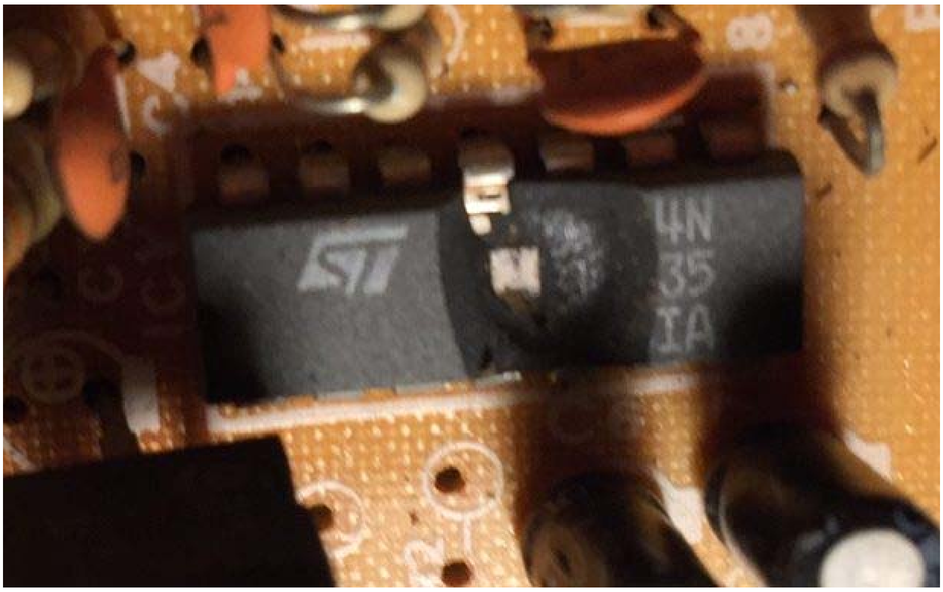
Alinco DM1350 12v Power Supply Failure and repair

Ricky

I wanted to share my experience with you about a power supply failure, and how I found the problem. My Alinco DM1350 is an older power supply, which was hit with lightning. After the lightning strike, the power supply was no longer functional.

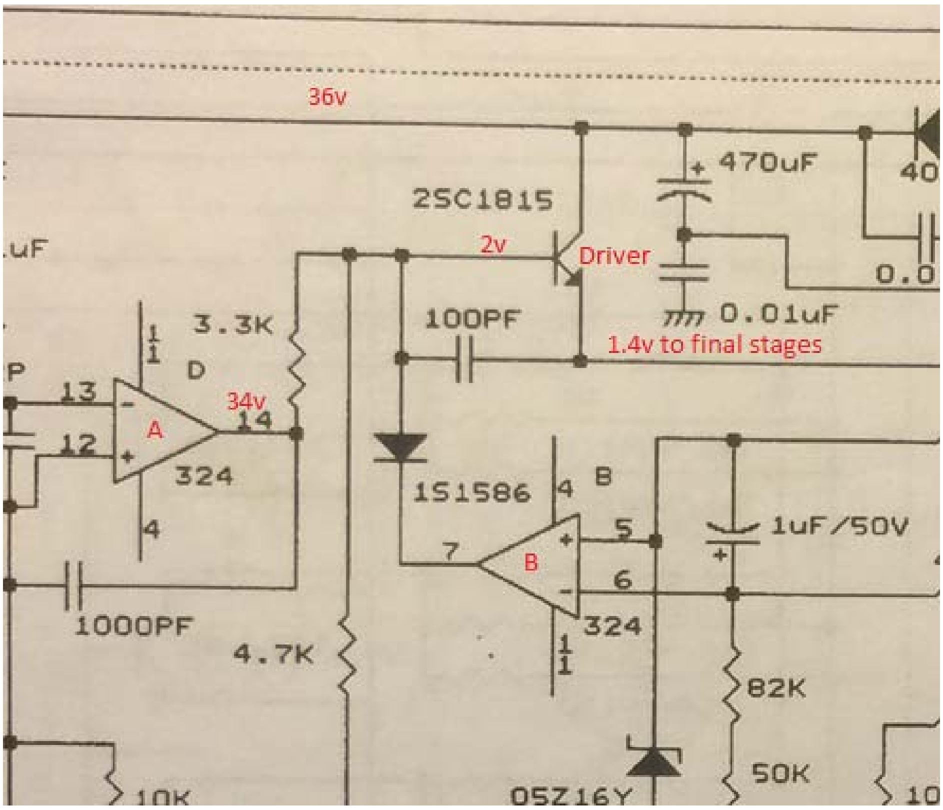
After opening the cover, I found that the Operation Amplifier (Op-Amp) was blown apart.



I replaced the 324 Op-Amp chip, but this time I used a socket, so it's easier to replace next time. When I powered the unit back up, however, the maximum output of the supply was only half a volt!

Looking at the Schematic

It’s time to look at the schematic for this board to see what is going on. The Schematics are from Alinco, who is the manufacturer of this power supply.

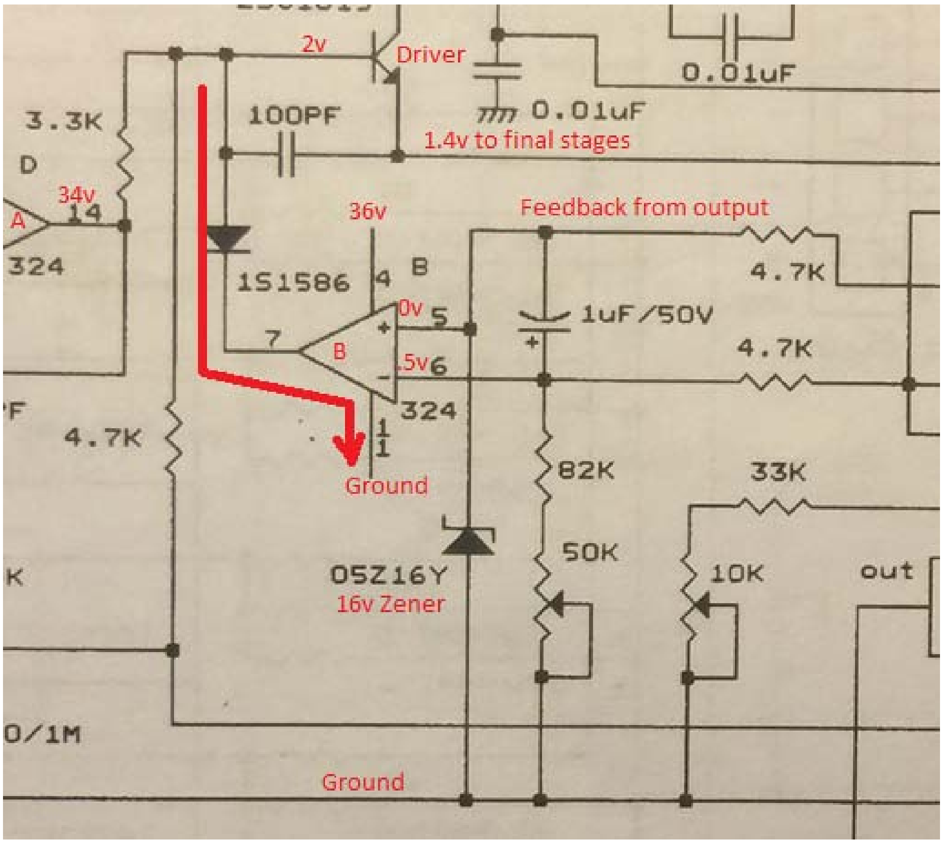


The Triangles (A & B) are part of the Op-Amp chip that I replaced. There are 4 internal Op-Amps on this chip, and here we see two of them.   There is some gain on the operational amplifiers.   For the purpose of providing a simple explanation, we will assume the gain is infinite.   If the voltage on the + terminal is higher than the voltage on the – terminal of the Op-Amp, the output will be high.   If the voltage at the – terminal of the opamp is higher than the voltage of the -, we will assume the output is “Ground”.

