ONKYO SERVICE MANUAL

5.1-CH HOME THEATER SPEAKER PACKAGE
MODEL HTP-320(S)

Front Speakers (L / R)
"SKF-320F"

Center Speaker
"SKC-320C"

Surround Speakers (L / R)
"SKM-320S"

Powered Subwoofer
"SKW-320X"

Silver model

SMDD	120 V AC, 60Hz
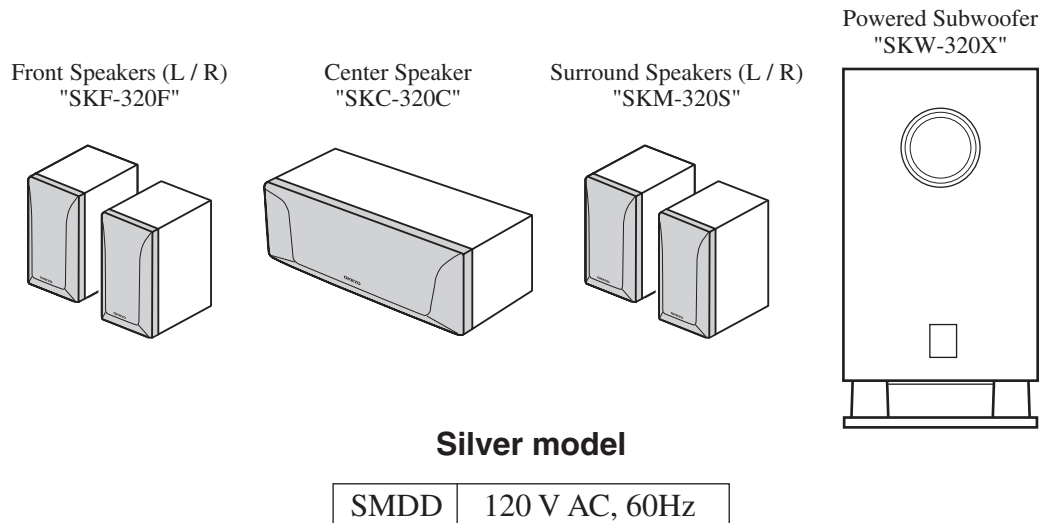
SAFETY-RELATED COMPONENT WARNING!!

COMPONENTS IDENTIFIED BY MARK ⚠ ON THE SCHEMATIC DIAGRAM AND IN THE PARTS LIST ARE CRITICAL FOR RISK OF FIRE AND ELECTRIC SHOCK. REPLACE THESE COMPONENTS WITH ONKYO PARTS WHOSE PART NUMBERS APPEAR AS SHOWN IN THIS MANUAL.
MAKE LEAKAGE-CURRENT OR RESISTANCE MEASUREMENTS TO DETERMINE THAT EXPOSED PARTS ARE ACCEPTABLY INSULATED FROM THE SUPPLY CIRCUIT BEFORE RETURNING THE APPLIANCE TO THE CUSTOMER.

ONKYO
IMAGINATIVE SIGHT & SOUND

SPECIFICATIONS

■ Powered Subwoofer (SKW-320X)

Type :	Powered Bass-reflex
Input sensitivity / impedance :	220 mV / 15 k ohm
Maximum output power :	100 W (Dynamic Power)
Frequency response :	35 Hz - 150 Hz
Cabinet capacity :	0.91 cubic feet (26 Litter)
Dimensions (W x H x D) :	9-1/16 x 17-13/16 x 15-7/8 inch (230 x 436 x 404 mm)
Weight :	24.7 lbs. (11.2 kg)
Speaker unit :	8 inch Cone
Power supply :	AC 120 V, 60 Hz
Power consumption :	75 W
Other :	Auto-Standby function

■ Center Speaker (SKC-320C)

Type :	2 Way Bass-reflex
Impedance :	8 ohm
Maximum input power :	100 W
Output sound pressure level :	78 dB/W/m
Frequency response :	70 Hz - 50 kHz
Crossover frequency :	4.5 kHz
Cabinet capacity :	0.057 cubic feet (1.6 Litter)
Dimensions (W x H x D) :	10-3/8 x 4 x 4-15/16 inch (264 x 101 x 126 mm)
Weight :	4.4 lbs. (2.0 kg)
Speaker unit :	
Woofer	3-1/8 inch Cone x 2
Tweeter	1 inch Balanced Dome
Terminal :	Spring type Color coded
Other :	Magnetic shielding

■ Front Speaker (SKF-320F)

Type :	2 Way Bass-reflex
Impedance :	8 ohm
Maximum input power :	100 W
Output sound pressure level :	76 dB/W/m
Frequency response :	70 Hz - 50 kHz
Crossover frequency :	4.5 kHz
Cabinet capacity :	0.035 cubic feet (1.0 Litter)
Dimensions (W x H x D) :	4 x 6-5/8 x 4-15/16 inch (101 x 169 x 126 mm)
Weight :	2.6 lbs. (1.2 kg)
Speaker unit :	
Woofer :	3-1/8 inch Cone
Tweeter :	1 inch Balanced Dome
Terminal :	Spring type Color coded
Other :	Magnetic shielding

■ Surround Speaker (SKM-320S)

Type :	2 Way Bass-reflex
Impedance :	8 ohm
Maximum input power :	100 W
Output sound pressure level :	79 dB/W/m
Frequency response :	70 Hz - 30 kHz
Crossover frequency :	10 kHz
Cabinet capacity :	0.035 cubic feet (1.0 Litter)
Dimensions (W x H x D) :	4 x 6-5/8 x 4-15/16 inch (101 x 169 x 126 mm)
Weight :	1.8 lbs. (0.8 kg)
Speaker unit :	
Woofer :	3-1/8 inch Cone Woofer
Tweeter :	3/4 inch Ceramic Tweeter
Terminal :	Spring type Color coded

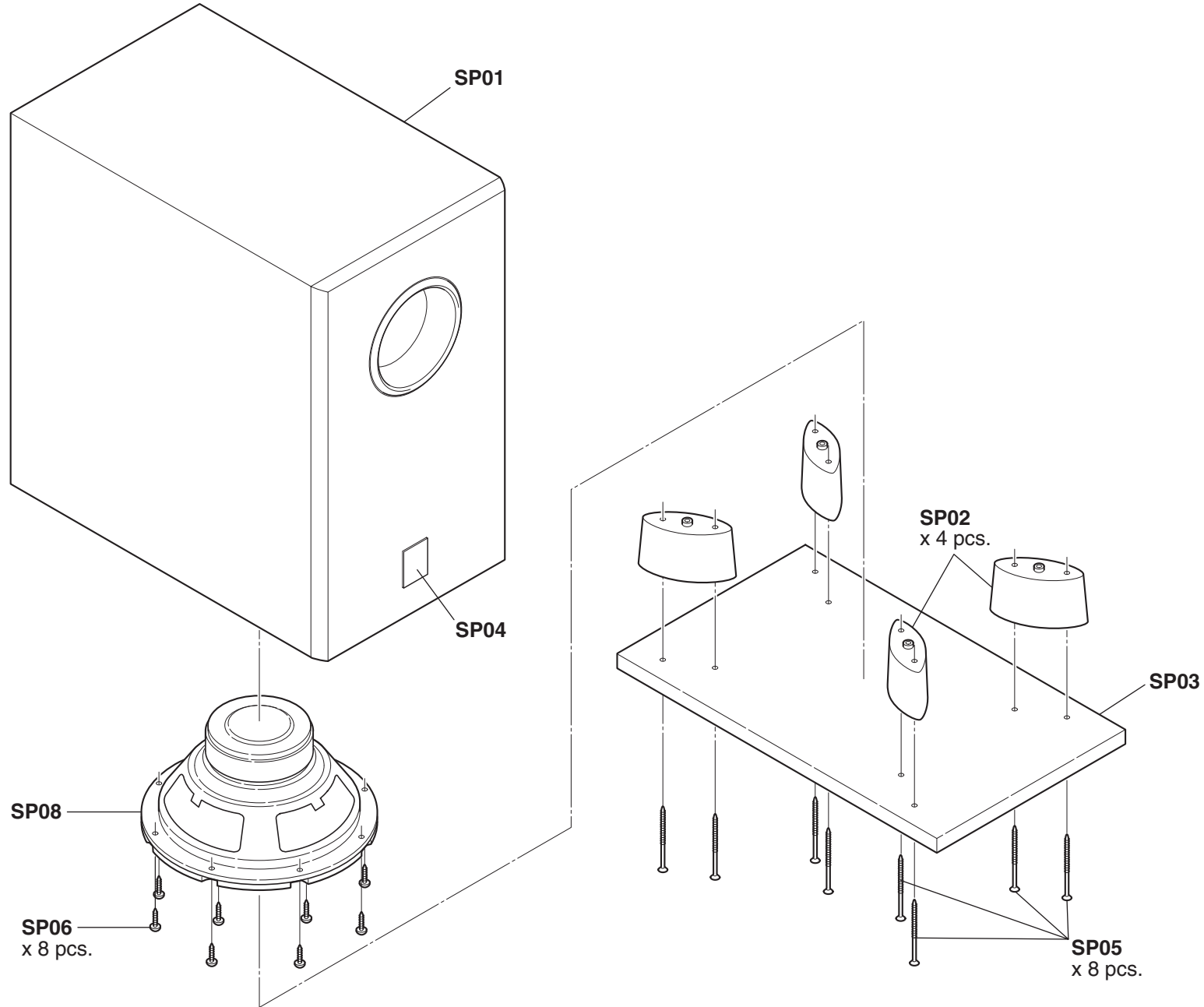Specifications and appearance are subject to change without prior notice.

