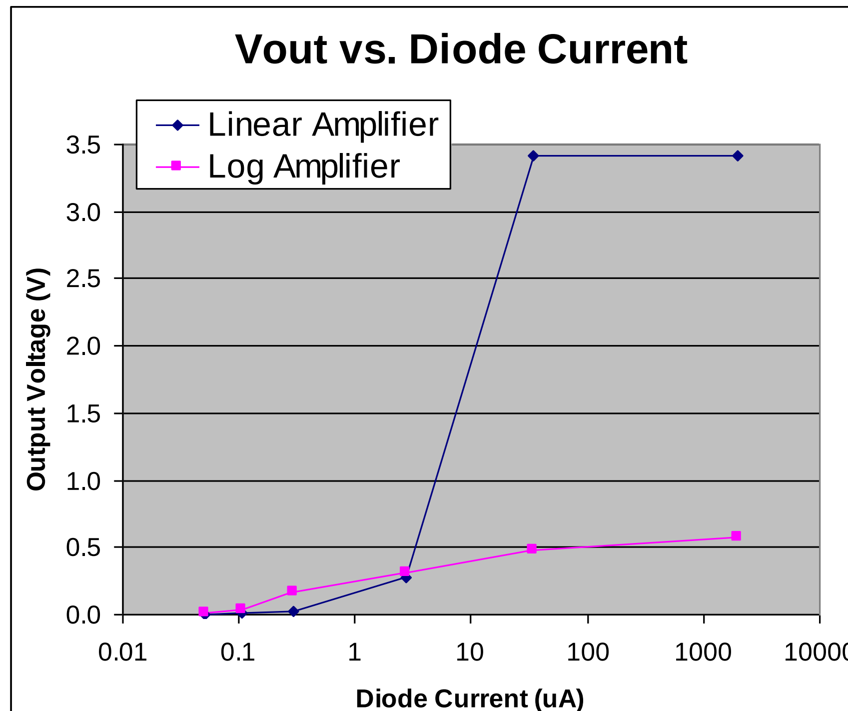
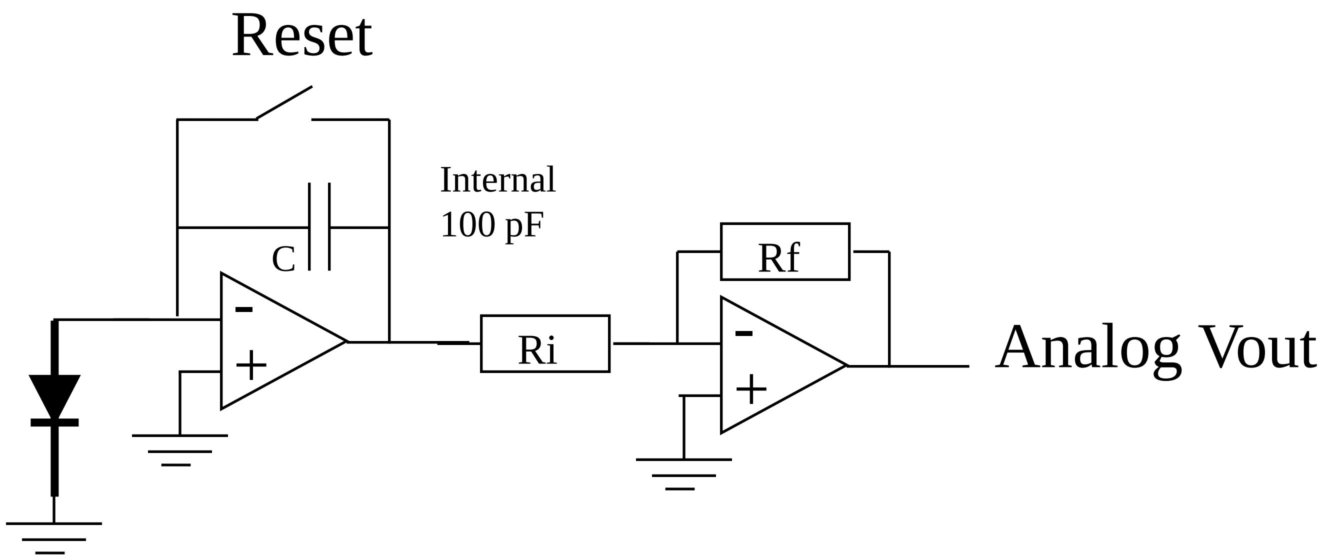


