Single Supply Op Amp Circuits

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3-1-12 OpAmpSingleSupply.ppt

OUTLINE

Introduction
Basic Dual Supply Op Amp Circuits
Power Supplies
NJU 703X Op Amp
LTC 6078 Op Amp
Single Supply Op Amp Circuits
- Virtual Ground
- Inverting Amplifier
- Non Inverting Amplifier
- Comparator
- Multivibrator
- Current to Voltage Converter
- Differential Amplifier

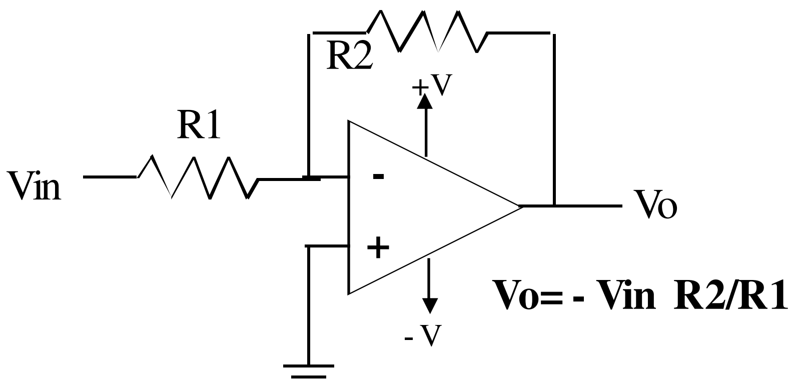
INTRODUCTION

This document discusses single-supply, low-voltage, rail-to-rail, Operational Amplifier (Op Amp) circuits. Although all op amps can operate with single supply or dual supply, most engineers are familiar with dual-supply Op Amp circuits such as those shown on the following page. The dual supply allows the input and output to be easily referenced to zero volts. (analog ground = earth ground)

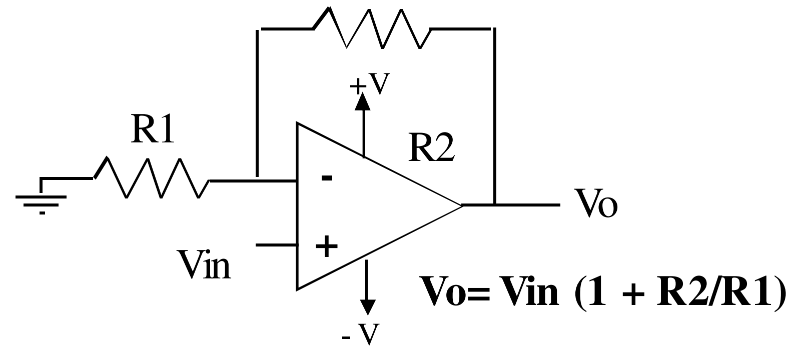
Single supply Op Amps usually refers to low voltage Op Amps using voltages of 5, 3.3 or smaller and ground. Some types of Op Amps will not work at these voltages. (some Op Amps use BJT current source biasing that takes a couple of diode drops of voltage to work thus the output voltage of these Op Amps can only get within 1.4 volts of the supply rails. For example at 5 volts, output is limited between 1.4 volts and 3.6 volts and with 3.3 volts supply some Op Amps may not work at all. With single supply Op Amp circuits we also can not have negative output voltages. There are several techniques for working with these limitations.

SOME BASIC DUAL SUPPLY OP AMP CIRCUITS

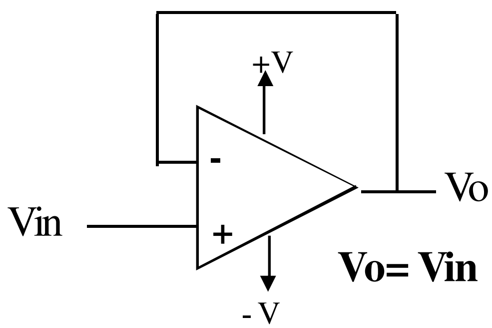
These dual supply circuits should be familiar:



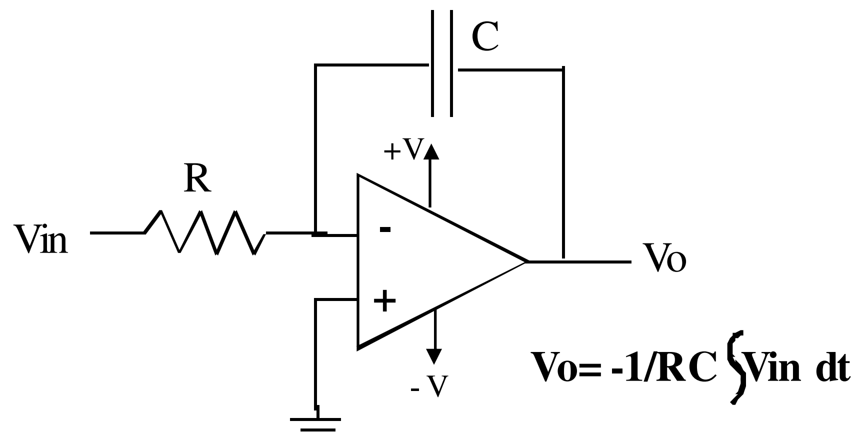
Inverting Amplifier



Non-Inverting Amplifier



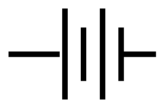
Unity Gain Buffer



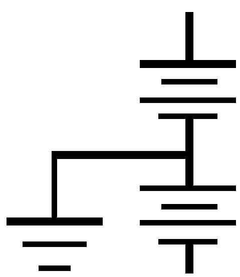
Integrator

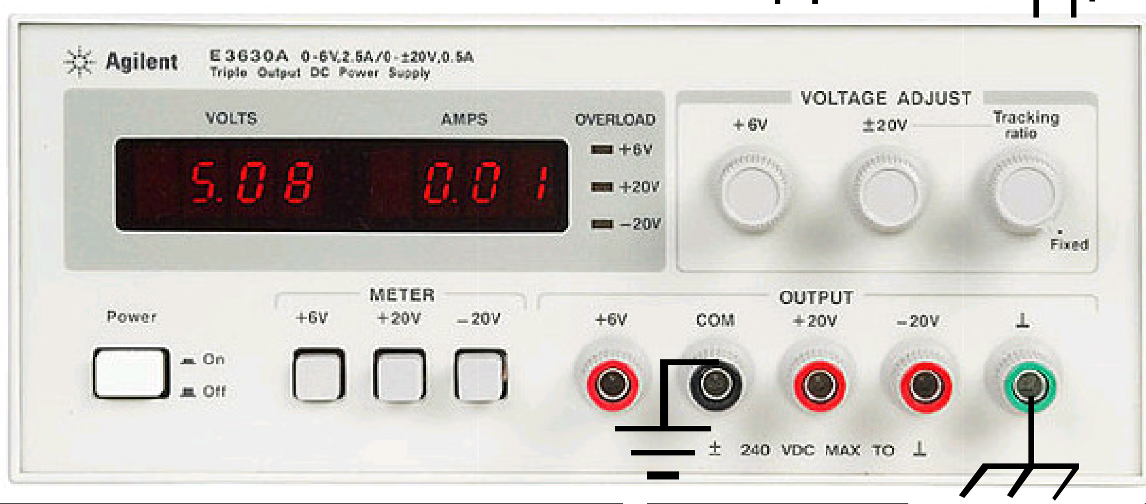
VOLTAGE SUPPLIES

Single Supply



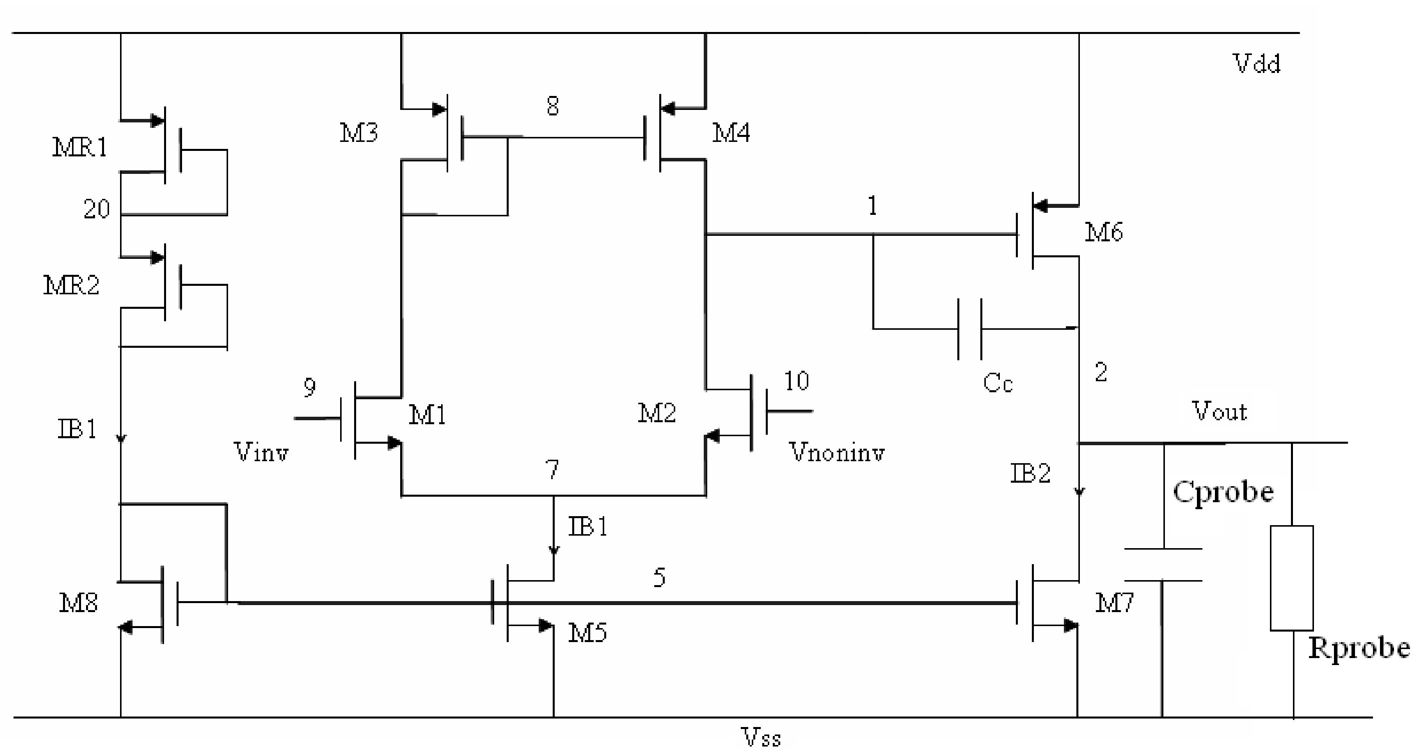
Dual DC Power Supply





Multiple Output Supplies

BASIC TWO STAGE CMOS OPERATIONAL AMPLIFIER



1. Low Voltage operation
2. Rail to Rail input and output voltages
3. Low Input bias ~ 1pA or smaller
4. Low Output Current (depends on M6 and M7)
5. Unity Gain Bandwidth depends on Cc

LOW VOLTAGE, RAIL-TO-RAIL OP AMP

JRC **NJU7031/32/34**

LOW VOLTAGE C-MOS OPERATIONAL AMPLIFIER

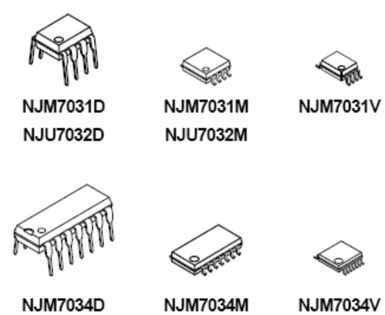
■ GENERAL DESCRIPTION

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.

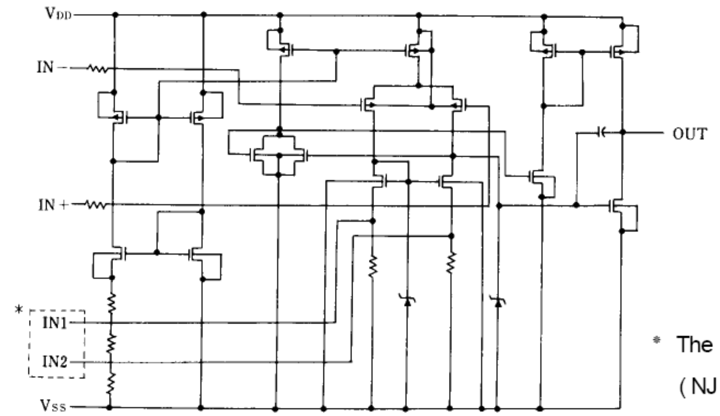
The NJU7031 has external offset null function.

■ PACKAGE OUTLINE



■ 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



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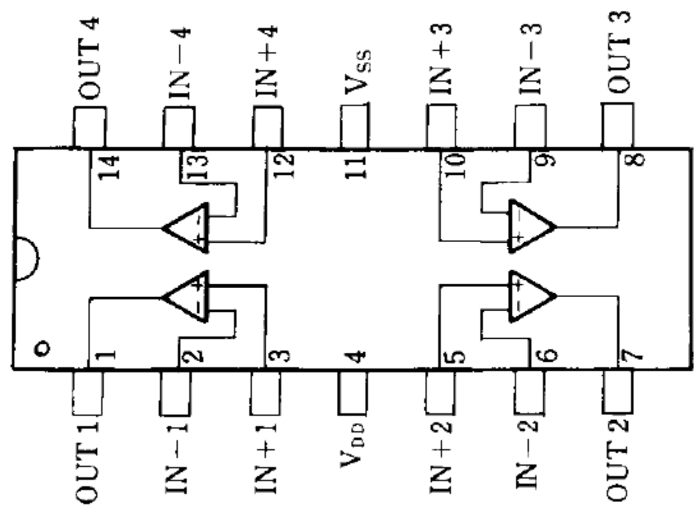
New Japan Radio Co.,Ltd



NJU7034D

1. 3 to 16 Volt operation
2. Rail to Rail input and output voltages
3. Low Input bias ~ 1pA
4. Output Current ~1mA
5. Unity Gain Bandwidth 1.5 MHz
6. Power Dissipation 1mA at 3 V = 3000uW

NJU703X OP AMP DATA SHEET

NJU7031/32/34

■ ABSOLUTE MAXIMUM RATINGS

(Ta=25°C)

PARAMETER	SYMBOL	RATINGS	UNIT
Supply Voltage	V_{DD}	18	V
Differential Input Voltage	V_{ID}	± 18 (note1)	V
Common Mode Input Voltage	V_{IC}	-0.3~18	V
Power Dissipation	P_D	(DIP14) 700 (DIP8) 500 (DMP8,14) 300 (SSOP8,14) 300	mW
Operating Temperature Range	T_{opr}	-40~+85	°C
Storage Temperature Range	T_{stg}	-40~+125	°C

(note1) If the supply voltage (V_{DD}) is less than 18V, the input voltage must not over the V_{DD} level though 18V is limit specified.

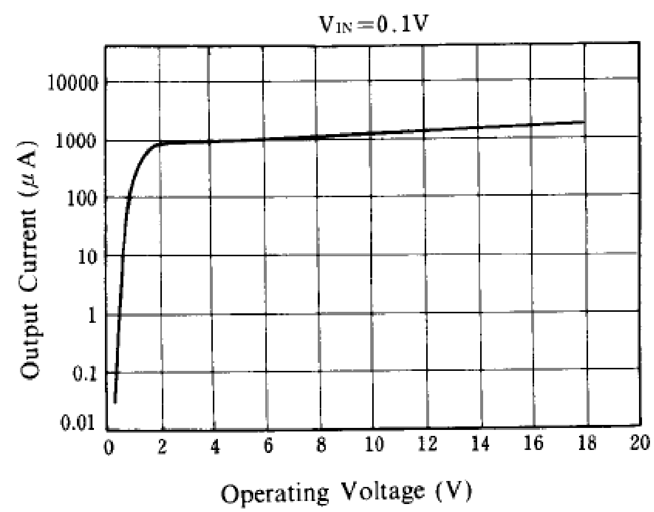
■ ELECTRICAL CHARACTERISTICS

(Ta=25°C,V_{DD}=10

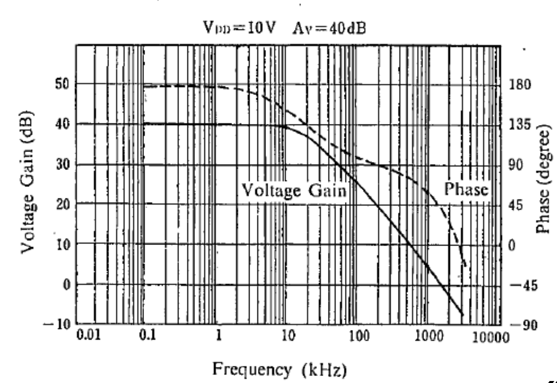
PARAMETER	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Input Offset Voltage	V_{IO}	R_S=50Ω	-	-	10	mV
Input Offset Current	I_{IO}		-	1	-	pA
Input Bias Current	I_{IB}		-	1	-	pA
Input Impedance	R_{IN}		-	1	-	TΩ
Large Signal Voltage Gain	A_V		80	95	-	dB
Input Common Mode Voltage Range	V_{ICM}		0~9	-	-	V
Maximum Output Swing Voltage	V_{OM}	R_L=1MΩ	9.80	9.98	-	V
Common Mode Rejection Ratio	CMR		60	75	-	dB
Supply Voltage Rejection Ratio	SVR		60	75	-	dB
Operating Current/Circuit	I_{DD}		-	1	2	mA/Cir
Slew Rate	SR		-	3.5	-	V/μs
Unity Gain Bandwidth	F_t	A_V=40dB,C_L=10pF	-	1.5	-	MHz