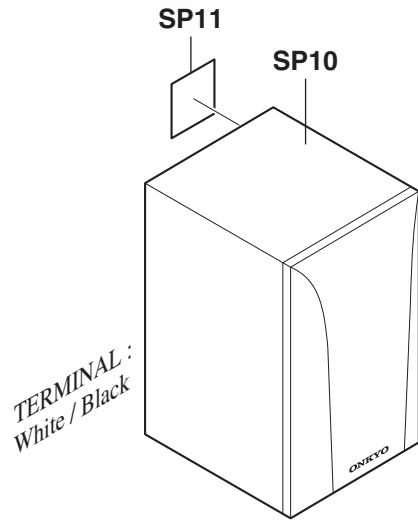# EXPLODED VIEWS-1

SKW-320X : POWERED SUBWOOFER

SP06
x 10 pcs.

A02

A01

Refer to "EXPLODED VIEWS-2"

A03

U03

U02

U01

A05 x 4 pcs.

F903

F902

A04
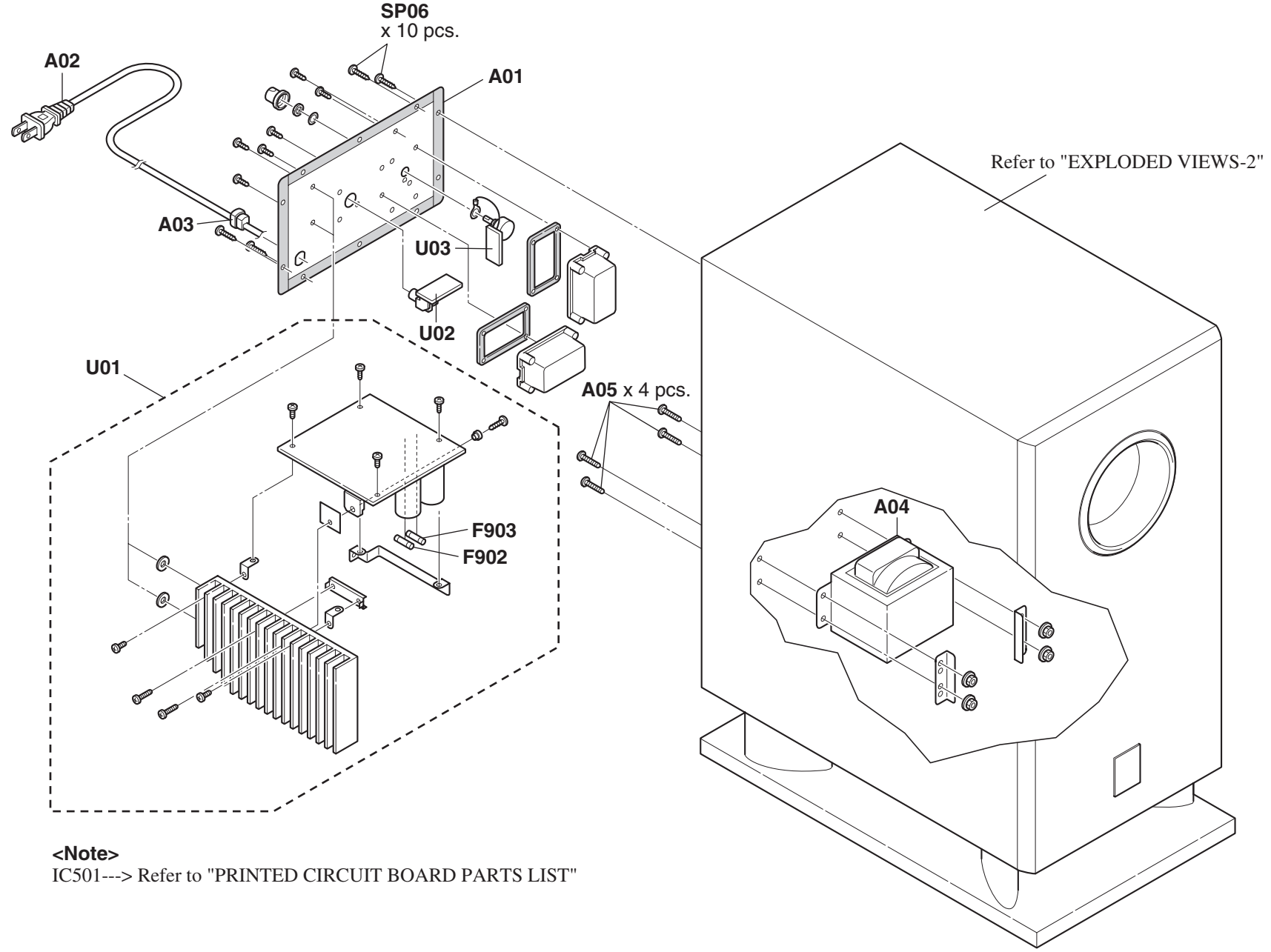
<Note>
IC501---> Refer to "PRINTED CIRCUIT BOARD PARTS LIST"

EXPLODED VIEWS-2
SKW-320X : POWERED SUBWOOFER

SP01

SP04

SP02
x 4 pcs.

SP03

SP08

SP06
x 8 pcs.

SP05
x 8 pcs.

EXPLODED VIEWS-3
SKF-320F / SKC-320C / SKM-320S

SP11
SP10
TERMINAL :
White / Black
ONKYO

"SKF-320F (L)"

SP13
SP12
TERMINAL :
Red / Black
ONKYO

"SKF-320F (R)"

SP14
SP15
TERMINAL :
Green / Black
ONKYO

"SKC-320C"

SP16
SP17
TERMINAL :
Blue / Black
ONKYO
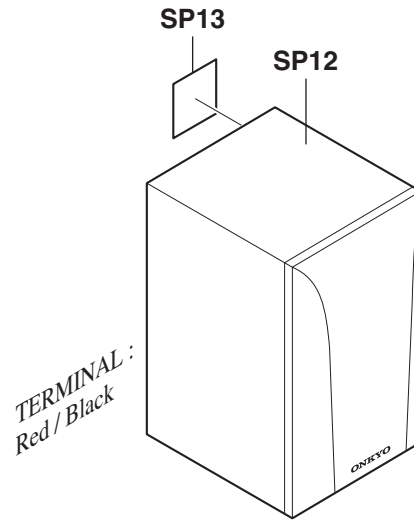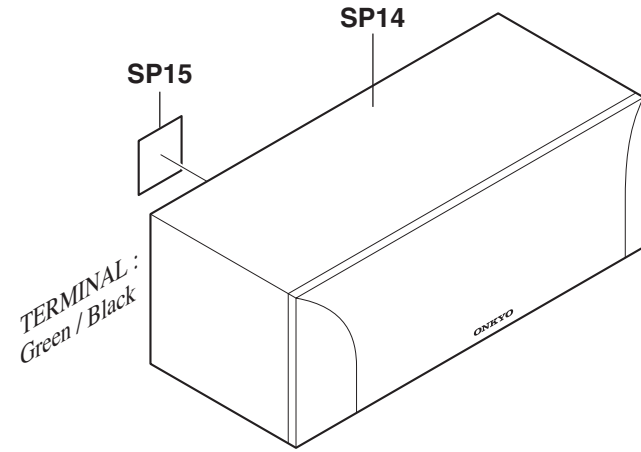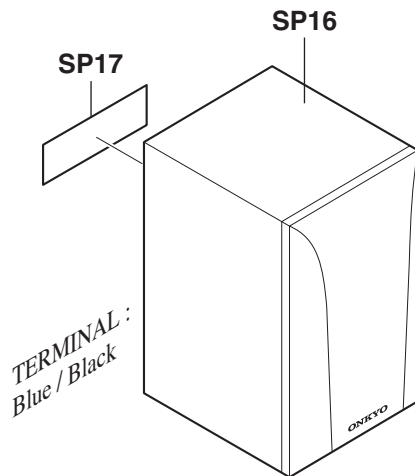
"SKM-320S (L)"
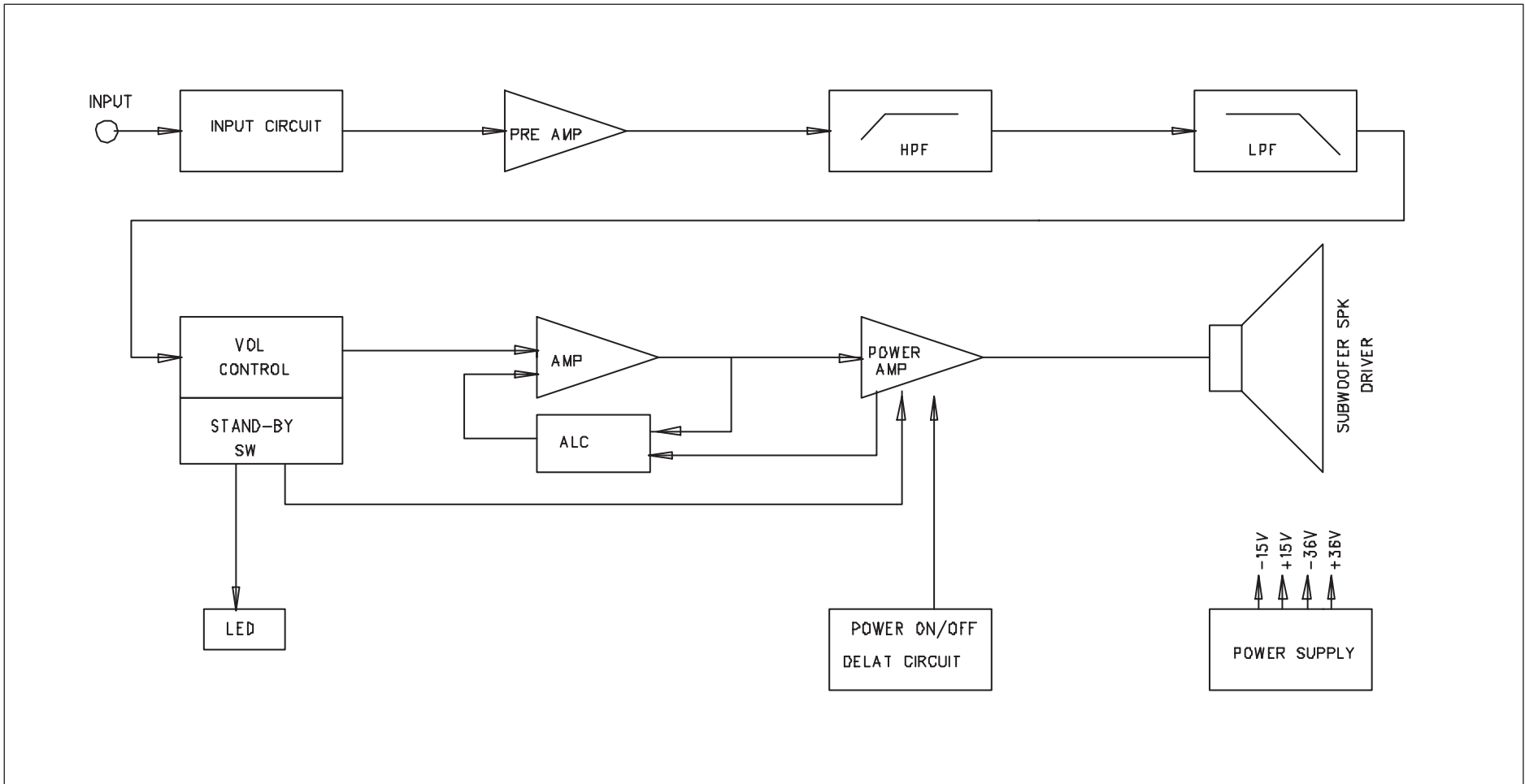NOT MAGNETICALLY SHIELDED