PHOTO DIODE I TO V INTEGRATING AMPLIFIER



Integrator and amplifier allow for measurement at low light levels

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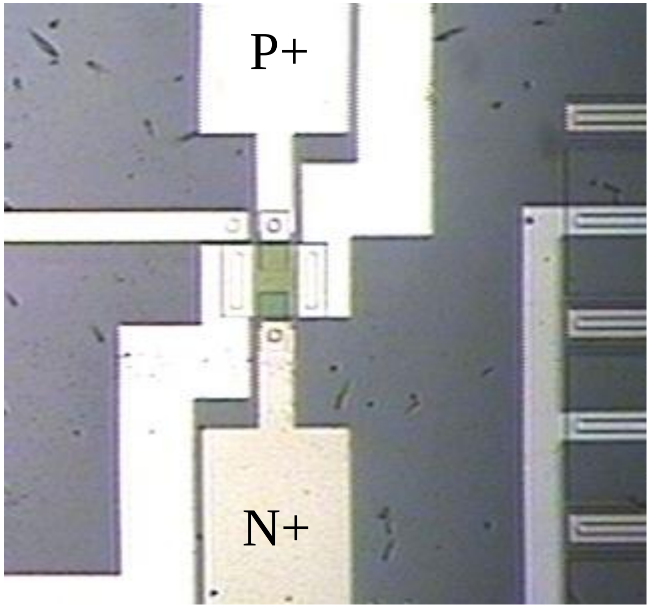
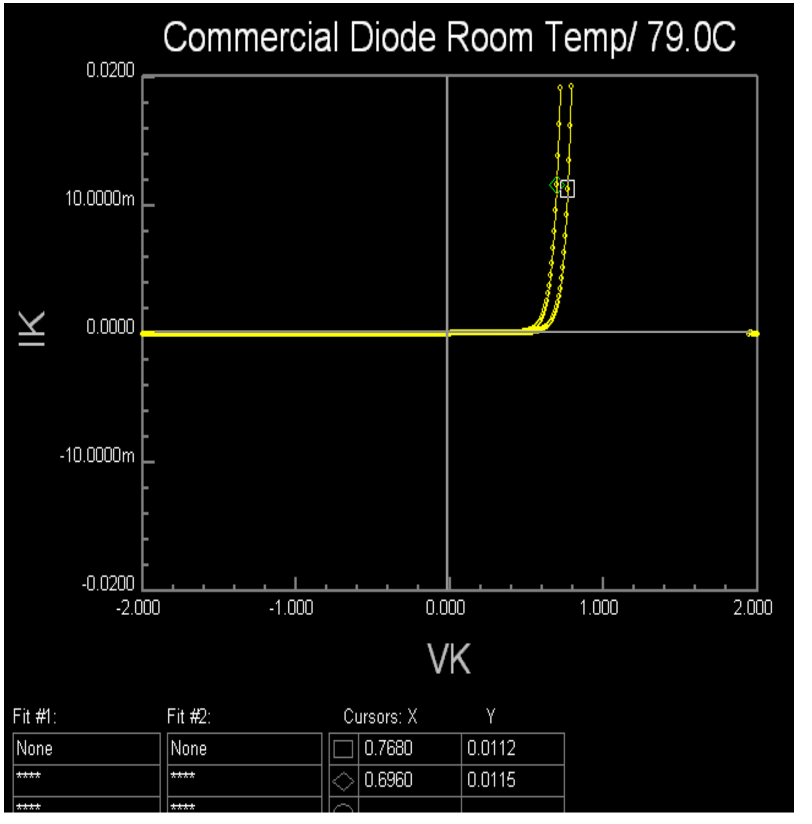
DIODE AS A TEMPERATURE SENSOR