■ OFFSET ADJUSTMENT CIRCUIT (Only For NJU7031)

Output Current vs. Operating Voltage



Voltage Gain・Phase vs. Frequency



Microelectronic Engineering

LTC6078 OP AMP

LINEAR TECHNOLOGY

LTC6078/LTC6079

Micropower Precision, Dual/Quad CMOS Rail-to-Rail Input/Output Amplifiers

FEATURES

- **Maximum Offset Voltage of 25μV (25°C)**
- **Maximum Offset Drift of 0.7μV/°C**
- **Maximum Input Bias:**
  - **1pA (25°C)**
  - **50pA (≤85°C)**
- Micropower: 54μA per Amp
- 95dB CMRR (Min)
- 100dB PSRR (Min)
- Input Noise Voltage Density: 16nV/√Hz
- Rail-to-Rail Inputs and Outputs
- 2.7V to 5.5V Operation Voltage
- LTC6078 Available in 8-Lead MSOP and 10-Lead DFN Packages; LTC6079 Available in 16-Lead SSOP and DFN Packages

APPLICATIONS

- Photodiode Amplifier
- High Impedance Sensor Amplifier

DESCRIPTION

The LTC®6078/LTC6079 are dual/quad, low offset, low noise operational amplifiers with low power consumption and rail-to-rail input/output swing.

Input offset voltage is trimmed to less than 25μV and the CMOS inputs draw less than 50pA of bias current. The low offset drift, excellent CMRR, and high voltage gain make it a good choice for precision signal conditioning.

Each amplifier draws only 54μA current on a 3V supply. The micropower, rail-to-rail operation of the LTC6078/LTC6079 is well suited for portable instruments and single supply applications.

The LTC6078/LTC6079 are specified on power supply voltages of 3V and 5V from –40 to 125°C. The dual amplifier LTC6078 is available in 8-lead MSOP and 10-lead DFN packages. The quad amplifier LTC6079 is available in 16-lead SSOP and DFN packages.

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. Test conditions are V^+ = 3V, V^- = 0V, V_{CM} = 0.5V unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		C, I SUFFIXES MIN	C, I SUFFIXES TYP	C, I SUFFIXES MAX	H SUFFIX MIN	H SUFFIX TYP	H SUFFIX MAX	UNITS
V_{OS}	Offset Voltage (Note 5)	LTC6078MS8, LTC6078AMS8, LTC6079GN V_{CM} = 0.5V, 2.5V			±7	±25		±7	±25	μV
		LTC6078DD, LTC6079DHC V_{CM} = 0.5V, 2.5V			±7	±30				μV
		LTC6078AMS8 V_{CM} = 0.5V	●		±20	±70		±25	±95	μV
		LTC6078MS8 V_{CM} = 0.5V	●		±25	±97		±30	±135	μV
		LTC6079GN V_{CM} = 0.5V	●		±30	±115		±35	±165	μV
		LTC6078DD V_{CM} = 0.5V	●		±30	±120				μV
		LTC6079DHC V_{CM} = 0.5V	●		±35	±150				μV
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift (Note 5)	LTC6078AMS8	●		±0.2	±0.7		±0.2	±0.7	μV/°C
		LTC6078MS8	●			±1.1			±1.1	μV/°C
		LTC6078DD, LTC6079GN	●		±0.3	±1.4		±0.3	±1.4	μV/°C
		LTC6079DHC	●		±0.3	±1.8				μV/°C
I_B	Input Bias Current (Note 6)	$V_{CM} = V^+/2$			0.2	1		0.2	1	pA
		$V_{CM} = V^+/2$	●		10	50		150	350	pA
I_{OS}	Input Offset Current (Note 6)	$V_{CM} = V^+/2$			0.1			0.1		pA
		$V_{CM} = V^+/2$	●		0.5	25		10	100	pA
e_n	Input Noise Voltage	0.1Hz to 10Hz			1			1		$μV_{P-P}$
	Input Noise Voltage Density	f = 1kHz			18			18		nV/√Hz
		f = 10kHz			16			16		nV/√Hz
i_n	Input Noise Current Density (Note 8)				0.56			0.56		fA/√Hz
	Input Common Mode Range		●	V^-		V^+	V^-		V^+	V
C_{DIFF}	Differential Input Capacitance				10			10		pF
C_{CM}	Common Mode Input Capacitance				18			18		pF
CMRR	Common Mode Rejection Ratio	All Packages V_{CM} = 0V to 3V		95	110		95	110		dB
		LTC6078AMS8 V_{CM} = 0V to 3V	●	87	105		87	103		dB
		LTC6078AMS8 V_{CM} = 0V to 1.7V	●	91	103		91	103		dB
		LTC6078MS8 V_{CM} = 0V to 3V	●	85	102		85	100		dB
		LTC6078MS8 V_{CM} = 0V to 1.7V	●	89	102		89	102		dB
		LTC6079GN V_{CM} = 0V to 3V	●	84	102		84	100		dB
		LTC6079GN V_{CM} = 0V to 1.7V	●	88	102		88	102		dB
		LTC6078DD, LTC6079DHC V_{CM} = 0V to 3V	●	83	100					dB
		LTC6078DD, LTC6079DHC V_{CM} = 0V to 1.7V	●	87	102					dB
PSRR	Power Supply Rejection Ratio	V_S = 2.7V to 5.5V		100	120		100	120		dB
			●	97			97			dB
V_{OUT}	Output Voltage, High (Referred to V^+)	No Load			1			1		mV
		I_{SOURCE} = 0.2mA	●	35	15		40	15		mV
		I_{SOURCE} = 2mA	●	350	150		400	150		mV
	Output Voltage, Low (Referred to V^-)	No Load			1			1		mV
		I_{SINK} = 0.2mA	●		10	30		10	35	mV
		I_{SINK} = 2mA	●		100	300		100	350	mV
A_{VOL}	Large-Signal Voltage Gain	R_{LOAD} = 10k, 0.5V ≤ V_{OUT} ≤ 2.5V	●	115	130		110	125		dB
I_{SC}	Output Short-Circuit Current	Source	●	5	10		4	10		mA
		Sink	●	7	14		6	14		mA
SR	Slew Rate	A_V = 1			0.05			0.05		V/μs
GBW	Gain-Bandwidth Product (f_{TEST} = 10kHz)	R_L = 100k		420	750		420	750		kHz
			●	360			320			kHz
Φ_0	Phase Margin	R_L = 10k, C_L = 200pF			66			66		Deg
t_S	Settling Time 0.1%	A_V = 1, 1V Step			24			24		μs

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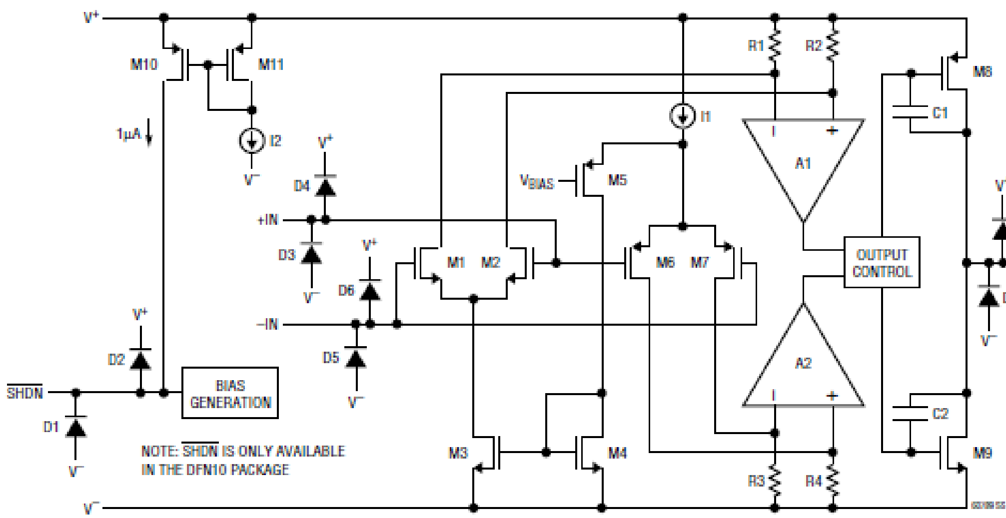
LINEAR TECHNOLOGY 3

1. 2.7 to 5.5 Volt operation
2. Rail to Rail input and output voltages
3. Low Input bias ~ 1pA
4. Output Current ~5mA
5. Unity Gain Bandwidth ~350Khz
6. Power dissipation 54 uA at 3 V = 162uW