SP18
SP19
TERMINAL :
Gray / Black
ONKYO
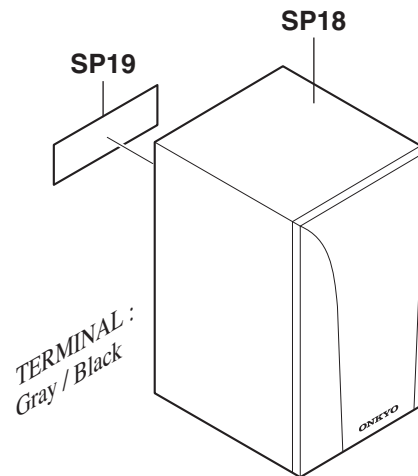
"SKM-320S (R)"
NOT MAGNETICALLY SHIELDED

BLOCK DIAGRAM
SKW-320 : POWERED SUBWOOFER
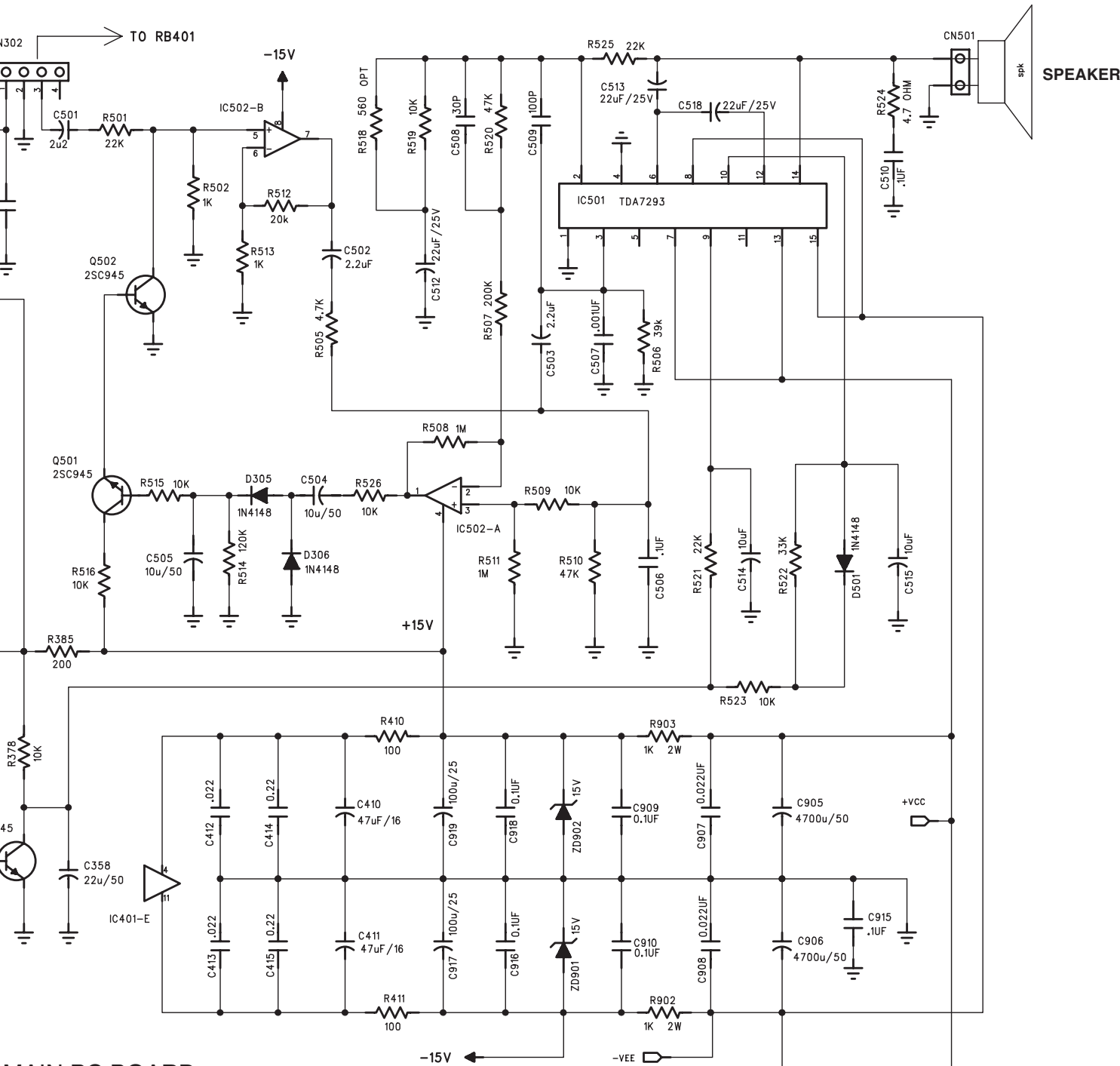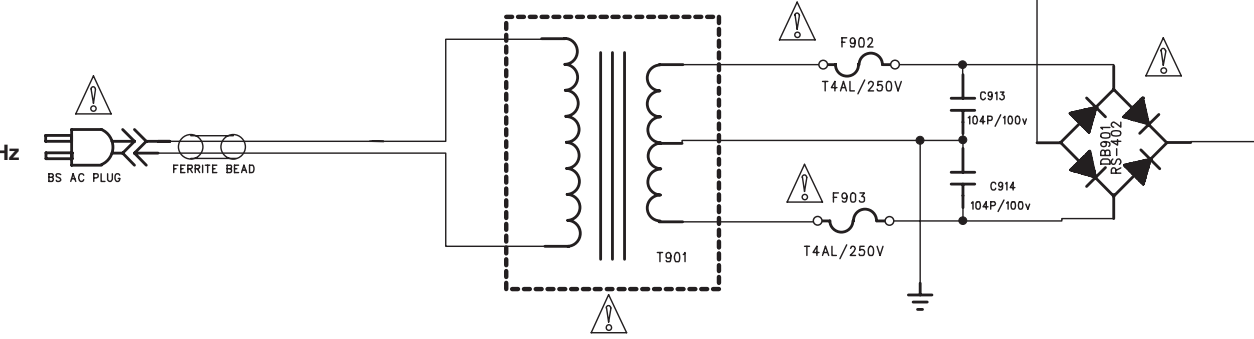
SCHEMATIC DIAGRAM
SKW-320: POWERED SUBWOOFER

CN301

TO RB301

C304 1uF
R305 47K
C306 .022UF
R402 10K
C401 100P
C351 2.2uF
R304 6K8
C402 .012u
R401 150K
IC401-A

C403 .068UF
R403 22k
C418 200P
C404 .068UF
R404 150K
IC401-D

C405 .033UF
C419 200P
R405 15k
R406 56k
C406 .0068UF
IC401-C
C407 1uF
R407 4.7k
C517 .22UF
CN302

R351 100K
R384 2.2K
R372 330

C365 100u/16
R356 10K
R358 270K
R360 10K
R361 10K
R362 1K
C364 0.1uF
C360 220u/16
ZD301 9V
R366 680K
R368 680K
Q301 2SC945
R352 100K
C353 47P
R355 2M2
C354 4u7
IC301-B JRC4558
C356 10u/16
D302 1N4148
R364 220K
IC301-A JRC4558
R354 2K
C352 0.1UF
Q302 2SC945
R359 270K
R363 560K
D301 1N4148
C357 220u/16
R365 1M
R367 82K
R353 4K7
R357 390
C355 47P