Look at the Op-Amp that I’ve labeled A.   It seems to do it’s job.   It’s providing 34v out (from pin 14) in an attempt to drive the base of the transistor. The problem is the base of the transistor is only receiving 2 volts when I measure it. This means that something is sinking the current to ground very badly!   The only thing that can do this is a controlled way is Op-Amp B.   Let’s take a closer look at Op-Amp B.

Finding the ground

Let’s look at the schematic again to find out why we are getting a path to ground on Op-Amp “B”.



We know how an op-amp works now.   Looking at Op-Amp “B”, if terminal 5 is at a higher potential than terminal 6, the output will be a + voltage. If terminal 6 is at a higher potential, then terminal 7 will be at (or near) Ground potential. In this case, we know that terminal 7 is at ground because of the voltage drop across the 3.3k resistor near Op-Amp A. We also know that terminal 7 will only be at ground if terminal 6 is at a higher voltage than terminal 5 (which it is).

The question then becomes, “Why is terminal 5 grounded”. The only way terminal 5 can be grounded is the the 16v zener shown in the schematic. The Zener diode, should not start to conduct, however, until terminal 5 is at 16 volts. The problem is the 16V zener is ALWAYS conducting.

Because the 16v Zener is always conducting, terminal 5 is always at zero volts. This means that the inverting input (terminal 6) to the Op-Amp is always higher than the non inverting input (terminal 5). Therefore, terminal 7 is always at ground, Because terminal 7 is always at ground, any power to the base of the driver transistor is diverted to ground.

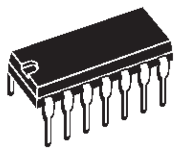
By replacing the 16v Zener, the power supply is now up and running, and I’m getting a full 12v output!

— Ricky Bryce

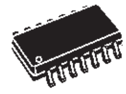
LM124
LM224 - LM324

LOW POWER QUAD OPERATIONAL AMPLIFIERS

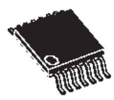
- WIDE GAIN BANDWIDTH : 1.3MHz
- INPUT COMMON-MODE VOLTAGE RANGE INCLUDES GROUND
- LARGE VOLTAGE GAIN : 100dB
- VERY LOW SUPPLY CURRENT/AMPLI : 375µA
- LOW INPUT BIAS CURRENT : 20nA
- LOW INPUT OFFSET VOLTAGE : 5mV max.
  (for more accurate applications, use the equivalent parts LM124A-LM224A-LM324A which feature 3mV max)
- LOW INPUT OFFSET CURRENT : 2nA
- WIDE POWER SUPPLY RANGE :
  SINGLE SUPPLY : +3V TO +30V
  DUAL SUPPLIES : ±1.5V TO ±15V



N
DIP14
(Plastic Package)



D
SO14
(Plastic Micropackage)



P
TSSOP14
(Thin Shrink Small Outline Package)

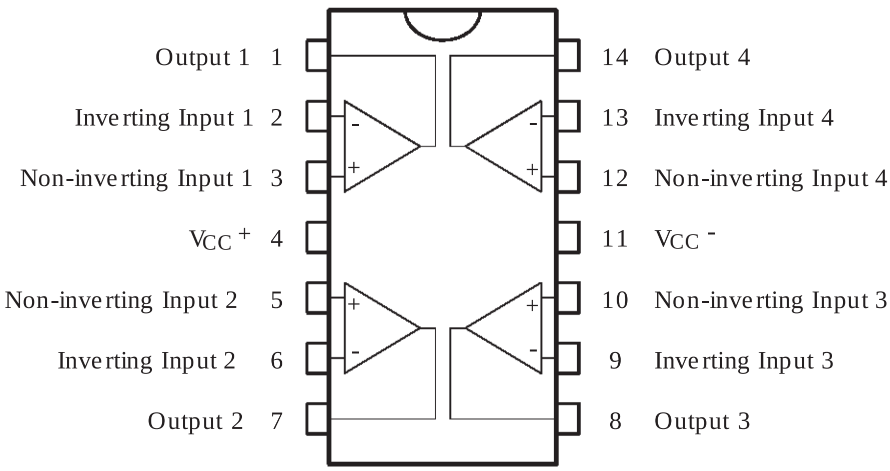
DESCRIPTION

These circuits consist of four independent, high gain, internally frequency compensated operational amplifiers . They operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