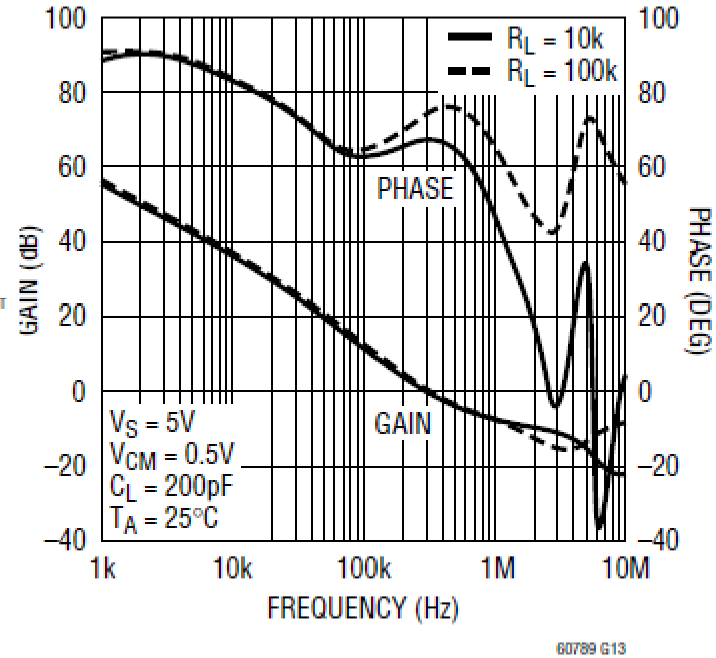
LTC6078 OP AMP

SIMPLIFIED SCHEMATIC



Simplified Schematic of the Amplifier

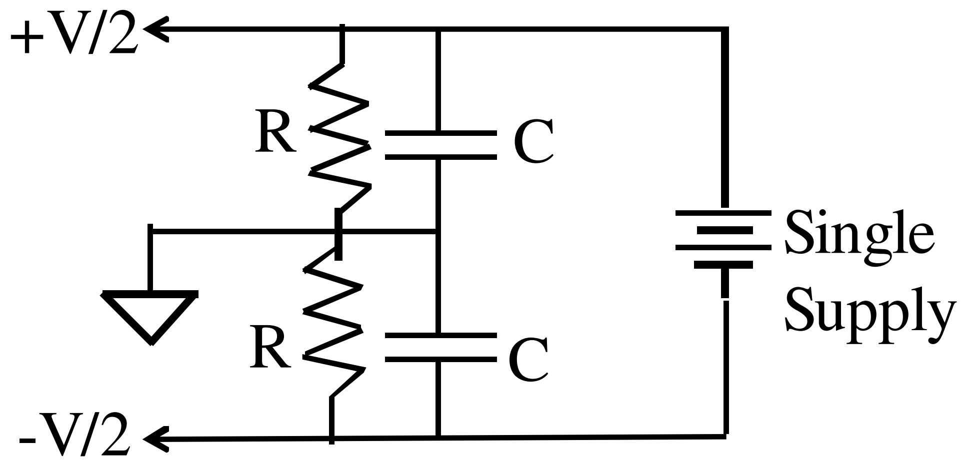
Open Loop Gain vs Frequency

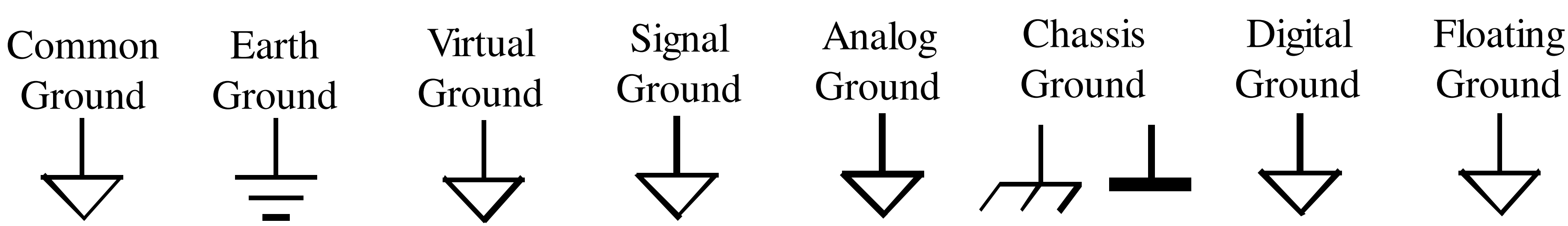


CREATING A SPLIT SUPPLY FROM A SINGLE SUPPLY

The simple voltage splitter draws a lot of power if R's are low. C's ensure AC short (for AC signals). C's might not be needed for DC signals.

Simple Voltage Splitter





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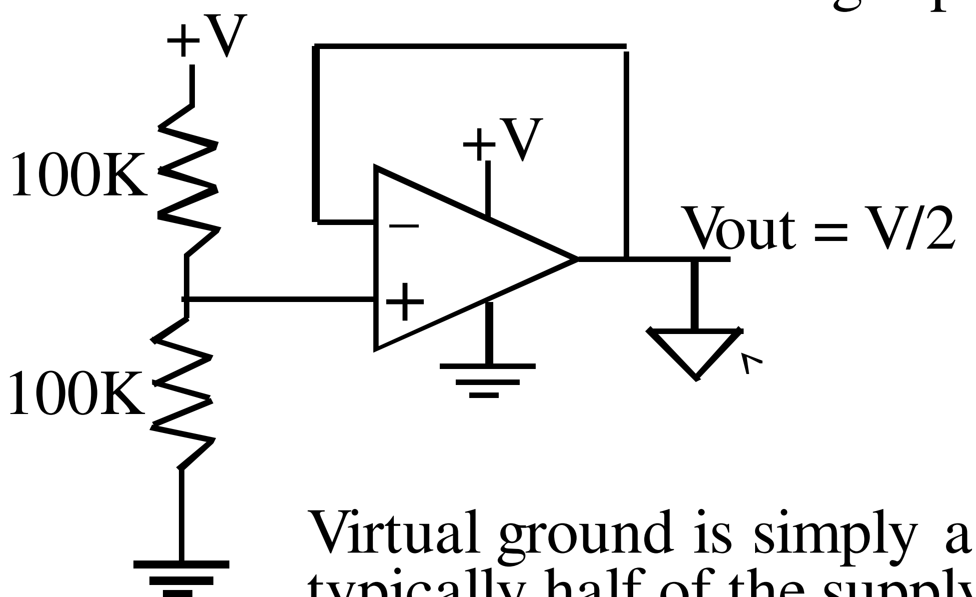
Microelectronic Engineering

VIRTUAL GROUND / VOLTAGE SPLITTER

Virtual Ground Using Op Amp



Virtual ground is simply a voltage reference typically half of the supply voltage.

This virtual ground can supply/sink only as much current as the maximum Op Amp output current.

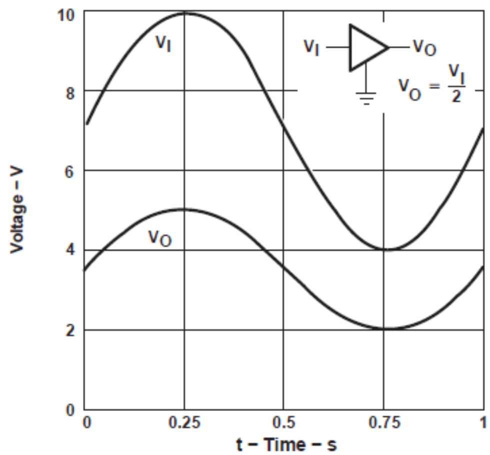
TLE2426 RAIL SPLITTER (COMMERCIAL VIRTUAL GND)

TLE2426, TLE2426Y THE “RAIL SPLITTER” PRECISION VIRTUAL GROUND

SLOS098D – AUGUST 1991 – REVISED MAY 1998

- 1/2 V_I Virtual Ground for Analog Systems
- Self-Contained 3-terminal TO-226AA Package
- Micropower Operation . . . 170 µA Typ, V_I = 5 V
- Wide V_I Range . . . 4 V to 40 V
- High Output-Current Capability
  - Source . . . 20 mA Typ
  - Sink . . . 20 mA Typ
- Excellent Output Regulation
  - −45 µV Typ at I_O = 0 to −10 mA
  - +15 µV Typ at I_O = 0 to +10 mA
- Low-Impedance Output . . . 0.0075 Ω Typ
- Noise Reduction Pin (D, JG, and P Packages Only)

INPUT/OUTPUT TRANSFER CHARACTERISTICS



description

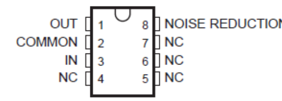
In signal-conditioning applications utilizing a single power source, a reference voltage equal to one-half the supply voltage is required for termination of all analog signal grounds. Texas Instruments presents a precision virtual ground whose output voltage is always equal to one-half the input voltage, the TLE2426 “rail splitter.”