TO CN301

JK301 CTP0008-001
RB301
R301 12K
C302 1uF
R303 10k
C301 100P
R302 6.8K

TO CN302

LINE INPUT

RB401
VR401 50K
LD401

CN401

R374 2K2
R373 1K5
R369 OUTPUT LEVEL
R378

Q304 2SC945
R371 10K
R376 10K
Q303 2SC945
R375 1K
R370 10K
R377 33K

INPUT PC BOARD

VR / LE

E F G H

TO RB401

−15V

IC502-B

C501 2u2
R501 22K
R502 1K
R512 20k
R513 1K
C502 2.2uF

Q502 2SC945

R518 560 OPT
R519 10K
C508 30P
R520 47K
C509 100P
R505 4.7K
C512 22uF/25V
R507 200K

R525 22K
C513 22uF/25V
C518 22uF/25V

IC501 TDA7293

CN501
spk
SPEAKER

R524 4.7 OHM
C510 .1UF

C503 2.2uF
C507 .001UF
R506 39k

Q501 2SC945
R515 10K
D305 1N4148
C504 10u/50
R526 10K
IC502-A
R509 10K
C505 10u/50
R514 120K
D306 1N4148
R516 10K
R508 1M
R511 1M
R510 47K
C506 .1UF

R521 22K
C514 10uF
R522 33K
D501 1N4148
C515 10uF

+15V

R385 200

R378 10K

C358 22u/50
IC401-E

R410 100
C412 .022
C414 0.22
C410 47uF/16
C919 100u/25
C918 0.1UF
ZD902 15V
C909 0.1UF
C907 0.022UF
C905 4700u/50
+VCC

C413 .022
C415 0.22
C411 47uF/16
C917 100u/25
C916 0.1UF
ZD901 15V
C910 0.1UF
C908 0.022UF
C906 4700u/50
C915 .1UF

R903 1K 2W

R411 100
R902 1K 2W

−15V
−VEE

MAIN PC BOARD

F902 T4AL/250V
C913 104P/100v
C914 104P/100v
F903 T4AL/250V

Hz
BS AC PLUG   FERRITE BEAD
T901
RDB901 RSB402

SCHEMATIC DIAGRAM

SKW-320: POWERED SUBWOOFER

PC BOARD CONNECTION DIAGRAM
SKW-320 : POWERED SUBWOOFER

INPUT PC BOARD

JK301

LVM0199C021

CN301

RB301

LVAD222C001

RB401

LED

VR / LED PC BOARD

IC501

IC401

LVM0199C011

CN302

MAIN PC BOARD

CN401

CN501

SPK DRIVER

RB904

PWR TRANS

LINE CORD

WIRE CONNECTOR

A B C D
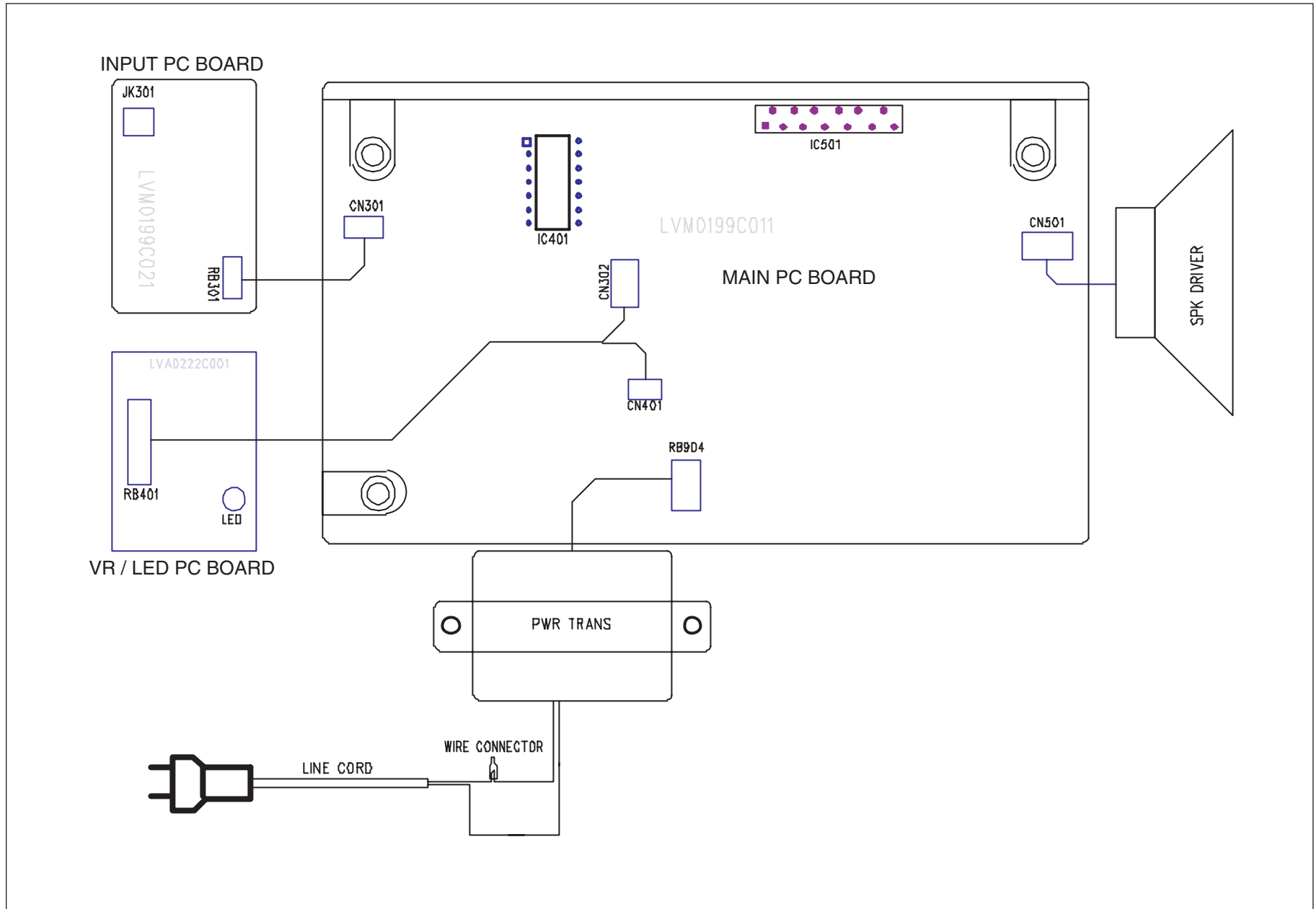
PRINTED CIRCUIT BOARD VIEW
SKW-320POWERED SUBWOOFER

U01 MAIN PC BOARD

1

2

3

4

5
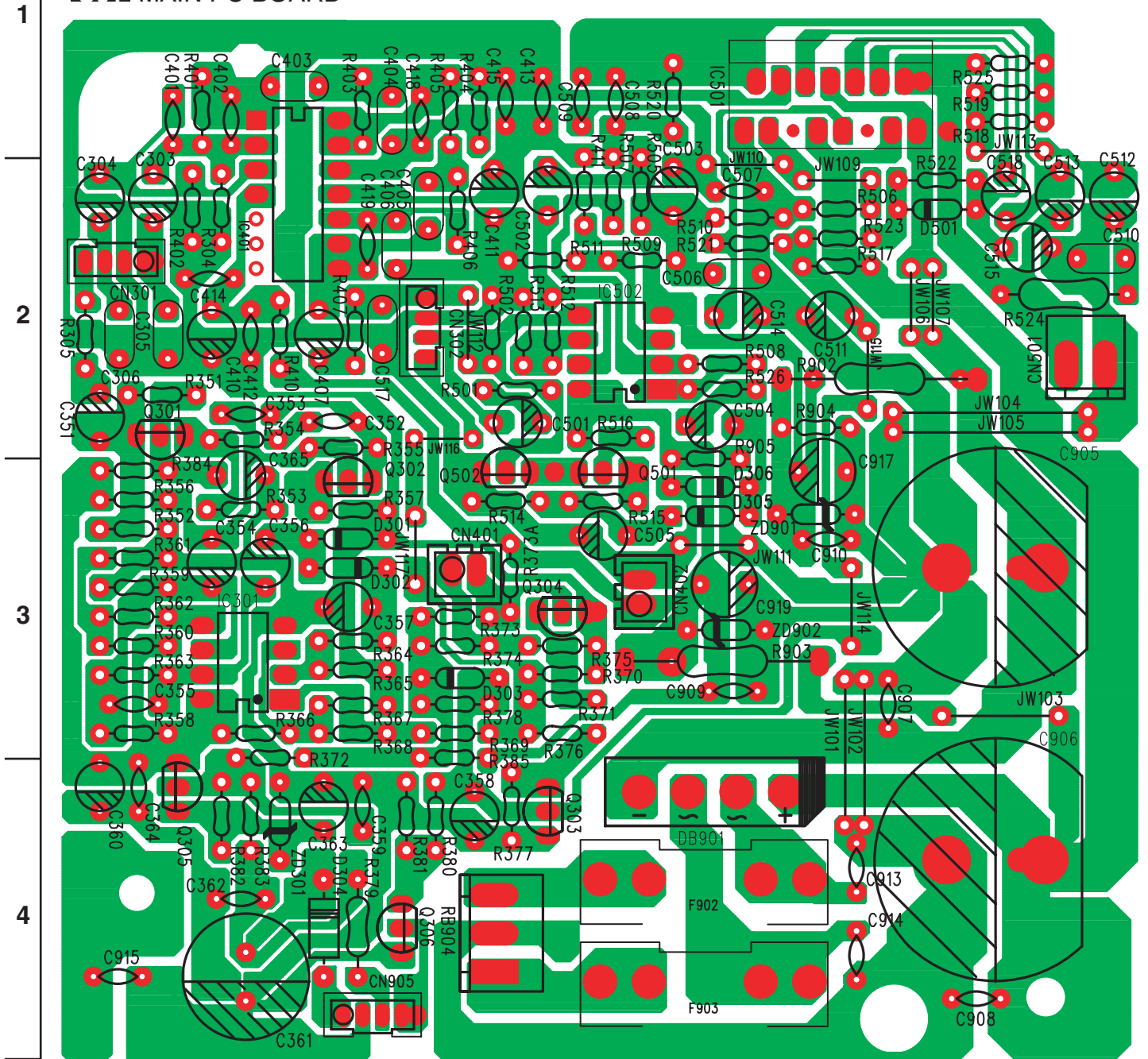
U02 INPUT PC BOARD
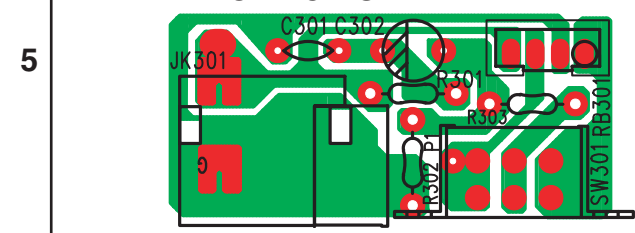
U03 VR / LED PC BOARD