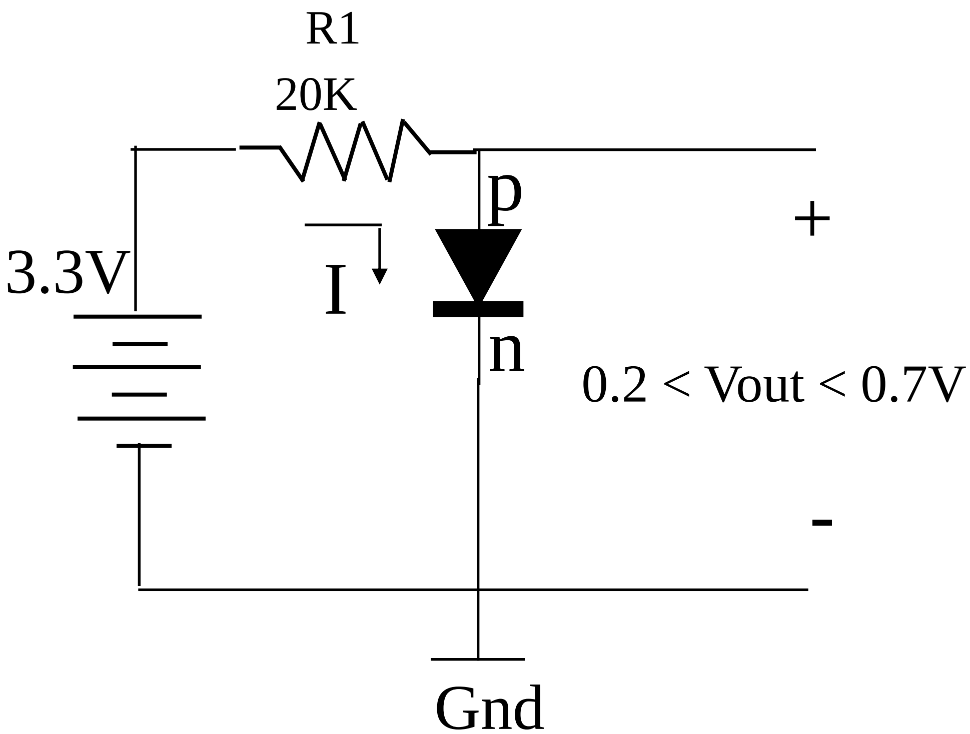


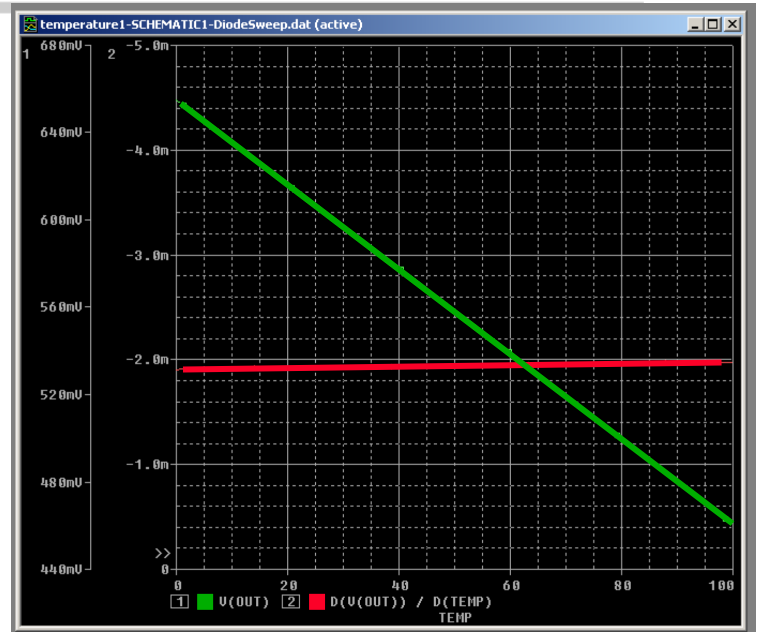
Poly Heater, Buried pn Diode,
N+ Poly to Aluminum Thermocouple