The unique combination of a high-performance, micropower operational amplifier and a precision-trimmed divider on a single silicon chip results in a precise V_O/V_I ratio of 0.5 while sinking and sourcing current. The TLE2426 provides a low-impedance output with 20 mA of sink and source capability while drawing less than 280 µA of supply current over the full input range of 4 V to 40 V. A designer need not pay the price in terms of board space for a conventional signal ground consisting of resistors, capacitors, operational amplifiers, and voltage references. The performance and precision of the TLE2426 is available in an easy-to-use, space saving, 3-terminal LP package. For increased performance, the optional 8-pin packages provide a noise-reduction pin. With the addition of an external capacitor (C_{NR}), peak-to-peak noise is reduced while line ripple rejection is improved.

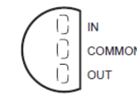
description (continued)

The C-suffix devices are characterized for operation from 0°C to 70°C. The I suffix devices are characterized for operation from −40°C to 85°C. The M suffix devices are characterized over the full military temperature range of −55°C to 125°C.

D, JG, OR P PACKAGE (TOP VIEW)



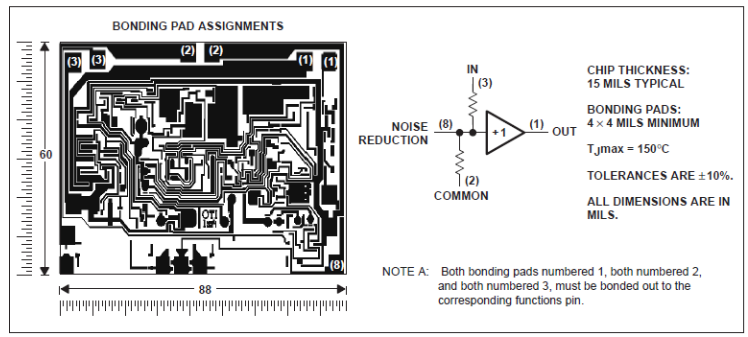
LP PACKAGE (TOP VIEW)



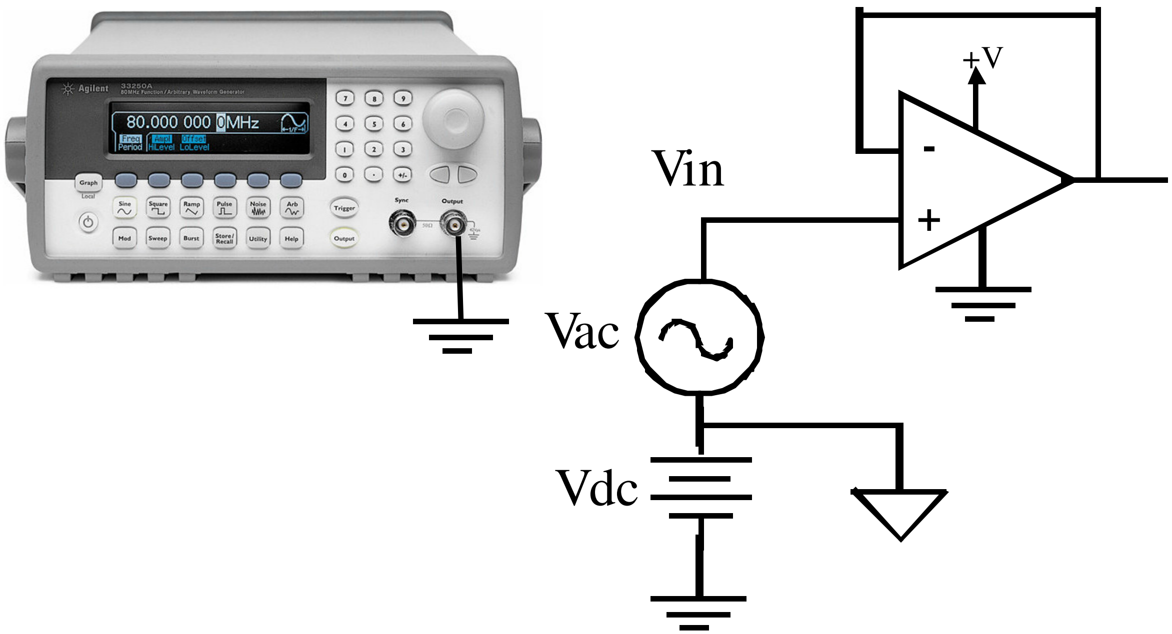
NC – No internal connection

TLE2426Y chip information

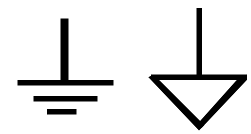
This chip, properly assembled, displays characteristics similar to the TLE2426C. Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. The chips may be mounted with conductive epoxy or a gold-silicon preform.