No PC board view
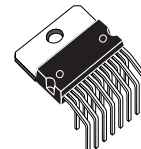Look over the actual PC board on hand

![ST logo] ®

TDA7293

120V - 100W DMOS AUDIO AMPLIFIER WITH MUTE/ST-BY

- VERY HIGH OPERATING VOLTAGE RANGE (±50V)
- DMOS POWER STAGE
- HIGH OUTPUT POWER (100W @ THD = 10%, $R_L = 8\Omega$, $V_S = \pm40V$)
- MUTING/STAND-BY FUNCTIONS
- NO SWITCH ON/OFF NOISE
- VERY LOW DISTORTION
- VERY LOW NOISE
- SHORT CIRCUIT PROTECTED (WITH NO INPUT SIGNAL APPLIED)
- THERMAL SHUTDOWN
- CLIP DETECTOR
- MODULARITY (MORE DEVICES CAN BE EASILY CONNECTED IN PARALLEL TO DRIVE VERY LOW IMPEDANCES)

DESCRIPTION

The TDA7293 is a monolithic integrated circuit in Multiwatt15 package, intended for use as audio class AB amplifier in Hi-Fi field applications (Home Stereo, self powered loudspeakers, Top-

MULTIPOWER BCD TECHNOLOGY
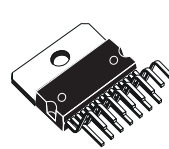
Multiwatt15V   **Multiwatt15H**
ORDERING NUMBERS:
TDA7293V   TDA7293HS

class TV). Thanks to the wide voltage range and to the high out current capability it is able to supply the highest power into both 4Ω and 8Ω loads.

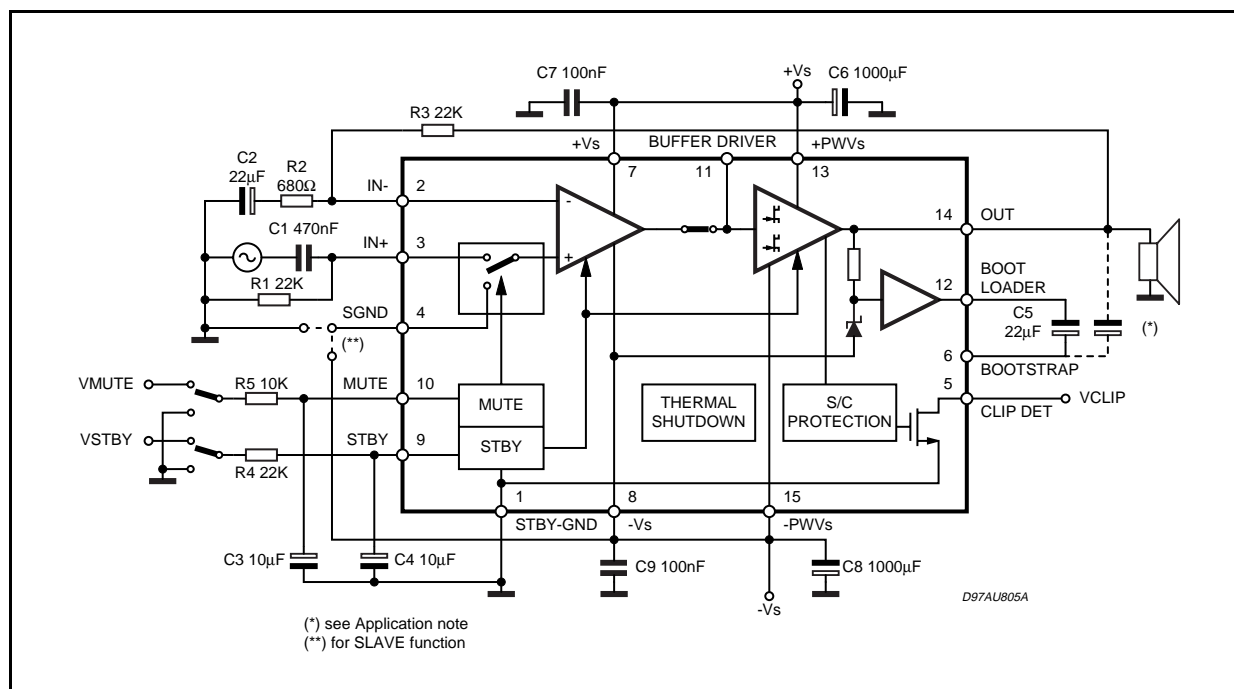The built in muting function with turn on delay simplifies the remote operation avoiding switching on-off noises.

Parallel mode is made possible by connecting more device through of pin11. High output power can be delivered to very low impedance loads, so optimizing the thermal dissipation of the system.
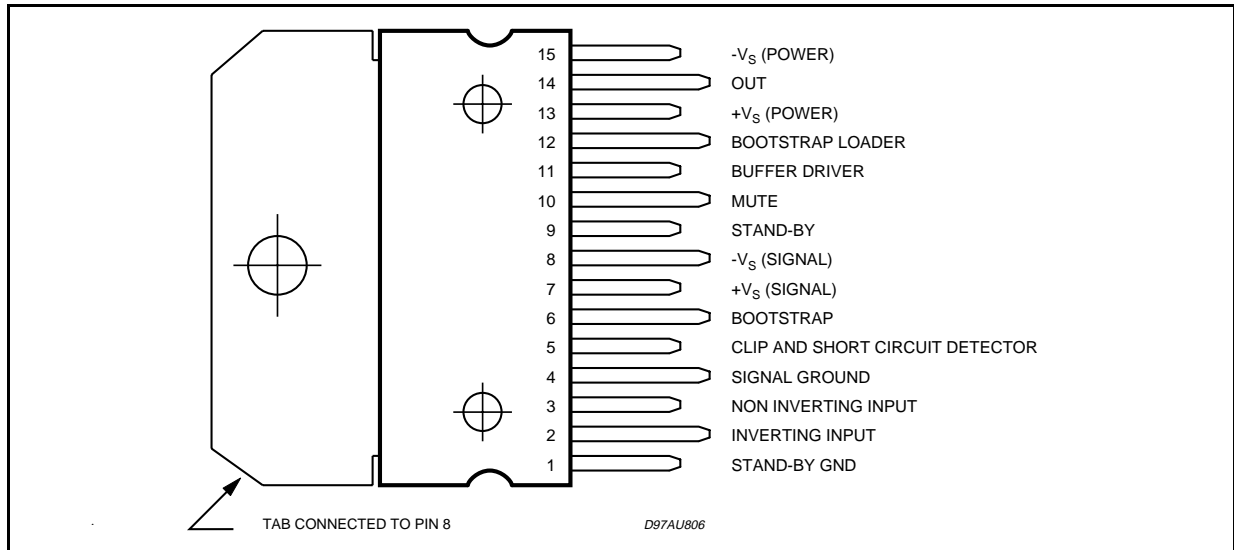
Figure 1: Typical Application and Test Circuit

(*) see Application note
(**) for SLAVE function

PIN CONNECTION (Top view)

Pin	Description
15	-V$_S$ (POWER)
14	OUT
13	+V$_S$ (POWER)
12	BOOTSTRAP LOADER
11	BUFFER DRIVER
10	MUTE
9	STAND-BY
8	-V$_S$ (SIGNAL)
7	+V$_S$ (SIGNAL)
6	BOOTSTRAP
5	CLIP AND SHORT CIRCUIT DETECTOR
4	SIGNAL GROUND
3	NON INVERTING INPUT
2	INVERTING INPUT
1	STAND-BY GND

TAB CONNECTED TO PIN 8   D97AU806

ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V$_S$	Supply Voltage (No Signal)	±60	V
V$_1$	V$_{STAND-BY}$ GND Voltage Referred to -V$_S$ (pin 8)	90	V
V$_2$	Input Voltage (inverting) Referred to -V$_S$	90	V
V$_2$ - V$_3$	Maximum Differential Inputs	±30	V
V$_3$	Input Voltage (non inverting) Referred to -V$_S$	90	V
V$_4$	Signal GND Voltage Referred to -V$_S$	90	V
V$_5$	Clip Detector Voltage Referred to -V$_S$	120	V
V$_6$	Bootstrap Voltage Referred to -V$_S$	120	V
V$_9$	Stand-by Voltage Referred to -V$_S$	120	V
V$_{10}$	Mute Voltage Referred to -V$_S$	120	V
V$_{11}$	Buffer Voltage Referred to -V$_S$	120	V
V$_{12}$	Bootstrap Loader Voltage Referred to -V$_S$	100	V
I$_O$	Output Peak Current	10	A
P$_{tot}$	Power Dissipation T$_{case}$ = 70°C	50	W
T$_{op}$	Operating Ambient Temperature Range	0 to 70	°C
T$_{stg}$, T$_j$	Storage and Junction Temperature	150	°C

THERMAL DATA

Symbol	Description	Typ	Max	Unit
R$_{th\ j-case}$	Thermal Resistance Junction-case	1	1.5	°C/W

ELECTRICAL CHARACTERISTICS (Refer to the Test Circuit $V_S = \pm40V$, $R_L = 8\Omega$, $R_g = 50\ \Omega$; $T_{amb} = 25°C$, $f = 1$ kHz; unless otherwise specified).