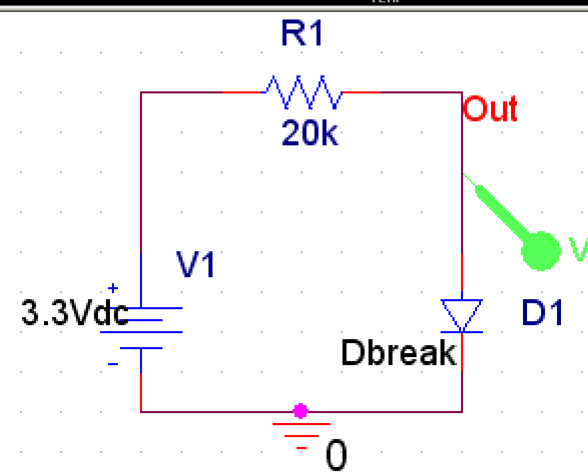


Compare with theoretical -2.2mV/°C

SIGNAL CONDITIONING FOR TEMPERATURE SENSOR



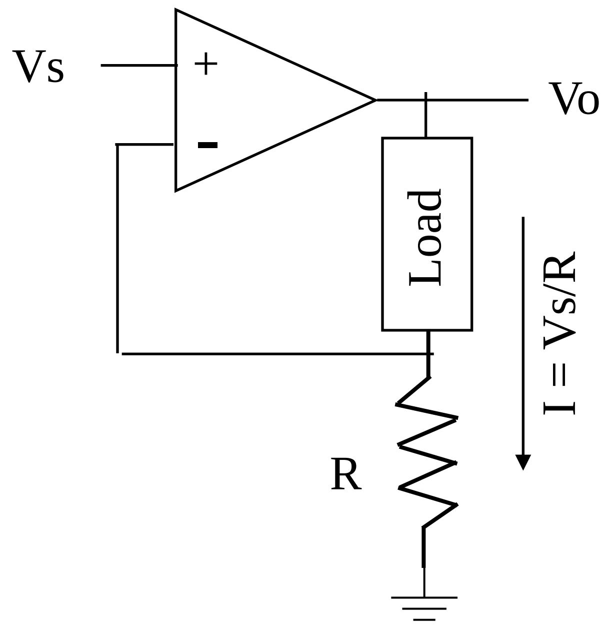




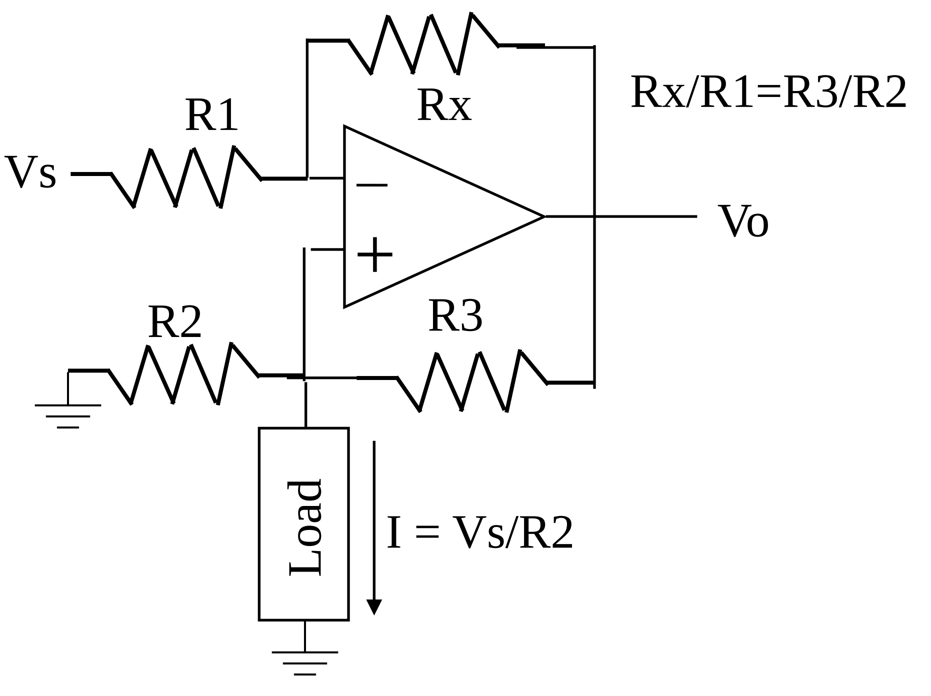
Rochester Institute of Technology
Microelectronic Engineering