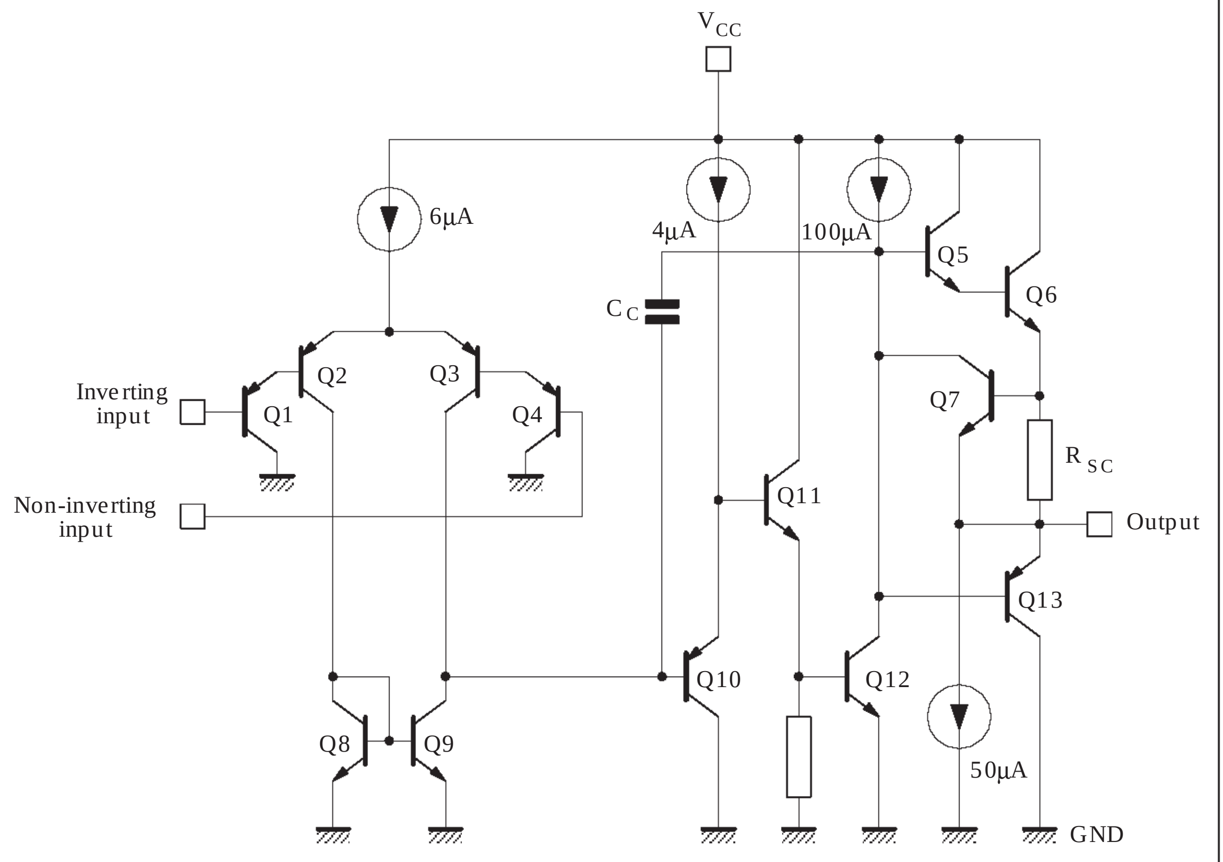
ORDER CODES

Part Number	Temperature Range	Package		
		N	D	P
LM124	-55°C, +125°C	•	•	•
LM224	-40°C, +105°C	•	•	•
LM324	0°C, +70°C	•	•	•
Example : LM224N				

PIN CONNECTIONS (top view)



SCHEMATIC DIAGRAM (1/4 LM124)



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	LM124	LM224	LM324	Unit
V_{cc}	Supply Voltage	±16 or 32			V
V_i	Input Voltage	-0.3 to +32			V
V_{id}	Differential Input Voltage - (*)	+32	+32	+32	V
P_{tot}	Power Dissipation N Suffix D Suffix	500 -	500 400	500 400	mW mW
-	Output Short-circuit Duration - (note 1)	Infinite			
I_{in}	Input Current – (note 6)	50	50	50	mA
T_{oper}	Operating Free Air Temperature Range	-55 to +125	-40 to +105	0 to +70	^oC
T_{stg}	Storage Temperature Range	-65 to +150	-65 to +150	-65 to +150	^oC

ELECTRICAL CHARACTERISTICS

V_{CC}^+ = +5V, V_{CC}^- = Ground, V_O = 1.4V, T_{amb} = +25°C (unless otherwise specified)

Symbol	Parameter	LM124 - LM224 - LM324			Unit
		Min.	Typ.	Max.	
V_{io}	Input Offset Voltage (note 3) T_{amb} = +25°C LM324 $T_{min.} \leq T_{amb} \leq T_{max.}$ LM324		2	5 7 7 9	mV
I_{io}	Input Offset Current T_{amb} = +25°C $T_{min.} \leq T_{amb} \leq T_{max.}$		2	30 100	nA
I_{ib}	Input Bias Current (note 2) T_{amb} = +25°C $T_{min.} \leq T_{amb} \leq T_{max.}$		20	150 300	nA
A_{vd}	Large Signal Voltage Gain (V_{CC}^+ = +15V, R_L = 2kΩ, V_O = 1.4V to 11.4V) T_{amb} = +25°C $T_{min.} \leq T_{amb} \leq T_{max.}$	50 25	100		V/mV
SVR	Supply Voltage Rejection Ratio ($R_S \leq$ 10kΩ) (V_{CC}^+ = 5V to 30V) T_{amb} = +25°C $T_{min.} \leq T_{amb} \leq T_{max.}$	65 65	110		dB
I_{CC}	Supply Current, all Amp, no load T_{amb} = +25°C V_{CC} = +5V V_{CC} = +30V $T_{min.} \leq T_{amb} \leq T_{max.}$ V_{CC} = +5V V_{CC} = +30V		0.7 1.5 0.8 1.5	1.2 3 1.2 3	mA
V_{icm}	Input Common Mode Voltage Range (V_{CC} = +30V) - (note 4) T_{amb} = +25°C $T_{min.} \leq T_{amb} \leq T_{max.}$	0 0		V_{CC} -1.5 V_{CC} -2	V
CMR	Common-mode Rejection Ratio ($R_S \leq$ 10kΩ) T_{amb} = +25°C $T_{min.} \leq T_{amb} \leq T_{max}$	70 60	80		dB
I_{source}	Output Current Source (V_{id} = +1V) V_{CC} = +15V, V_o = +2V	20	40	70	mA
I_{sink}	Output Sink Current (V_{id} = -1V) V_{CC} = +15V, V_o = +2V V_{CC} = +15V, V_o = +0.2V	10 12	20 50		mA µA

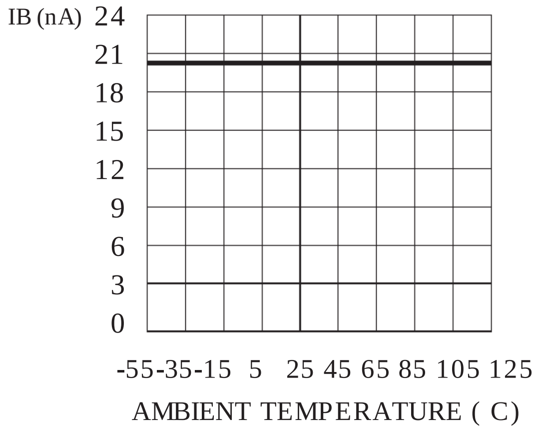
ELECTRICAL CHARACTERISTICS (continued)

Symbol	Parameter	LM124 - LM224 - LM324			Unit
		Min.	Typ.	Max.	
V_{OH}	High Level Output Voltage (V_{CC} = +30V) T_{amb} = +25°C R_L = 2kΩ $T_{min.} \le T_{amb} \le T_{max.}$ T_{amb} = +25°C R_L = 10kΩ $T_{min.} \le T_{amb} \le T_{max.}$ (V_{CC} = +5V, R_L = 2kΩ) T_{amb} = +25°C $T_{min.} \le T_{amb} \le T_{max.}$	 26 26 27 27 3.5 3	 27 28		V
V_{OL}	Low Level Output Voltage (R_L = 10kΩ) T_{amb} = +25°C $T_{min.} \le T_{amb} \le T_{max.}$		 5	 20 20	mV
SR	Slew Rate V_{CC} = 15V, V_I = 0.5 to 3V, R_L = 2kΩ, C_L = 100pF, unity gain)		0.4		V/µs
GBP	Gain Bandwidth Product V_{CC} = 30V, f = 100kHz, V_{in} = 10mV R_L = 2kΩ, C_L = 100pF		1.3		MHz
THD	Total Harmonic Distortion f = 1kHz, A_V = 20dB, R_L = 2kΩ, V_O = $2V_{pp}$ C_L = 100pF, V_{CC} = 30V		0.015		%
e_n	Equivalent Input Noise Voltage f = 1kHz, R_s = 100Ω, V_{CC} = 30V		40		$\frac{nV}{\sqrt{Hz}}$
DV_{io}	Input Offset Voltage Drift		7	30	µV/°C
DI_{IO}	Input Offset Current Drift		10	200	pA/°C
V_O1/V_O2	Channel Separation (note 5) 1kHz ≤ f ≤ 20kHz		120		dB