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
V_S	Supply Range		±12		±50	V
I_q	Quiescent Current			50	100	mA
I_b	Input Bias Current			0.3	1	µA
V_{OS}	Input Offset Voltage		-10		10	mV
I_{OS}	Input Offset Current				0.2	µA
P_O	RMS Continuous Output Power	d = 1%: $R_L = 4\Omega$; Vs = ± 29V,	75	80 80		W
		d = 10% $R_L = 4\Omega$; $V_S = \pm29V$	90	100 100		W
d	Total Harmonic Distortion (**)	$P_O = 5W$; f = 1kHz $P_O = 0.1$ to 50W; f = 20Hz to 15kHz		0.005	0.1	% %
I_{SC}	Current Limiter Threshold	Vs ≤ ± 40V		6.5		A
SR	Slew Rate		5	10		V/µs
G_V	Open Loop Voltage Gain			80		dB
G_V	Closed Loop Voltage Gain (1)		29	30	31	dB
e_N	Total Input Noise	A = curve f = 20Hz to 20kHz		1 3	10	µV µV
R_i	Input Resistance		100			kΩ
SVR	Supply Voltage Rejection	f = 100Hz; $V_{ripple} = 0.5Vrms$		75		dB
T_S	Thermal Protection	DEVICE MUTED		150		°C
		DEVICE SHUT DOWN		160		°C
STAND-BY FUNCTION (Ref: to pin 1)						
$V_{ST\ on}$	Stand-by on Threshold				1.5	V
$V_{ST\ off}$	Stand-by off Threshold		3.5			V
ATT_{st-by}	Stand-by Attenuation		70	90		dB
$I_{q\ st-by}$	Quiescent Current @ Stand-by			0.5	1	mA
MUTE FUNCTION (Ref: to pin 1)						
V_{Mon}	Mute on Threshold				1.5	V
V_{Moff}	Mute off Threshold		3.5			V
ATT_{mute}	Mute Attenuatlon		60	80		dB
CLIP DETECTOR						
Duty	Duty Cycle (pin 5)	THD = 1% ; RL = 10KΩ to 5V		10		%
		THD = 10% ; RL = 10KΩ to 5V	30	40	50	%
I_{CLEAK}		PO = 50W			3	µA
SLAVE FUNCTION pin 4 (Ref: to pin 8 -Vs)						
V_{Slave}	SlaveThreshold				1	V
V_{Master}	Master Threshold		3			V

Note (1): $G_{Vmin} \geq 26dB$

Note: Pin 11 only for modular connection. Max external load 1MΩ/10 pF, only for test purpose

Note (**): Tested with optimized Application Board (see fig. 2)

Figure 2: Typical Application P.C. Board and Component Layout (scale 1:1)
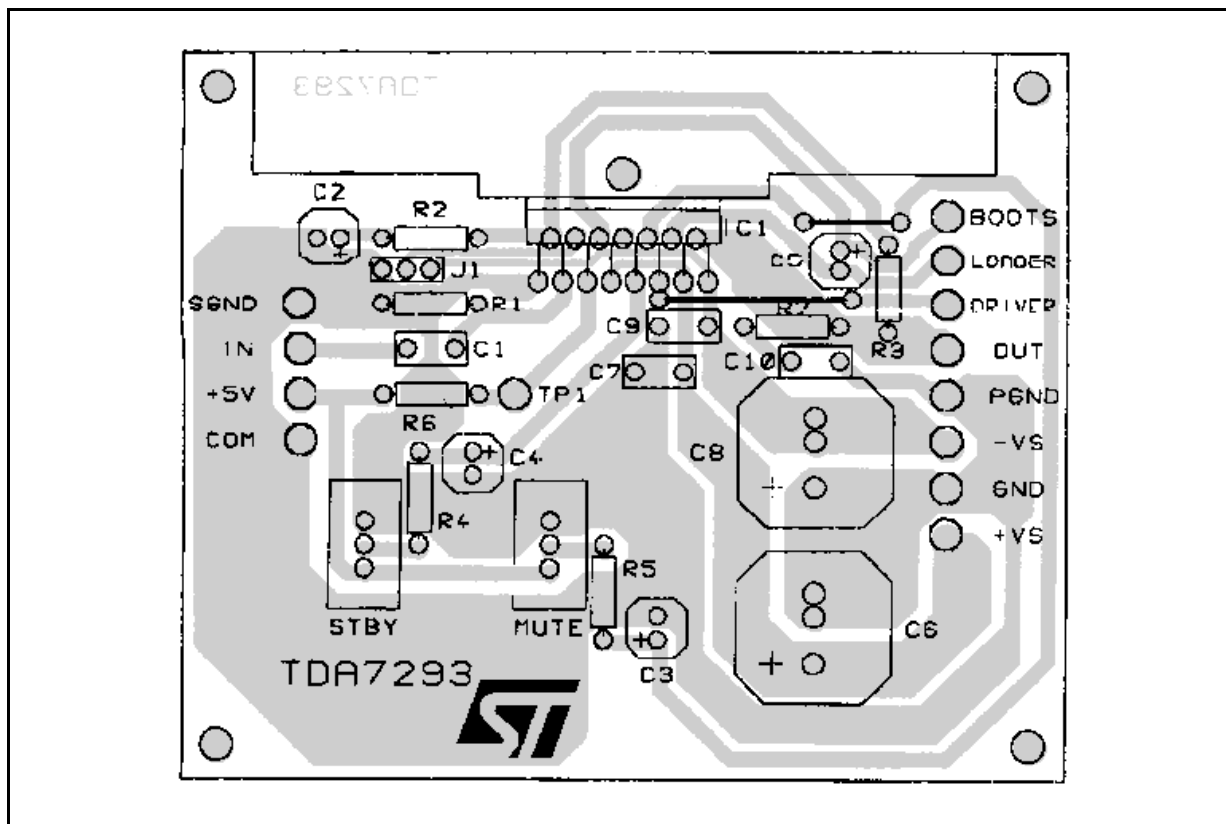
**APPLICATION SUGGESTIONS** (see Test and Application Circuits of the Fig. 1)

The recommended values of the external components are those shown on the application circuit of Figure 1. Different values can be used; the following table can help the designer.

COMPONENTS	SUGGESTED VALUE	PURPOSE	LARGER THAN SUGGESTED	SMALLER THAN SUGGESTED
R1 (*)	22k	INPUT RESISTANCE	INCREASE INPUT IMPEDANCE	DECREASE INPUT IMPEDANCE
R2	680Ω	CLOSED LOOP GAIN SET TO 30dB (**)	DECREASE OF GAIN	INCREASE OF GAIN
R3 (*)	22k		INCREASE OF GAIN	DECREASE OF GAIN
R4	22k	ST-BY TIME CONSTANT	LARGER ST-BY ON/OFF TIME	SMALLER ST-BY ON/OFF TIME; POP NOISE
R5	10k	MUTE TIME CONSTANT	LARGER MUTE ON/OFF TIME	SMALLER MUTE ON/OFF TIME
C1	0.47μF	INPUT DC DECOUPLING		HIGHER LOW FREQUENCY CUTOFF
C2	22μF	FEEDBACK DC DECOUPLING		HIGHER LOW FREQUENCY CUTOFF
C3	10μF	MUTE TIME CONSTANT	LARGER MUTE ON/OFF TIME	SMALLER MUTE ON/OFF TIME
C4	10μF	ST-BY TIME CONSTANT	LARGER ST-BY ON/OFF TIME	SMALLER ST-BY ON/OFF TIME; POP NOISE
C5	22μFXN (***)	BOOTSTRAPPING		SIGNAL DEGRADATION AT LOW FREQUENCY
C6, C8	1000μF	SUPPLY VOLTAGE BYPASS		
C7, C9	0.1μF	SUPPLY VOLTAGE BYPASS		DANGER OF OSCILLATION

(*) R1 = R3 for pop optimization

(**) Closed Loop Gain has to be $\geq$ 26dB

(***) Multiplay this value for the number of modular part connected

Slave function: pin 4 (Ref to pin 8 -VS**)**
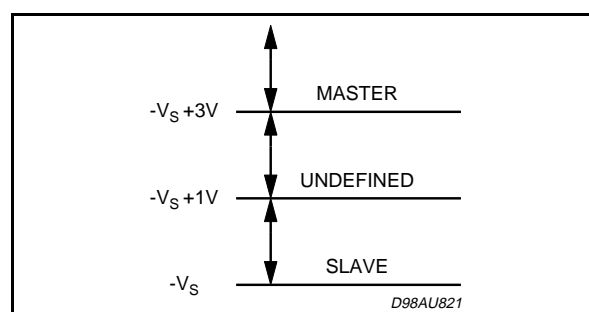
Note:

If in the application, the speakers are connected via long wires, it is a good rule to add between the output and GND, a Boucherot Cell, in order to avoid dangerous spurious oscillations when the speakers terminal are shorted.

The suggested Boucherot Resistor is 3.9Ω/2W and the capacitor is 1μF.

INTRODUCTION

In consumer electronics, an increasing demand has arisen for very high power monolithic audio amplifiers able to match, with a low cost, the performance obtained from the best discrete designs.

The task of realizing this linear integrated circuit in conventional bipolar technology is made extremely difficult by the occurence of 2nd breakdown phoenomenon. It limits the safe operating area (SOA) of the power devices, and, as a consequence, the maximum attainable output power, especially in presence of highly reactive loads.

Moreover, full exploitation of the SOA translates into a substantial increase in circuit and layout complexity due to the need of sophisticated protection circuits.

To overcome these substantial drawbacks, the use of power MOS devices, which are immune from secondary breakdown is highly desirable.