OP AMP CONSTANT CURRENT SOURCE

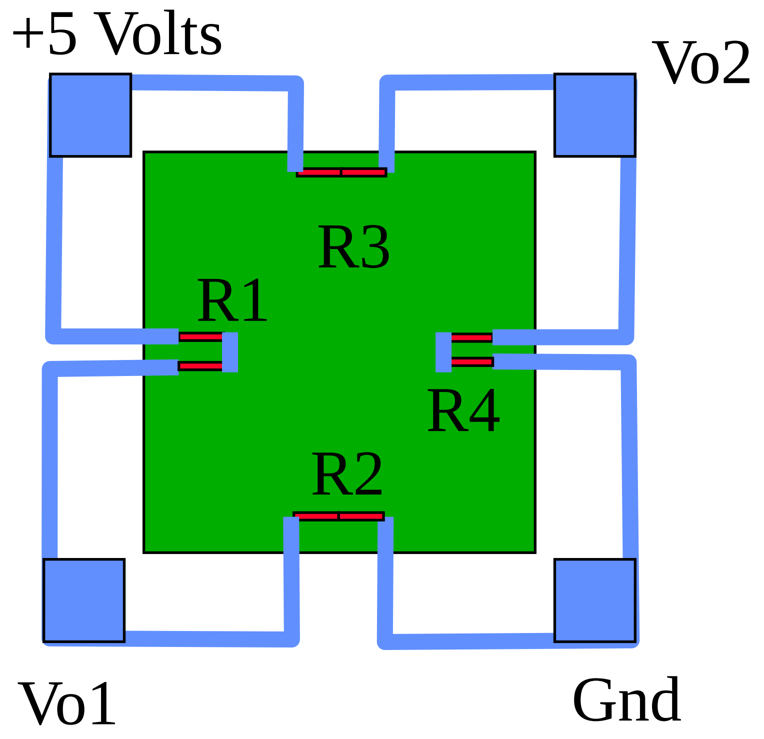
Floating Load



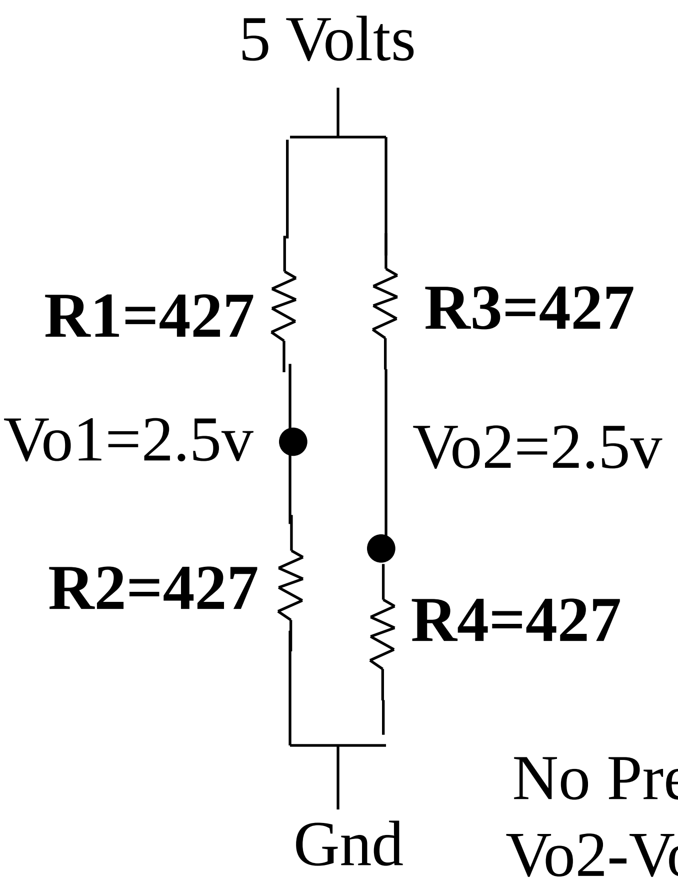
Grounded Load



RESISTIVE PRESSURE SENSOR



Resistors on a Diaphragm