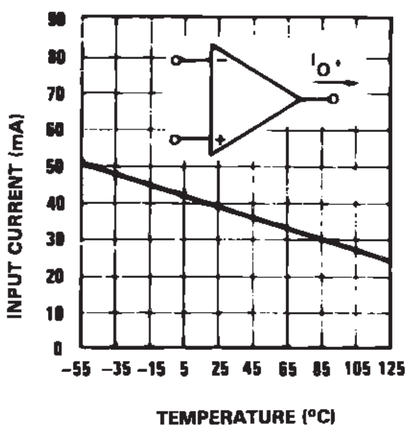
Notes :

1. Short-circuits from the output to V_{CC} can cause excessive heating if V_{CC} > 15V. The maximum output current is approximately 40mA independent of the magnitude of V_{CC}. Destructive dissipation can result from simultaneous short-circuit on all amplifiers.
2. The direction of the input current is out of the IC. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.
3. V_o = 1.4V, R_s = 0Ω, 5V < V_{CC}^+ < 30V, 0 < V_{ic} < V_{CC}^+ - 1.5V
4. The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3V. The upper end of the common-mode voltage range is V_{CC}^+ - 1.5V, but either or both inputs can go to +32V without damage.
5. Due to the proximity of external components insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitance increases at higher frequences.
6. This input current only exists when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistor becoming forward biased and thereby acting as input diodes clamps. In addition to this diode action, there is also NPN parasitic action on the IC chip. this transistor action can cause the output voltages of the Op-amps to go to the V_{CC} voltage level (or to ground for a large overdrive) for the time duration than an input is driven negative.
   This is not destructive and normal output will set up again for input voltage higher than -0.3V.

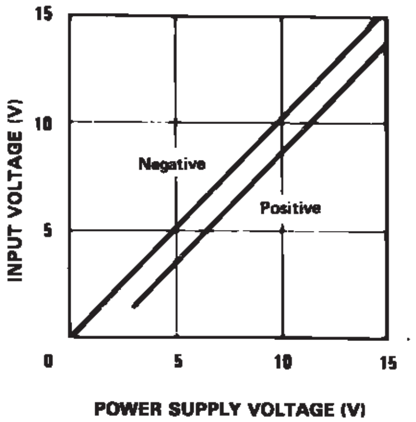
INPUT BIAS CURRENT
versus AMBIENT TEMPERATURE



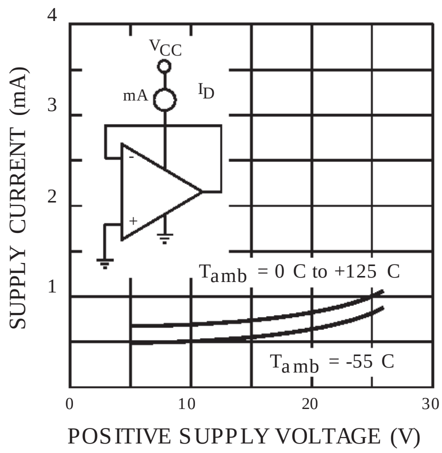
CURRENT LIMITING (Note 8)