The device described has therefore been developed in a mixed bipolar-MOS high voltage technology called BCDII 100/120.

1) Output Stage

The main design task in developping a power operational amplifier, independently of the technology used, is that of realization of the output stage.

The solution shown as a principle shematic by Fig3 represents the DMOS unity - gain output buffer of the TDA7293.

This large-signal, high-power buffer must be capable of handling extremely high current and voltage levels while maintaining acceptably low harmonic distortion and good behaviour over

frequency response; moreover, an accurate control of quiescent current is required.

A local linearizing feedback, provided by differential amplifier A, is used to fullfil the above requirements, allowing a simple and effective quiescent current setting.

Proper biasing of the power output transistors alone is however not enough to guarantee the absence of crossover distortion.

While a linearization of the DC transfer characteristic of the stage is obtained, the dynamic behaviour of the system must be taken into account.

A significant aid in keeping the distortion contributed by the final stage as low as possible is provided by the compensation scheme, which exploits the direct connection of the Miller capacitor at the amplifier's output to introduce a local AC feedback path enclosing the output stage itself.

2) Protections

In designing a power IC, particular attention must be reserved to the circuits devoted to protection of the device from short circuit or overload conditions.

Due to the absence of the 2nd breakdown phenomenon, the SOA of the power DMOS transistors is delimited only by a maximum dissipation curve dependent on the duration of the applied stimulus.

In order to fully exploit the capabilities of the power transistors, the protection scheme implemented in this device combines a conventional SOA protection circuit with a novel local temperature sensing technique which " dynamically" controls the maximum dissipation.

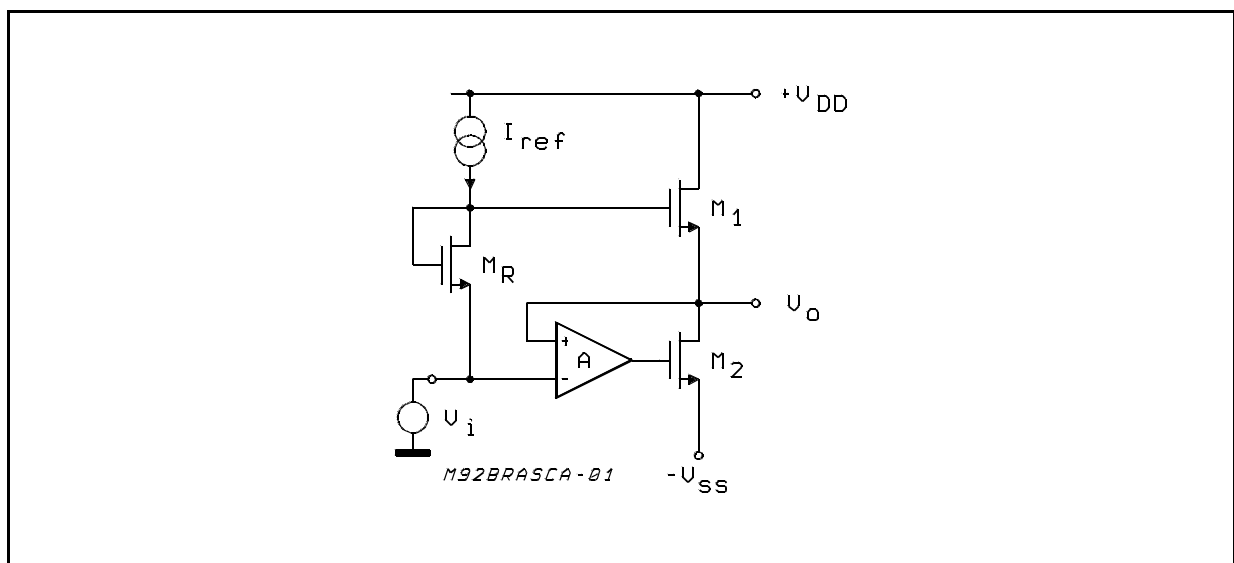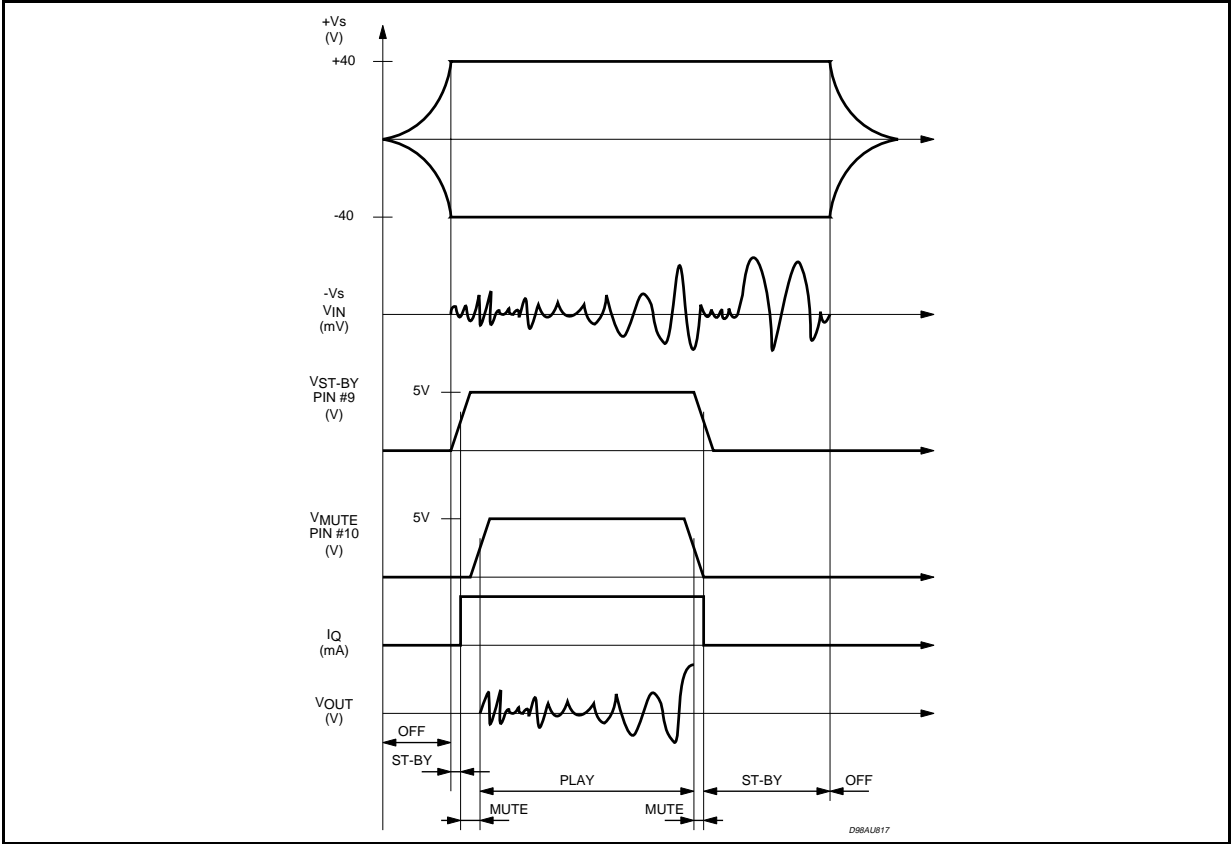**Figure 3:** Principle Schematic of a DMOS unity-gain buffer.

Figure 4: Turn ON/OFF Suggested Sequence

In addition to the overload protection described above, the device features a thermal shutdown circuit which initially puts the device into a muting state (@ Tj = 150 $^{\circ}$C) and then into stand-by (@ Tj = 160 $^{\circ}$C).

Full protection against electrostatic discharges on every pin is included.

Figure 5: Single Signal ST-BY/MUTE Control Circuit
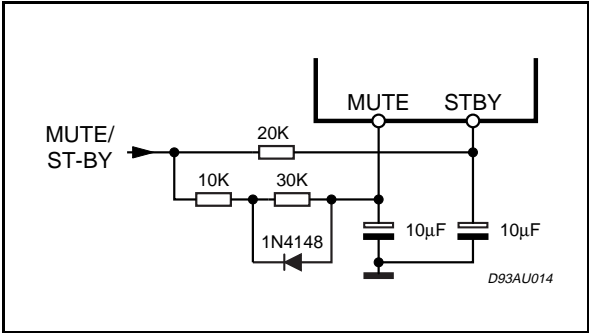
3) Other Features

The device is provided with both stand-by and mute functions, independently driven by two CMOS logic compatible input pins.

The circuits dedicated to the switching on and off of the amplifier have been carefully optimized to avoid any kind of uncontrolled audible transient at the output.

The sequence that we recommend during the ON/OFF transients is shown by Figure 4.

The application of figure 5 shows the possibility of using only one command for both st-by and mute functions. On both the pins, the maximum applicable range corresponds to the operating supply voltage.

APPLICATION INFORMATION

HIGH-EFFICIENCY

Constraints of implementing high power solutions are the power dissipation and the size of the power supply. These are both due to the low efficiency of conventional AB class amplifier approaches.

Here below (figure 6) is described a circuit proposal for a high efficiency amplifier which can be adopted for both HI-FI and CAR-RADIO applications.

The TDA7293 is a monolithic MOS power amplifier which can be operated at 100V supply voltage (120V with no signal applied) while delivering output currents up to ±6.5 A.

This allows the use of this device as a very high power amplifier (up to 180W as peak power with T.H.D.=10 % and Rl = 4 Ohm); the only drawback is the power dissipation, hardly manageable in the above power range.

The typical junction-to-case thermal resistance of the TDA7293 is 1 ^{o}C/W (max= 1.5 ^{o}C/W). To avoid that, in worst case conditions, the chip temperature exceeds 150 ^{o}C, the thermal resistance of the heatsink must be 0.038 ^{o}C/W (@ max ambient temperature of 50 ^{o}C).