VOLTAGE FOLLOWER EXAMPLE

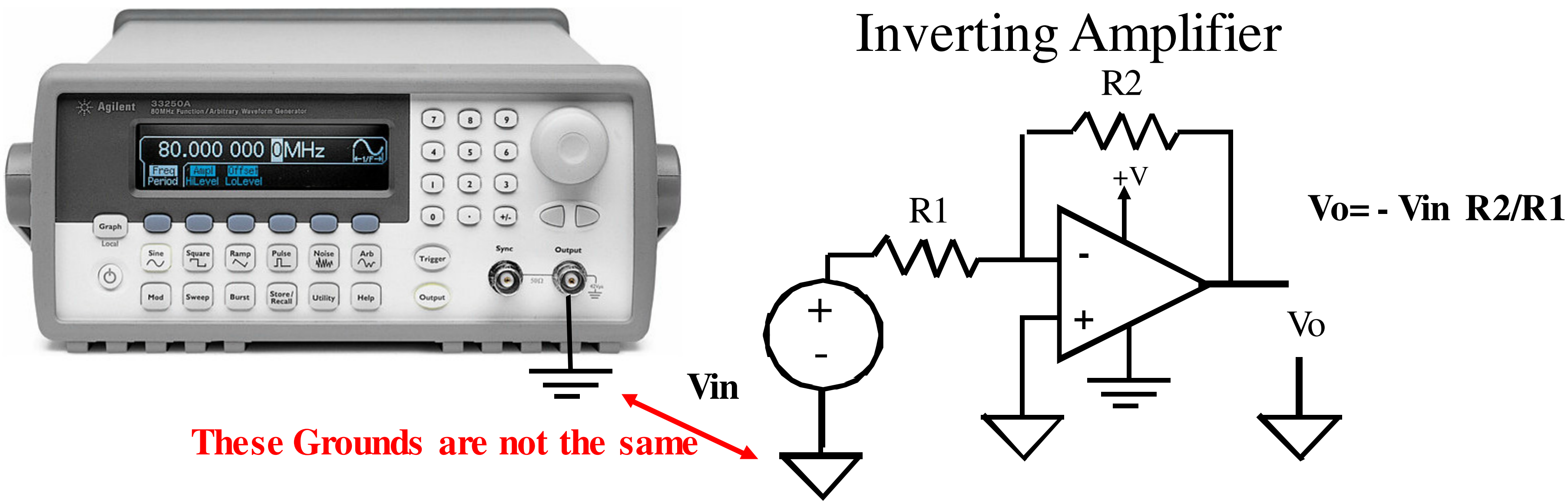


Vo = Vin = Vac + Vdc



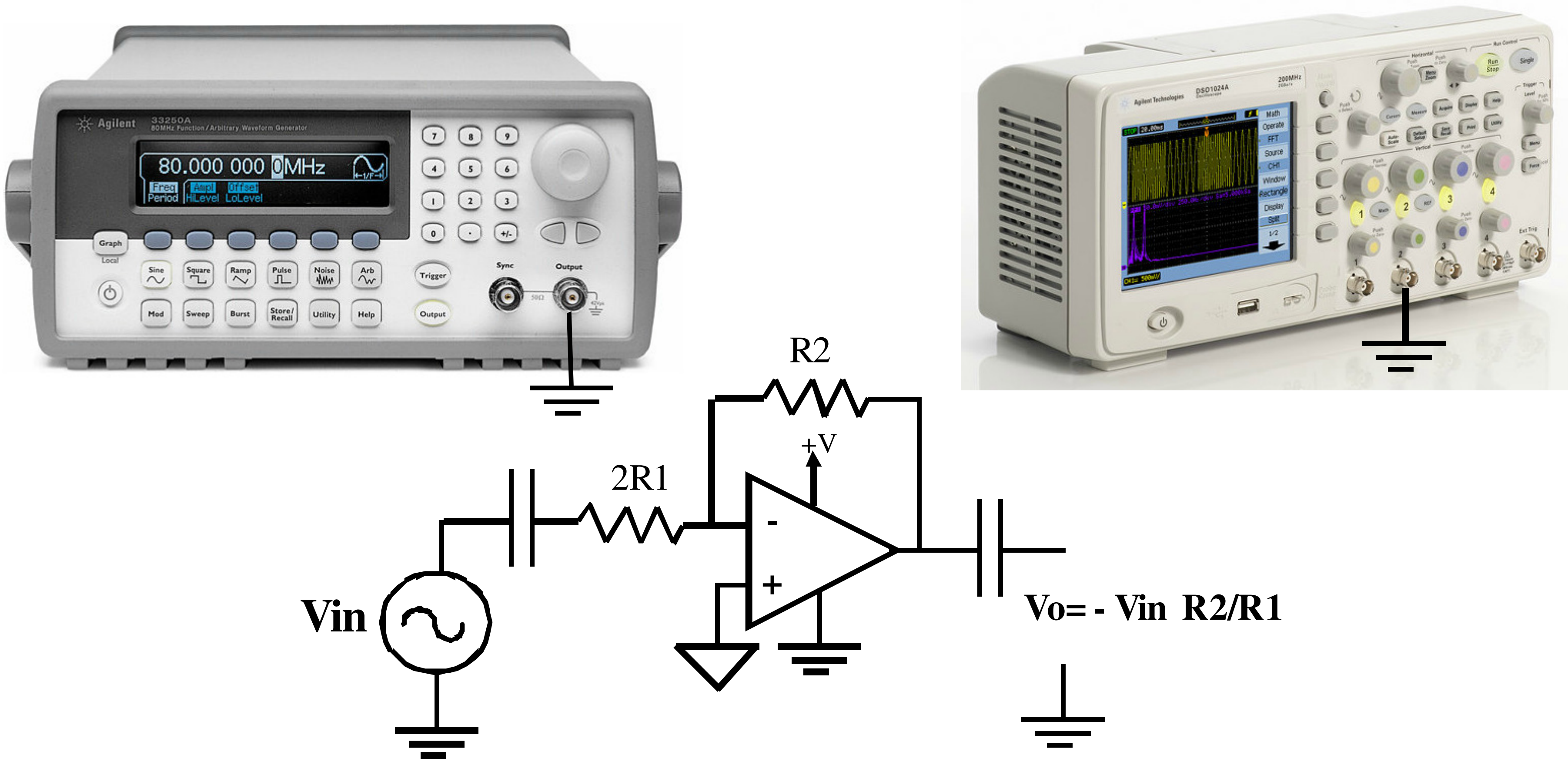
1. If Vin is between the +V and –V supply values then Vo = Vin
2. Vin can not go negative in the example shown because –V supply is ground.
3. If the signal generator has a DC offset (Vdc) that is larger than the signal amplitude then this circuit will work because Vin will never go negative.
4. The output can be referenced to ground or to analog ground
5. Vdc does not need to be V/2

INVERTING AMPLIFIER EXAMPLE



1. This is a DC and AC amplifier
2. The input is referenced to the virtual ground.
3. The virtual ground needs to source or sink the current Vin/R1
4. The Op Amp needs to source or sink Vo/R2
5. The output voltage is referenced to the virtual ground which may be ½ of +V
6. If a load is connected to Vo the virtual ground needs to source or sink the load current.

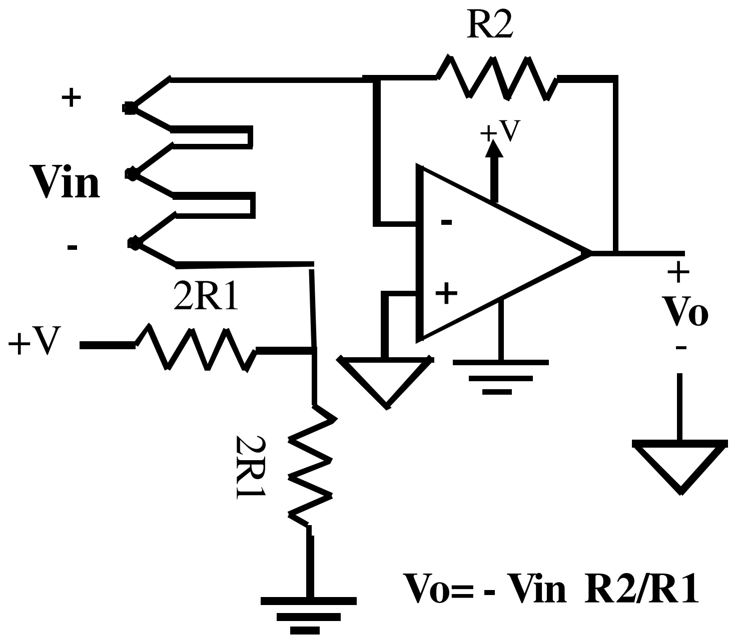
INVERTING AMPLIFIER EXAMPLES



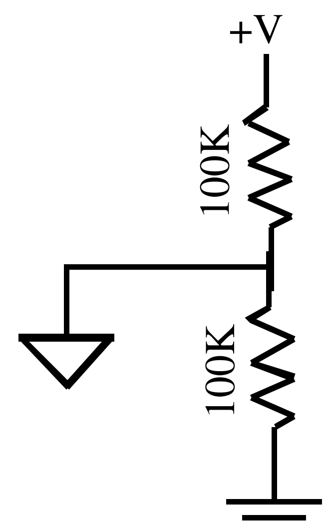
AC Inverting Amplifier
with capacitor coupling