No Pressure
Vo2-Vo1 = 0

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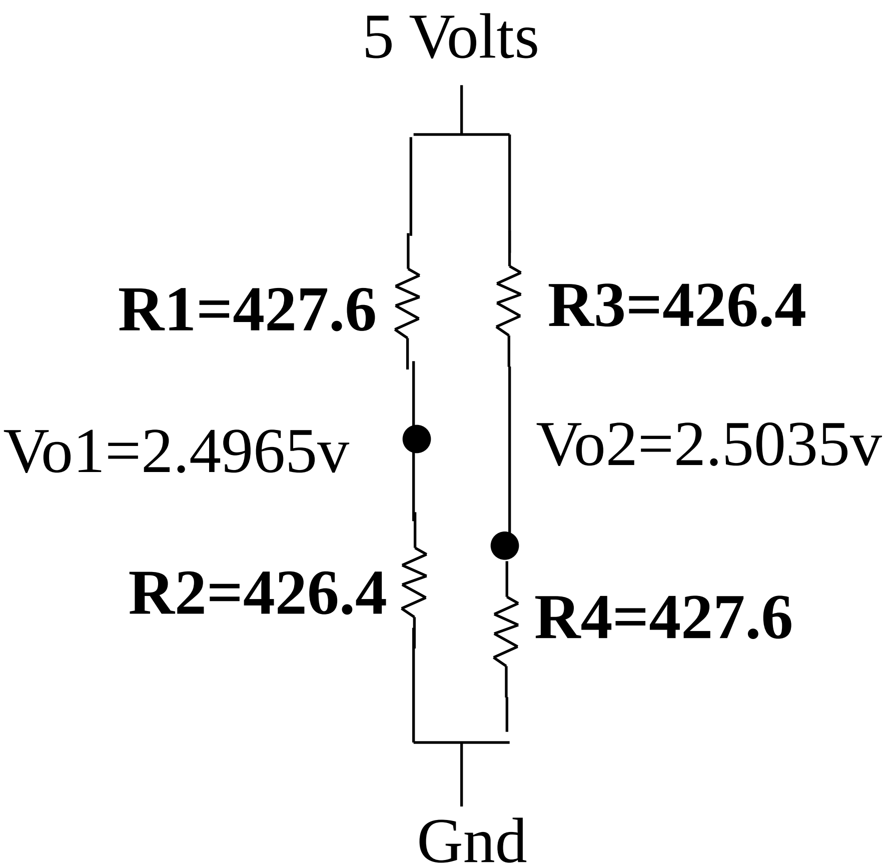
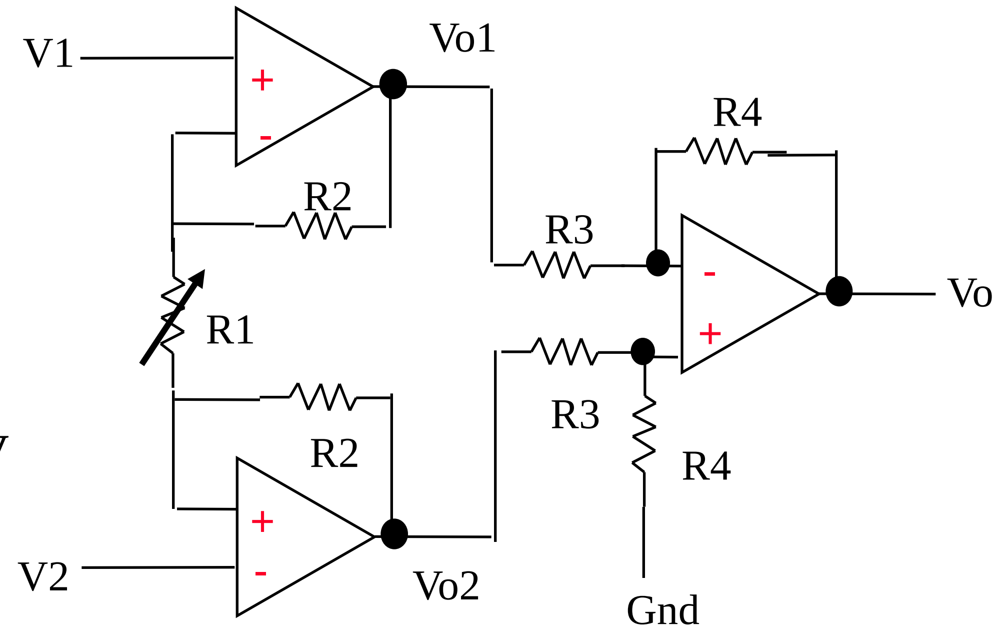
INSTRUMENTATION AMPLIFIER