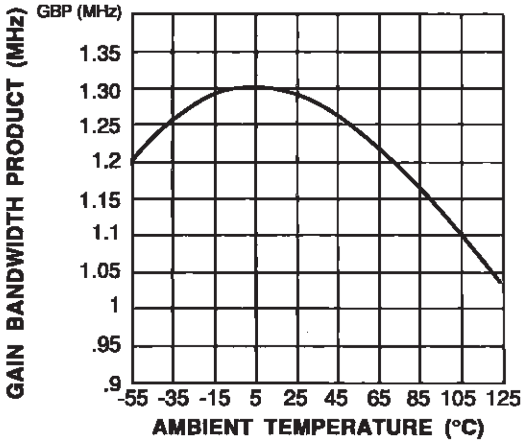
INPUT VOLTAGE RANGE



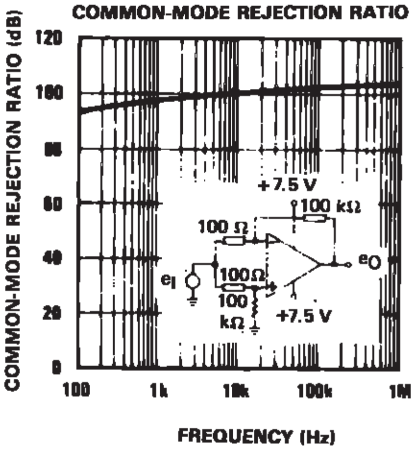
SUPPLY CURRENT



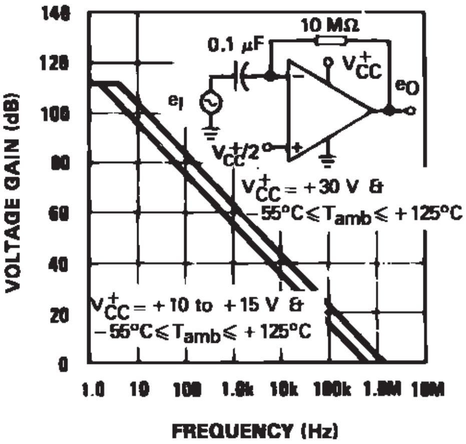
GAIN BANDWIDTH PRODUCT



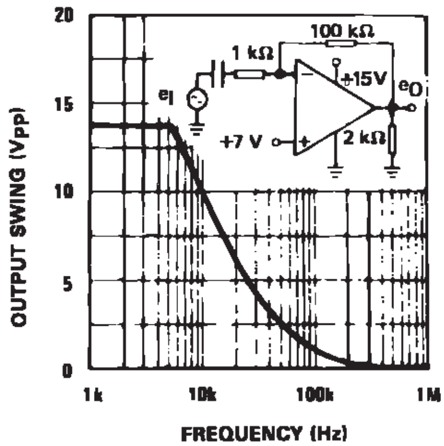
COMMON-MODE REJECTION RATIO



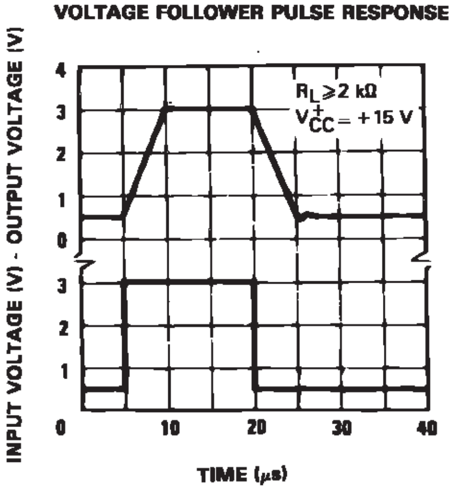
OPEN LOOP FREQUENCY RESPONSE



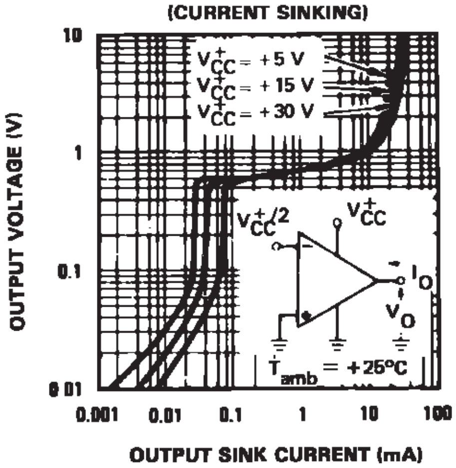
LARGE SIGNAL FREQUENCY RESPONSE



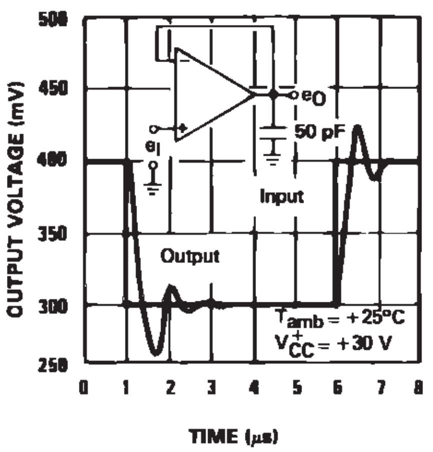
VOLTAGE FOLLOWER PULSE RESPONSE



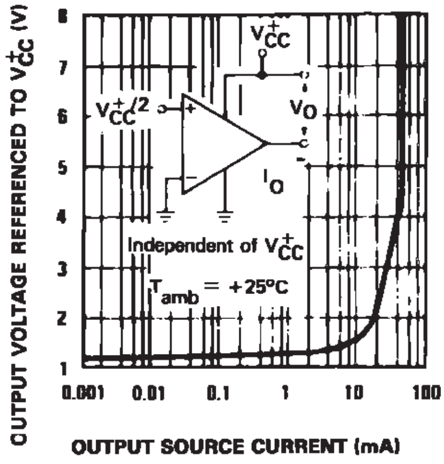
OUTPUT CHARACTERISTICS (CURRENT SINKING)

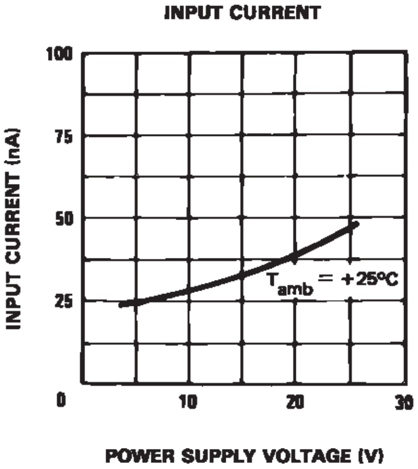


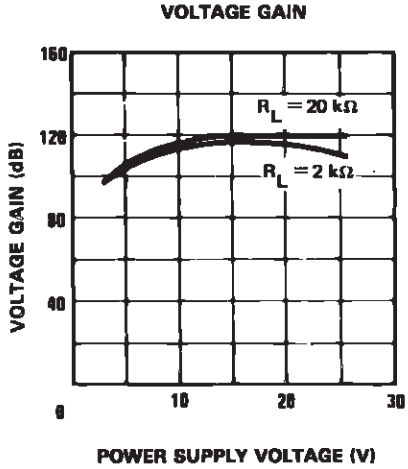
VOLTAGE FOLLOWER PULSE RESPONSE (SMALL SIGNAL)

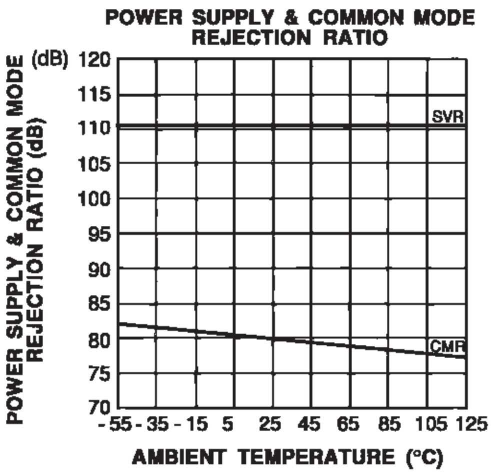


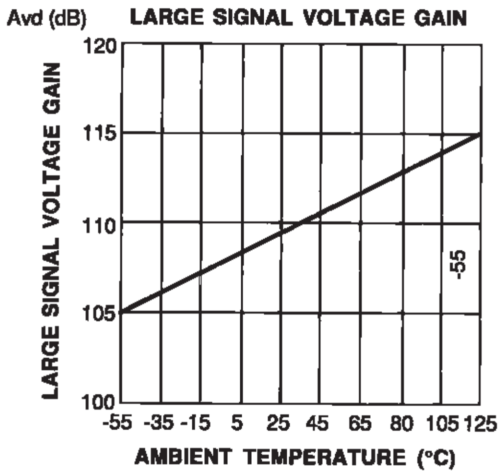
OUTPUT CHARACTERISTICS (CURRENT SOURCING)