INVERTING AMPLIFIER EXAMPLES

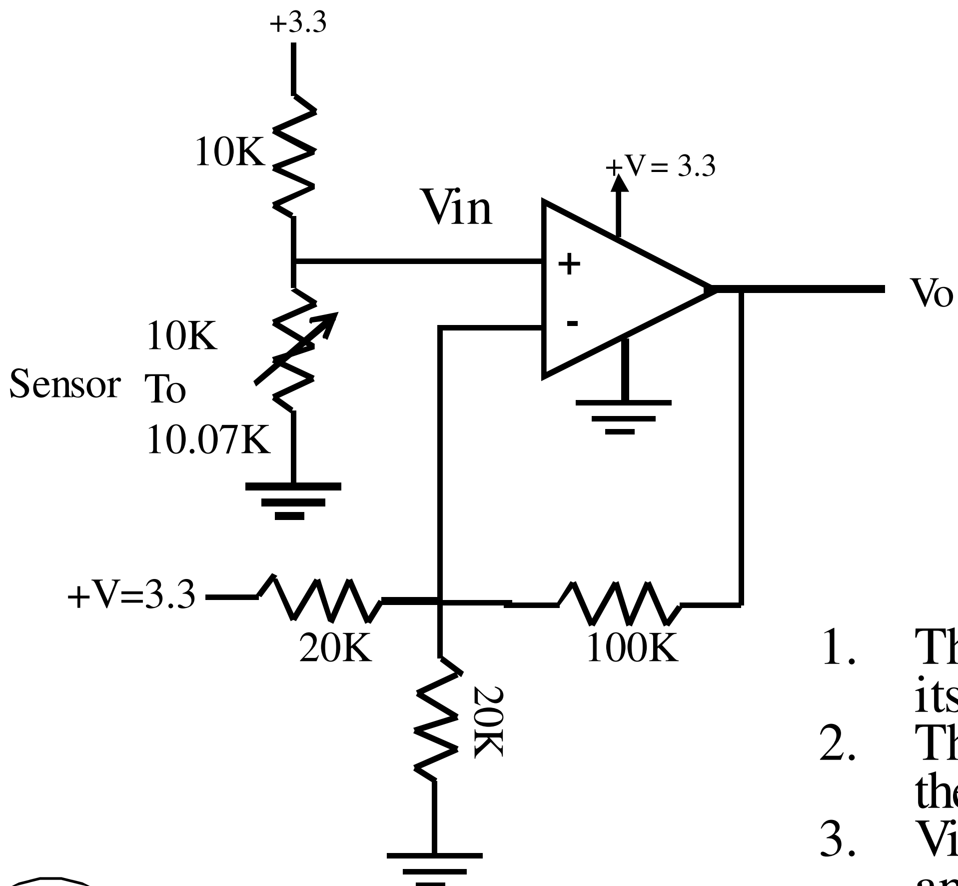
DC Inverting Amplifier



Vo= - Vin R2/R1

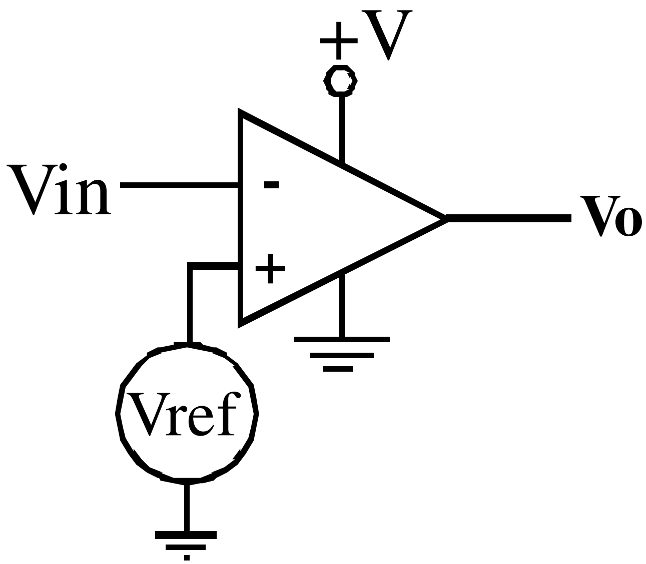


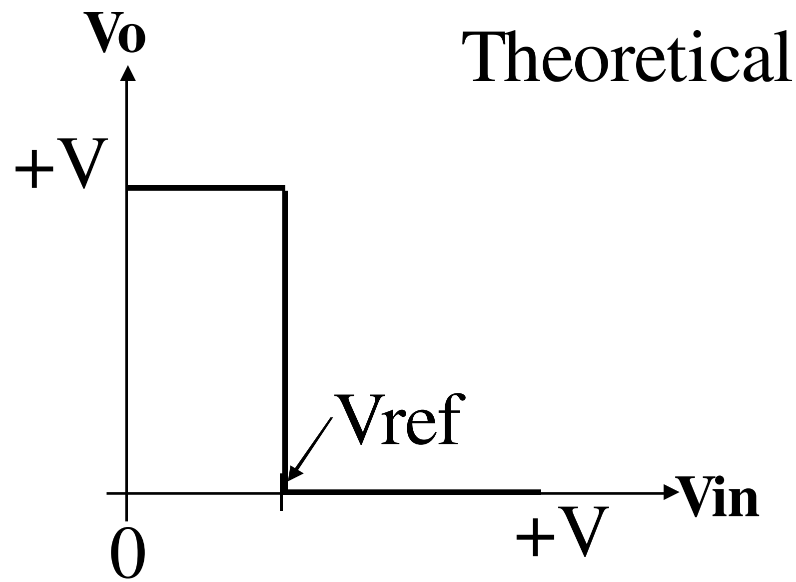
NON-INVERTING AMPLIFIER EXAMPLES



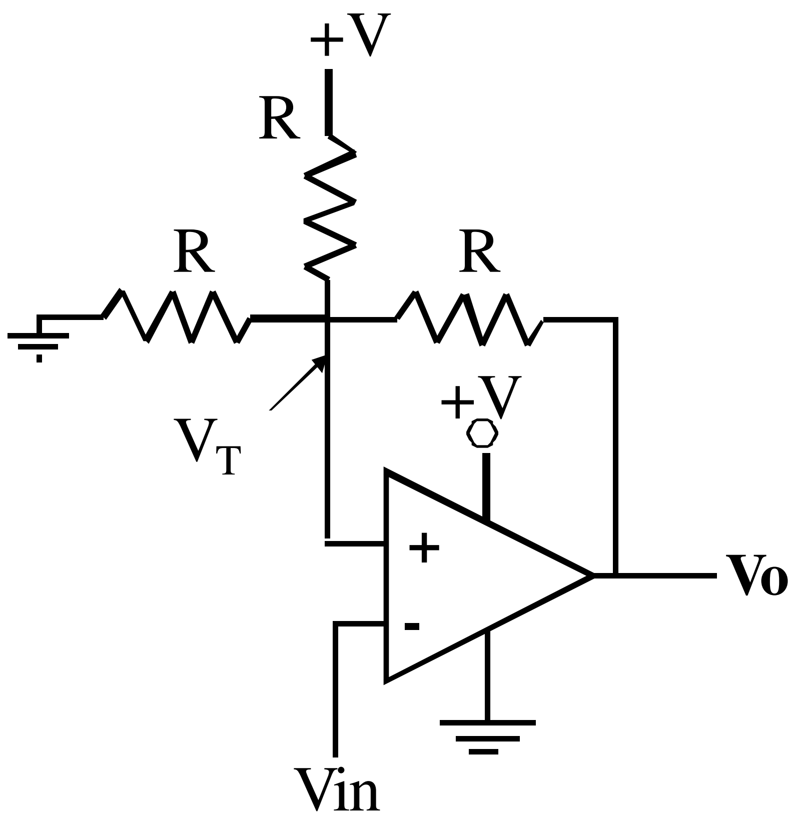
1. The two 20K resistors can be replaced by its Thevenin equivalent of V/2 and 10K
2. This sets up the analog ground at V/2 and the voltage gain to 11
3. Vin is V/2 (or zero if referenced to analog ground) if the sensor is 10K
4. If the sensor is not exactly10K then Vo will have a value of 11 x Vin

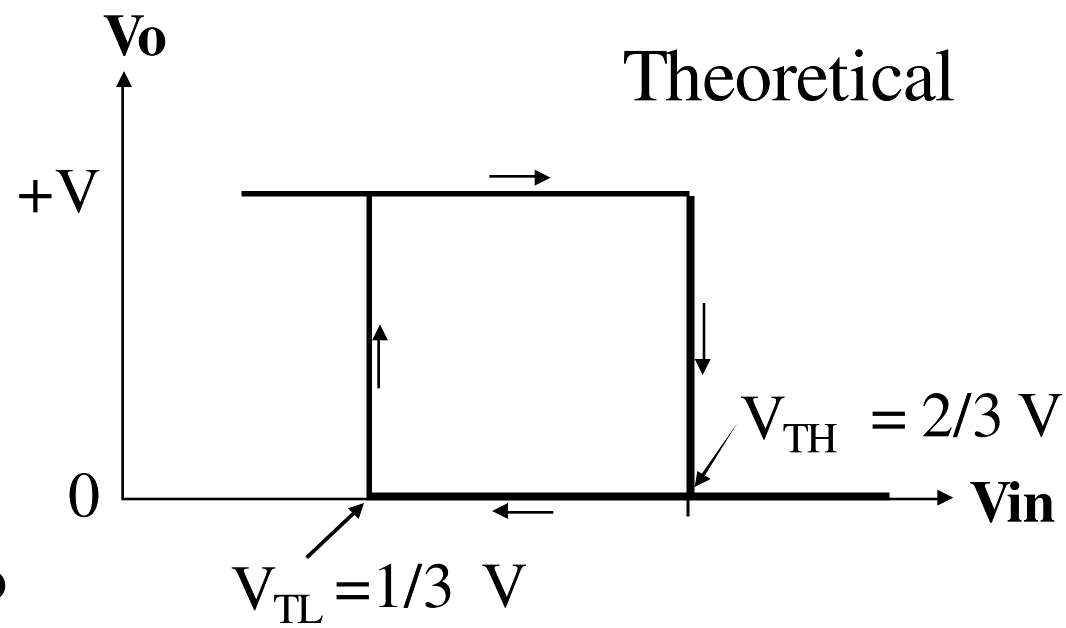
COMPARATOR





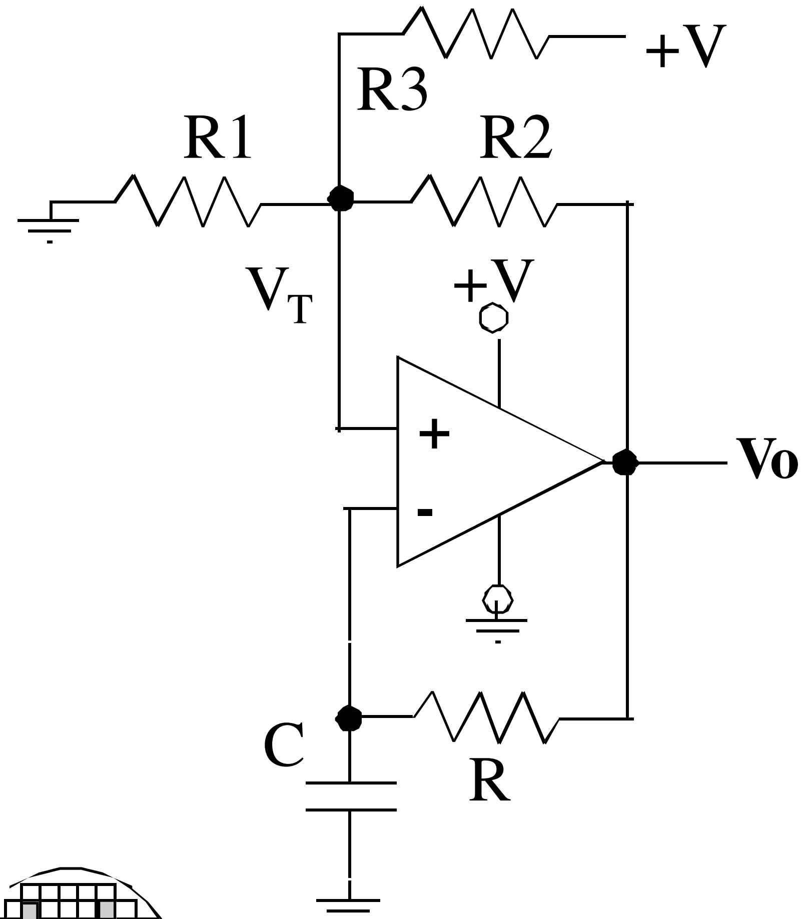
BISTABLE CIRCUIT WITH HYSTERESIS

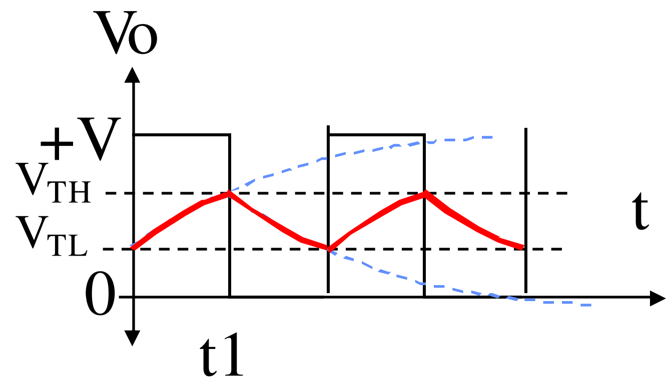




1. The R's set up the threshold voltage at V/3 and 2V/3
2. Vout is either +V or Ground

SINGLE SUPPLY OSCILLATOR (MULTIVIBRATOR)