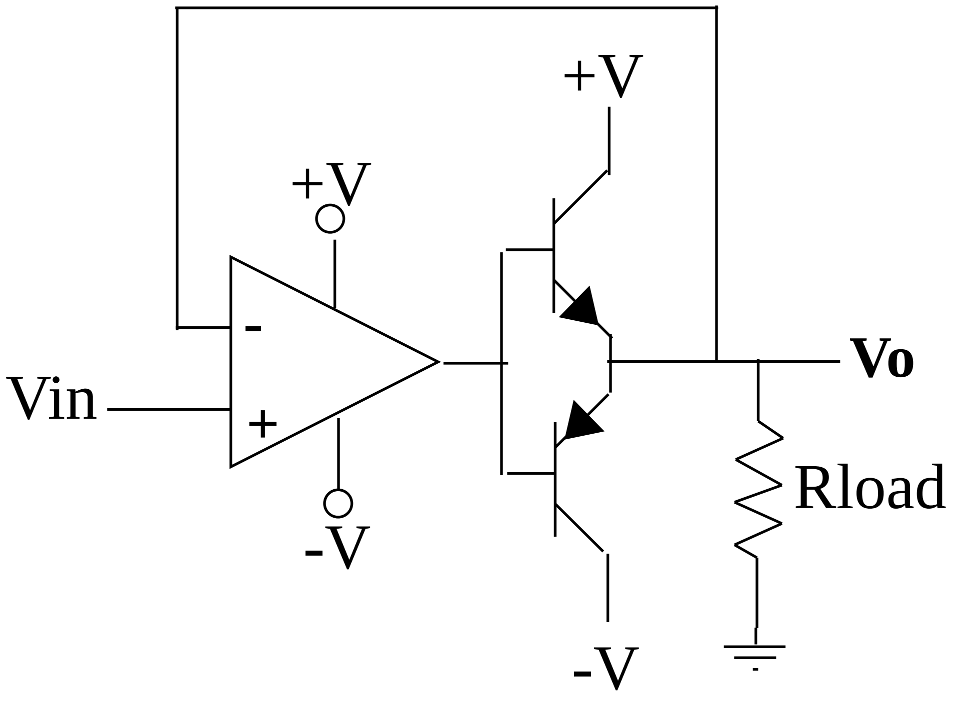




With Pressure
Vo2-Vo1 = 0.007v
=7 mV

$$Vo = (V2-V1)\,\frac{R4}{R3}\left(1 + \frac{2R2}{R1}\right)$$

POWER OUTPUT STAGE



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1. Switched Capacitor Circuits, Phillip E. Allen and Edgar Sanchez-Sinencio, Van Nostrand Reinhold Publishers, 1984.

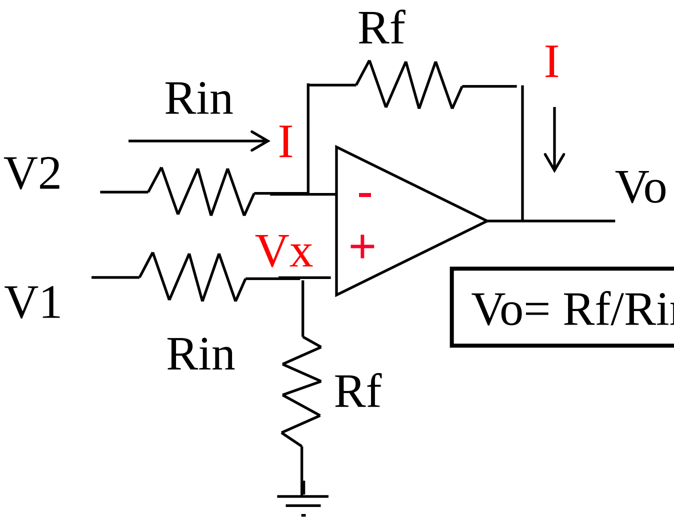
2. "Active Filter Design Using Operational Transconductance Amplifiers: A Tutorial," Randall L. Geiger and Edgar Sanchez-Sinencio, IEEE Circuits and Devices Magazine, March 1985, pg. 20-32.

3. Microelectronic Circuits, 5th Edition, Sedra and Smith

HOMEWORK – BASIC ANALOG CIRCUITS

1. Create one good homework problem and the solution related to the material covered in this document. (for next years students)
2. Design a bistable multivibrator witrh Vth of +/- 7.5 volts and frequency of 5 Khz.
3. Design a temperature sensor circuit that will shut down a heater if the temperature exceeds 90°C
4. Design a peak detector that will respond to changes in input in less than one second.
5. Derive the equation for the oscillator on page 15 (multivibrator).
6. Derive the voltage gain equation for the difference amplifier.

DERIVE GAIN EQUATION FOR DIFFERENCE AMP



Vo= Rf/Rin (V1-V2)

Difference Amplifier

I = (V1-Vx)/Rin

$$Vx = V1 \frac{Rf}{Rf + Rin}$$

Vo = -I Rf + Vx