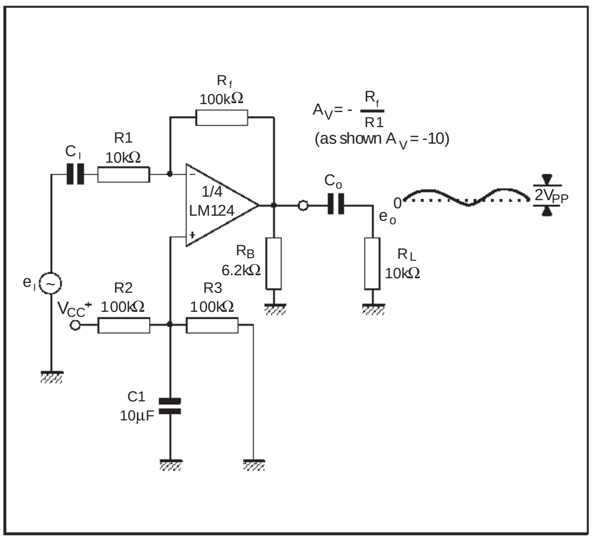




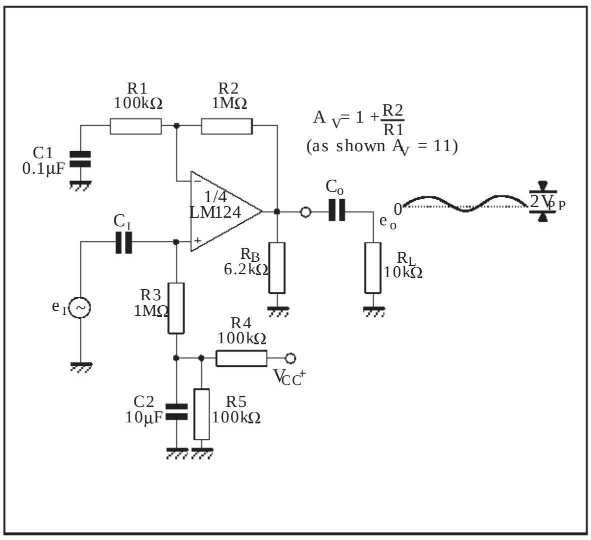


TYPICAL SINGLE - SUPPLY APPLICATIONS

AC COUPLED INVERTING AMPLIFIER

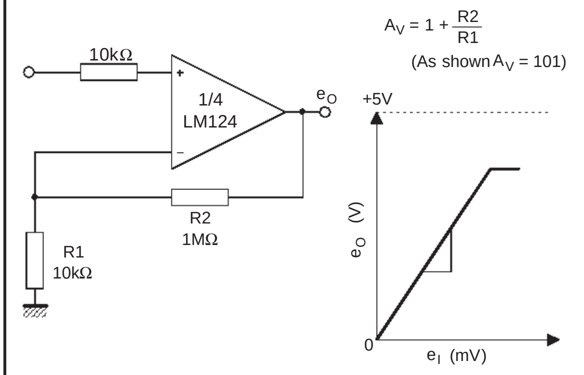


AC COUPLED NON-INVERTING AMPLIFIER

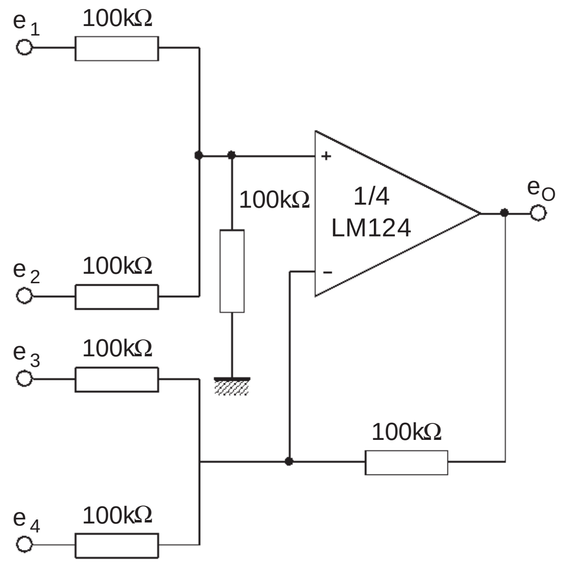


TYPICAL SINGLE - SUPPLY APPLICATIONS

NON-INVERTING DC GAIN

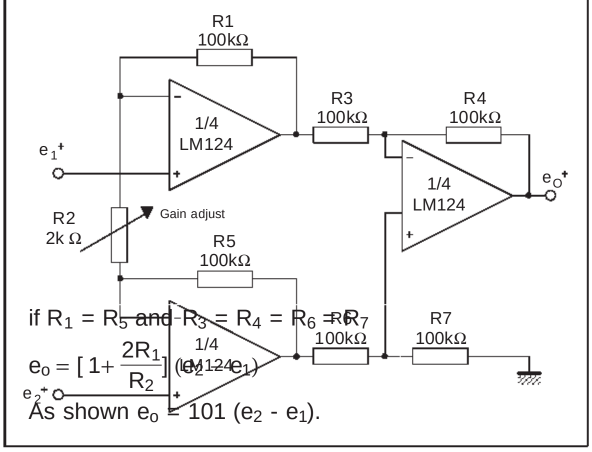


DC SUMMING AMPLIFIER



$e_o = e_1 + e_2 - e_3 - e_4$
where $(e_1 + e_2) \geq (e_3 + e_4)$
to keep $e_o \geq$ 0V

HIGH INPUT Z ADJUSTABLE GAIN DC INSTRUMENTATION AMPLIFIER

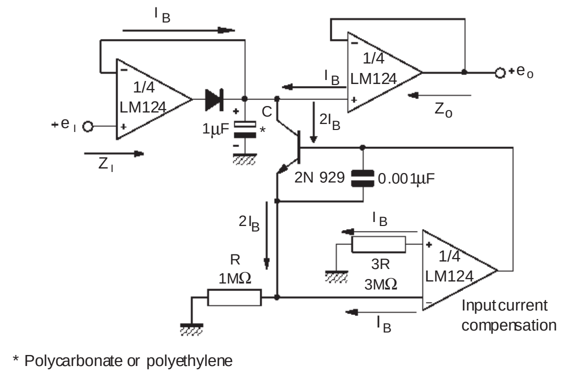


if $R_1 = R_5$ and $R_3 = R_4 = R_6 = R_7$

$e_o = \left[1 + \frac{2R_1}{R_2}\right](e_2 - e_1)$

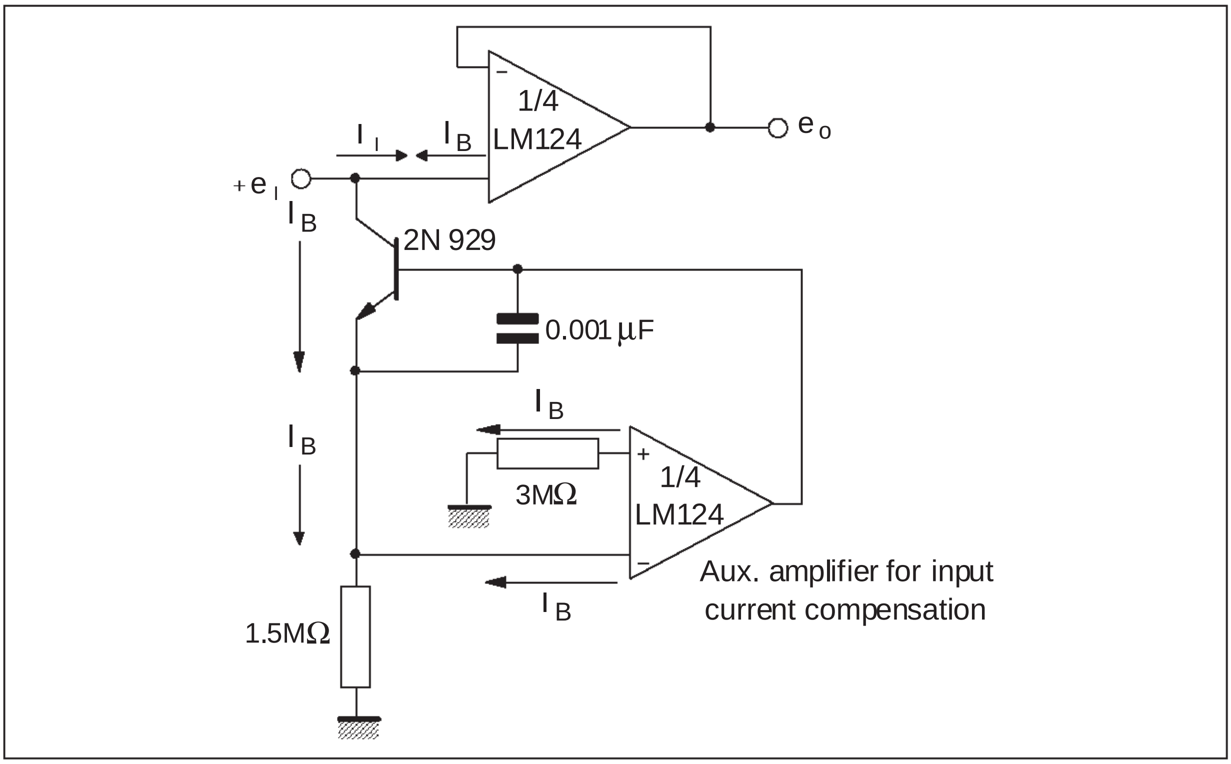
As shown $e_o = 101\ (e_2 - e_1)$.