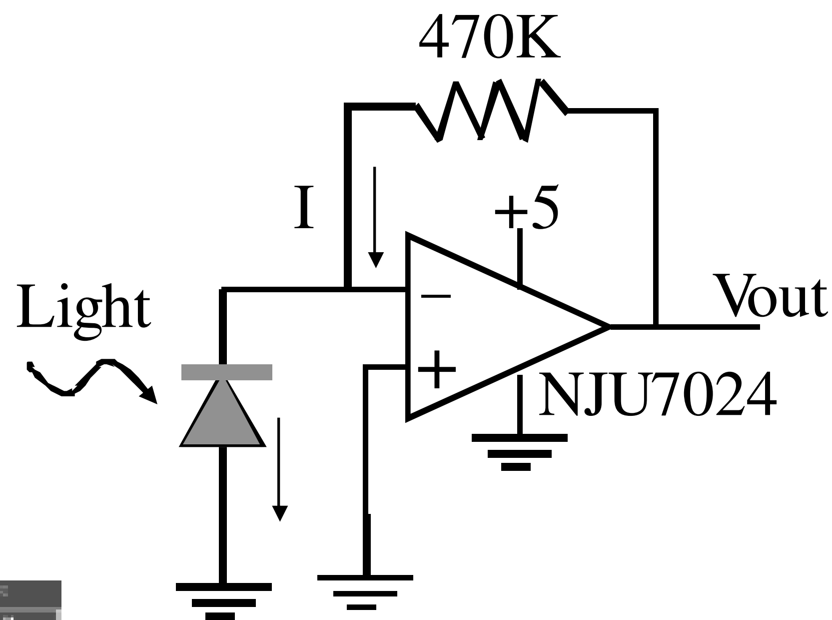


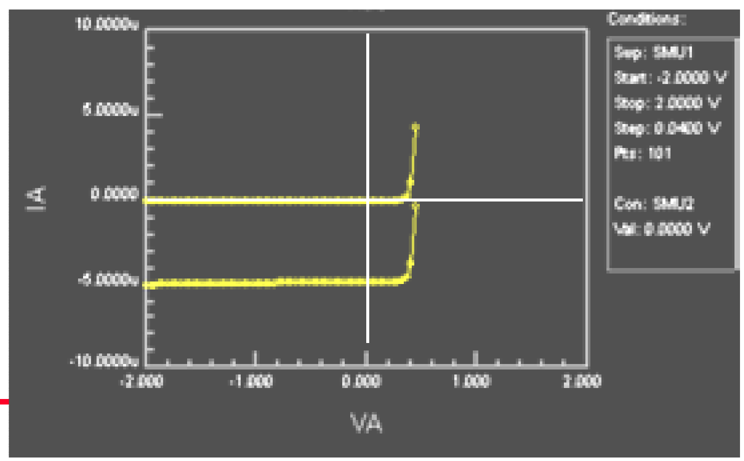


Let R1 = 100K, R2=R3=100K
and +V = 3.3
Then V_{TH} = 2.2 when Vo = 3.3
V_{TL} = 1.1 when Vo = 0

SINGLE SUPPLY PHOTO DETECTOR I TO V AMP

Vishay BPW46
Digikey No. 751-1017-ND



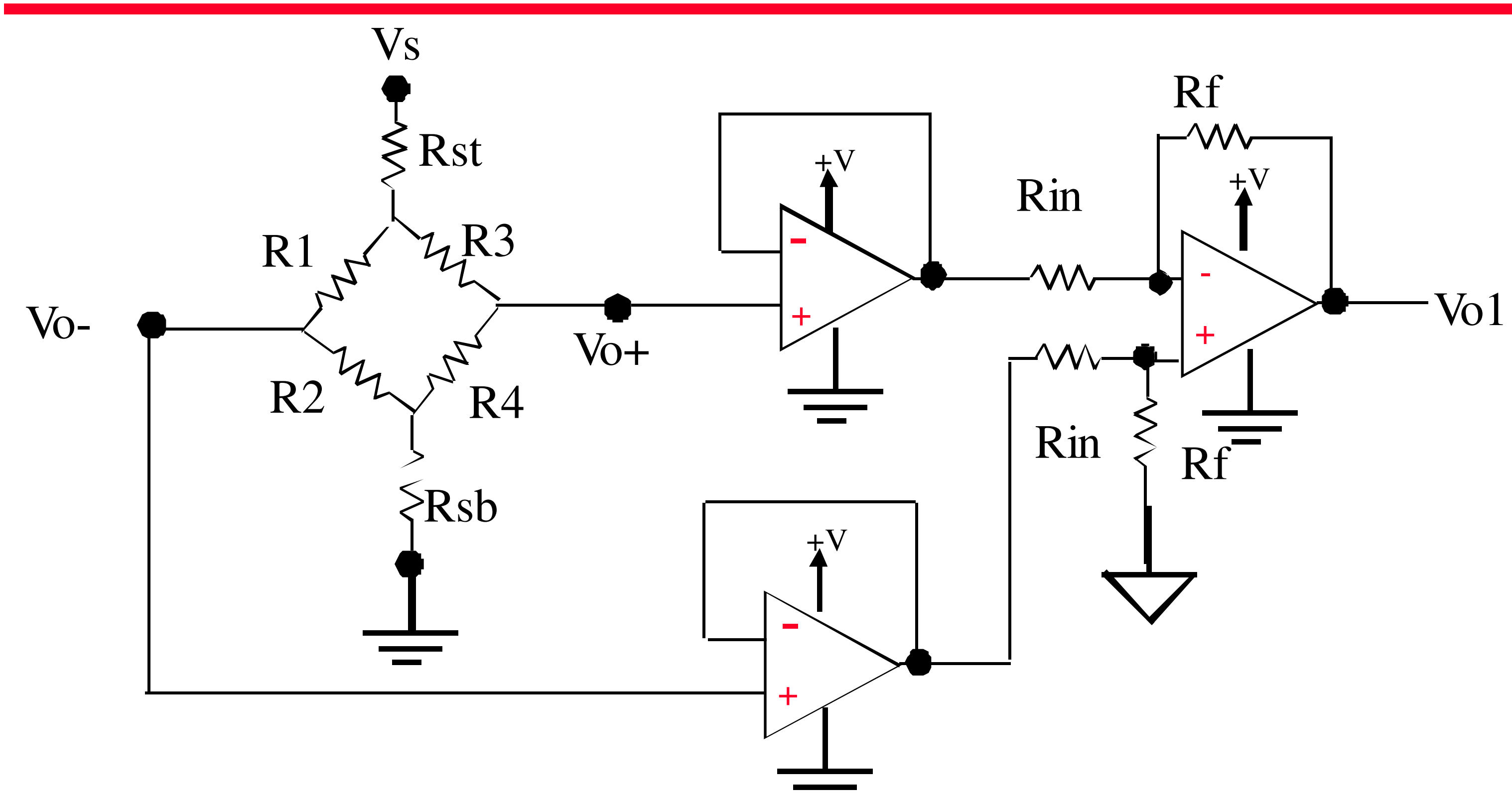


The voltage across the diode is zero volts in the dark and the current is zero

In the light I is 5uA (in direction shown, i.e. out of p-side)

What is Vout?

WHEATSTONE BRIDGE AND DIFFERENTIAL AMP



1. The R1=R2=R3=R4 make a Wheatstone bridge and are sensor resistors that will change in response to pressure.
2. Vo+ and Vo- should be equal to each other and ~Vs/2 with no pressure.

SUMMARY

Low voltage Op Amps are often used with a single supply.

Some circuits work just fine with single supply such as the comparator.

Other circuits use a virtual ground typically ½ of the supply voltage.

Since signal generators and oscilloscopes are referenced to earth ground. Op Amp circuits need to consider this if powered by a single supply referenced to earth ground. In that case earth ground and virtual ground are at different voltages.

REFERENCES

1. Using Single Supply Operational Amplifiers – from Microchip
2. Designing Single Supply, Low-Power Systems – from Analog Devices
3. Designing Circuits for Single Supply Operation – from Linear Technology
4. Single Supply Design – from TI
5. Design Trade-Offs for Single-Supply Op Amps – from Maxium

HOMEWORK – SINGLE SUPPLY OP AMP CKTS

1. Pick one of the example circuits above and do SPICE analysis.
2. More…