LOW DRIFT PEAK DETECTOR



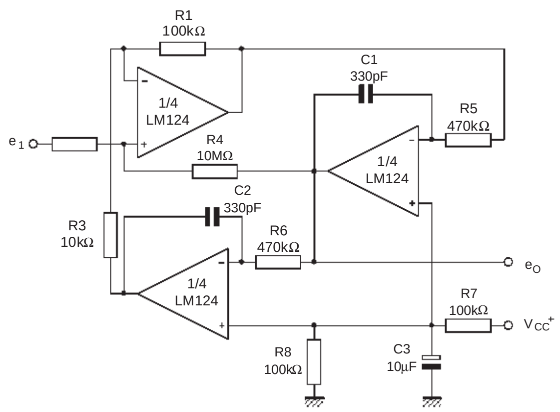
* Polycarbonate or polyethylene

USING SYMMETRICAL AMPLIFIERS TO REDUCE INPUT CURRENT (GENERAL CONCEPT)



TYPICAL SINGLE - SUPPLY APPLICATIONS

ACTIVER BANDPASS FILTER



F_O = 1kHz

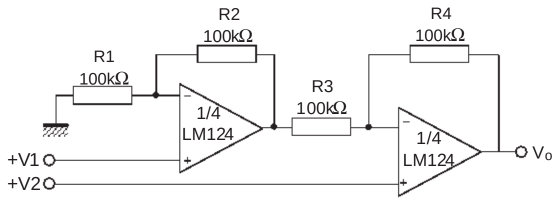
Q = 50

A_V = 100 (40dB)

HIGH INPUT Z, DC DIFFERENTIAL AMPLIFIER

For $\frac{R_1}{R_2} = \frac{R_4}{R_3}$

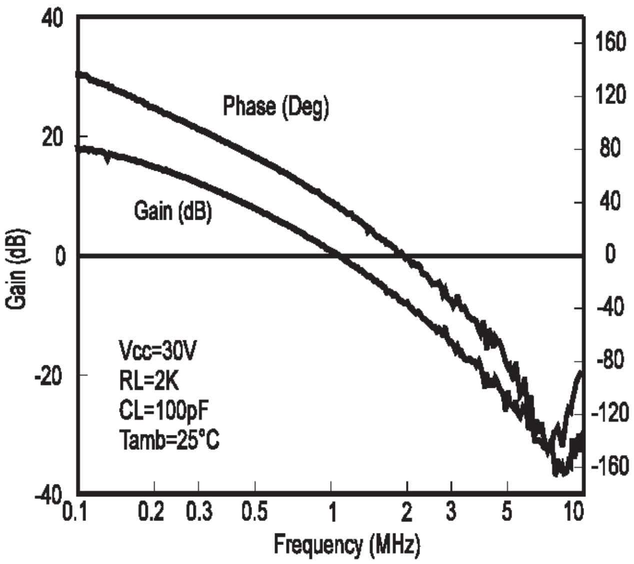
(CMRR depends on this resistor ratio match)



$e_o\ (1+\frac{R_4}{R_3})\ (e_2 - e_1)$

As shown $e_o = (e_2 - e_1)$

VOLTAGE GAIN AND PHASE vs FREQUENCY



- LARGE VOLTAGE GAIN : 100dB
- VERY LOW SUPPLY CURRENT/AMPLI : 375µA
- LOW INPUT BIAS CURRENT : 20nA
- LOW INPUT OFFSET VOLTAGE : 2mV
- LOW INPUT OFFSET CURRENT : 2nA
- WIDE POWER SUPPLY RANGE :
  SINGLE SUPPLY : +3V to +30V
  DUAL SUPPLIES : ±1.5V to ±15V

Applies to : LM124-LM224-LM324

```
** Standard Linear Ics Macromodels, 1993.
** CONNECTIONS :
* 1 INVERTING INPUT
* 2 NON-INVERTING INPUT
* 3 OUTPUT
* 4 POSITIVE POWER SUPPLY
* 5 NEGATIVE POWER SUPPLY

.SUBCKT LM124 1 3 2 4 5 (analog)
**********************************************************
.MODEL MDTH D IS=1E-8 KF=3.104131E-15
CJO=10F
* INPUT STAGE
CIP 2 5 1.000000E-12
CIN 1 5 1.000000E-12
EIP 10 5 2 5 1
EIN 16 5 1 5 1
RIP 10 11 2.600000E+01
RIN 15 16 2.600000E+01
RIS 11 15 2.003862E+02
DIP 11 12 MDTH 400E-12
DIN 15 14 MDTH 400E-12
VOFP 12 13 DC 0
VOFN 13 14 DC 0
IPOL 13 5 1.000000E-05
CPS 11 15 3.783376E-09
DINN 17 13 MDTH 400E-12
VIN 17 5 0.000000e+00
DINR 15 18 MDTH 400E-12
VIP 4 18 2.000000E+00
FCP 4 5 VOFP 3.400000E+01
FCN 5 4 VOFN 3.400000E+01
FIBP 2 5 VOFN 2.000000E-03
FIBN 5 1 VOFP 2.000000E-03
* AMPLIFYING STAGE
FIP 5 19 VOFP 3.600000E+02
FIN 5 19 VOFN 3.600000E+02
RG1 19 5 3.652997E+06
RG2 19 4 3.652997E+06
CC 19 5 6.000000E-09
DOPM 19 22 MDTH 400E-12
DONM 21 19 MDTH 400E-12
HOPM 22 28 VOUT 7.500000E+03
VIPM 28 4 1.500000E+02
HONM 21 27 VOUT 7.500000E+03
VINM 5 27 1.500000E+02
EOUT 26 23 19 5 1
VOUT 23 5 0
ROUT 26 3 20
COUT 3 5 1.000000E-12
DOP 19 25 MDTH 400E-12
VOP 4 25 2.242230E+00
DON 24 19 MDTH 400E-12
VON 24 5 7.922301E-01
.ENDS
```

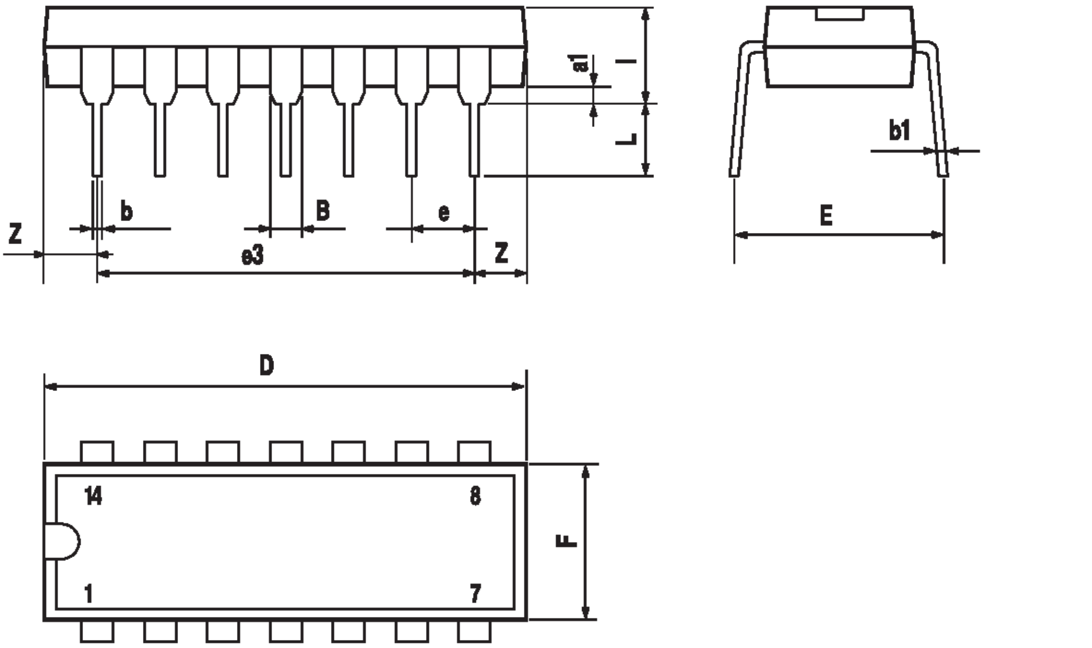
ELECTRICAL CHARACTERISTICS

$V_{CC}^+ = +5V$, $V_{CC}^- = 0V$, $T_{amb} = 25^oC$ (unless otherwise specified)

Symbol	Conditions	Value	Unit
V_{io}		0	mV
A_{vd}	$R_L = 2k\Omega$	100	V/mV
I_{CC}	No load, per operator	350	µA
V_{icm}		-15 to +13.5	V
V_{OH}	$R_L = 2k\Omega$ ($V_{CC}^+ = 15V$)	+13.5	V
V_{OL}	RL = 10kΩ	5	mV
I_{OS}	$V_O = +2V$, $V_{CC} = +15V$	+40	mA
GBP	$R_L = 2k\Omega$, $C_L = 100pF$	1.3	MHz
SR	$R_L = 2k\Omega$, $C_L = 100pF$	0.4	V/µs

PACKAGE MECHANICAL DATA

14 PINS - PLASTIC DIP

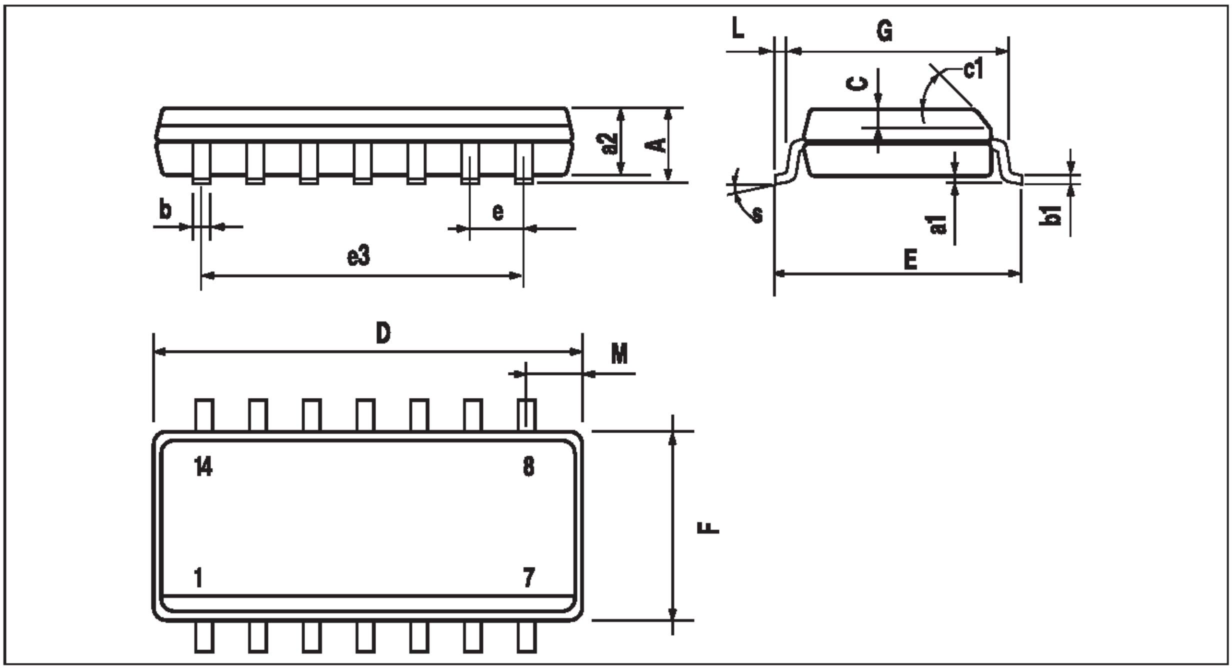


Dimensions	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
a1	0.51			0.020		
B	1.39		1.65	0.055		0.065
b		0.5			0.020	
b1		0.25			0.010	
D			20			0.787
E		8.5			0.335	
e		2.54			0.100	
e3		15.24			0.600	
F			7.1			0.280
i			5.1			0.201
L		3.3			0.130	
Z	1.27		2.54	0.050		0.100

DIP14.TBL

PACKAGE MECHANICAL DATA

14 PINS - PLASTIC MICROPACKAGE (SO)

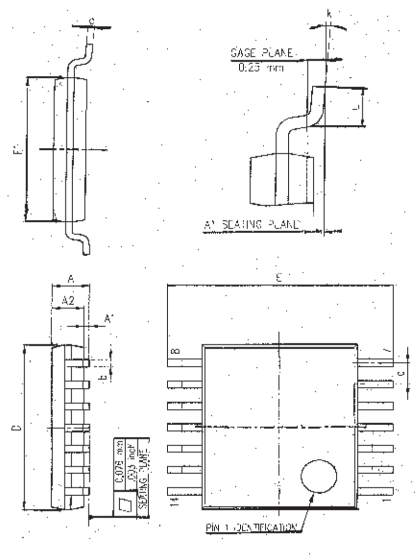


Dimensions	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
a1	0.1		0.2	0.004		0.008
a2			1.6			0.063
b	0.35		0.46	0.014		0.018
b1	0.19		0.25	0.007		0.010
C		0.5			0.020	
c1	45^o (typ.)					
D	8.55		8.75	0.336		0.334
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		7.62			0.300	
F	3.8		4.0	0.150		0.157
G	4.6		5.3	0.181		0.208
L	0.5		1.27	0.020		0.050
M			0.68			0.027
S	8^o (max.)					

SO14.TBL

PACKAGE MECHANICAL DATA

14 PINS - THIN SHRINK SMALL OUTLINE PACKAGE



Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.20			0.05
A1	0.05		0.15	0.01		0.006
A2	0.80	1.00	1.05	0.031	0.039	0.041
b	0.19		0.30	0.007		0.15
c	0.09		0.20	0.003		0.012
D	4.90	5.00	5.10	0.192	0.196	0.20
E		6.40			0.252	
E1	4.30	4.40	4.50	0.169	0.173	0.177
e		0.65			0.025	
k	0^o		8^o	0^o		8^o
l	0.50	0.60	0.75	0.09	0.0236	0.030