As the above value is pratically unreachable; a high efficiency system is needed in those cases where the continuous RMS output power is higher than 50-60 W.

The TDA7293 was designed to work also in higher efficiency way.

For this reason there are four power supply pins: two intended for the signal part and two for the power part.

T1 and T2 are two power transistors that only operate when the output power reaches a certain threshold (e.g. 20 W). If the output power increases, these transistors are switched on during the portion of the signal where more output voltage swing is needed, thus "bootstrapping" the power supply pins (#13 and #15).

The current generators formed by T4, T7, zener diodes Z1, Z2 and resistors R7,R8 define the minimum drop across the power MOS transistors of the TDA7293. L1, L2, L3 and the snubbers C9, R1 and C10, R2 stabilize the loops formed by the "bootstrap" circuits and the output stage of the TDA7293.

By considering again a maximum average output power (music signal) of 20W, in case of the high efficiency application, the thermal resistance value needed from the heatsink is 2.2^{o}C/W (Vs =±50 V and Rl= 8 Ohm).

All components (TDA7293 and power transistors T1 and T2) can be placed on a 1.5^{o}C/W heatsink, with the power darlingtons electrically insulated from the heatsink.

Since the total power dissipation is less than that of a usual class AB amplifier, additional cost savings can be obtained while optimizing the power supply, even with a high heatsink .

BRIDGE APPLICATION

Another application suggestion is the BRIDGE configuration, where two TDA7293 are used.

In this application, the value of the load must not be lower than 8 Ohm for dissipation and current capability reasons.

A suitable field of application includes HI-FI/TV subwoofers realizations.

The main advantages offered by this solution are:
- High power performances with limited supply voltage level.
- Considerably high output power even with high load values (i.e. 16 Ohm).

With Rl= 8 Ohm, Vs = ±25V the maximum output power obtainable is 150 W, while with Rl=16 Ohm, Vs = ±40V the maximum Pout is 200 W.

APPLICATION NOTE: (ref. fig. 7)

Modular Application (more Devices in Parallel)

The use of the modular application lets very high power be delivered to very low impedance loads. The modular application implies one device to act as a master and the others as slaves.

The slave power stages are driven by the master device and work in parallel all together, while the input and the gain stages of the slave device are disabled, the figure below shows the connections required to configure two devices to work together.

- The master chip connections are the same as the normal single ones.
- The outputs can be connected together **without the need of any ballast resistance.**
- The slave SGND pin must be tied to the negative supply.
- The slave ST-BY and MUTE pins must be connected to the master ST-BY and MUTE pins.
- The bootstrap lines must be connected together and the bootstrap capacitor must be increased: for N devices the boostrap capacitor must be 22μF times N.
- The slave IN-pin must be connected to the negative supply.

THE BOOTSTRAP CAPACITOR

For compatibility purpose with the previous devices of the family, the boostrap capacitor can be connected both between the bootstrap pin (6) and the output pin (14) or between the boostrap pin (6) and the bootstrap loader pin (12).

When the bootcap is connected between pin 6 and 14, the maximum supply voltage in presence of output signal is limited to 100V, due the bootstrap capacitor overvoltage.

When the bootcap is connected between pins 6 and 12 the maximum supply voltage extend to the full voltage that the technology can stand: 120V.

This is accomplished by the clamp introduced at the bootstrap loader pin (12): this pin follows the output voltage up to 100V and remains clamped at 100V for higher output voltages. This feature lets the output voltage swing up to a gate-source voltage from the positive supply (Vs -3 to 6V).
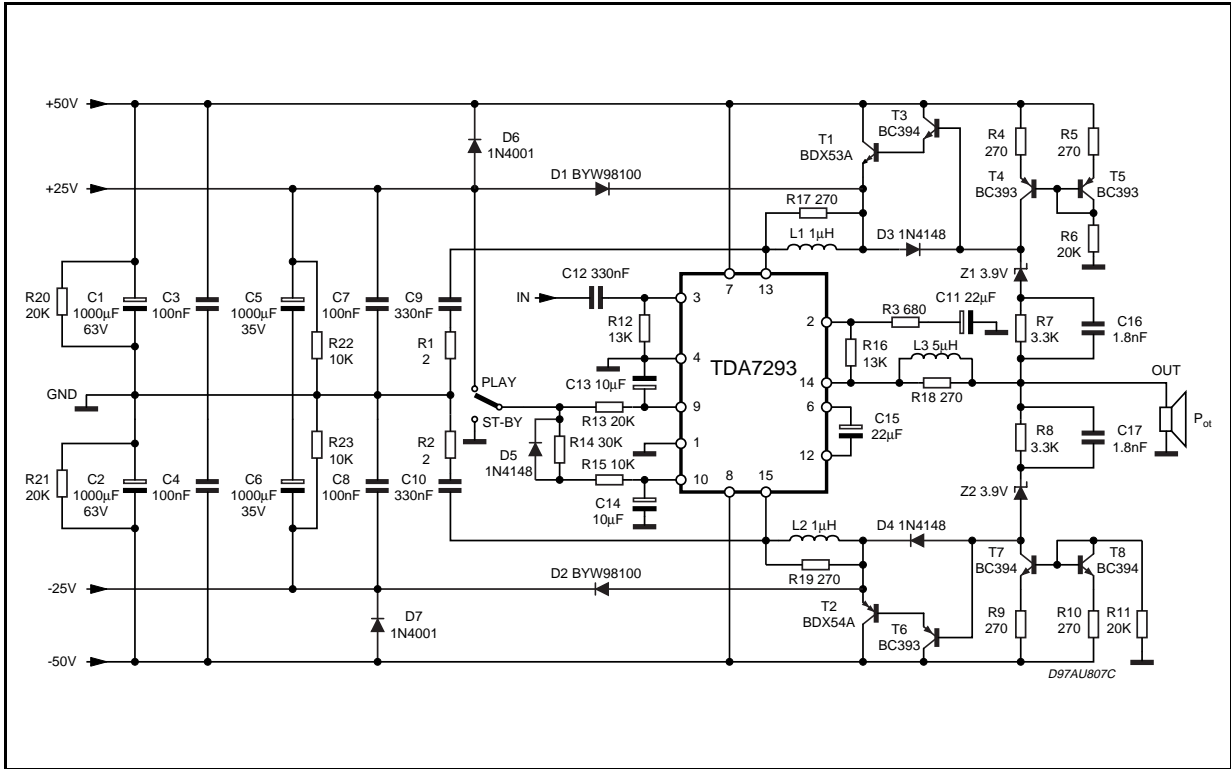
ST

Figure 6: High Efficiency Application Circuit

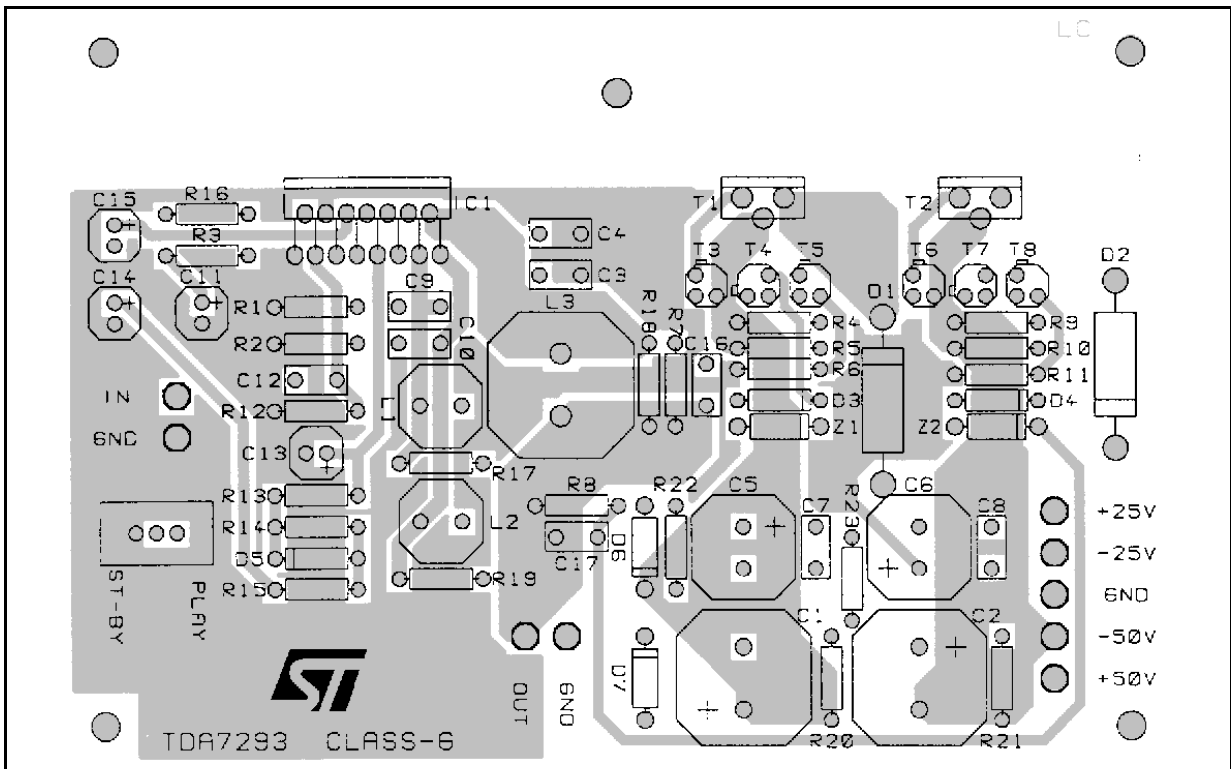**Figure 6a:** PCB and Component Layout of the fig. 6

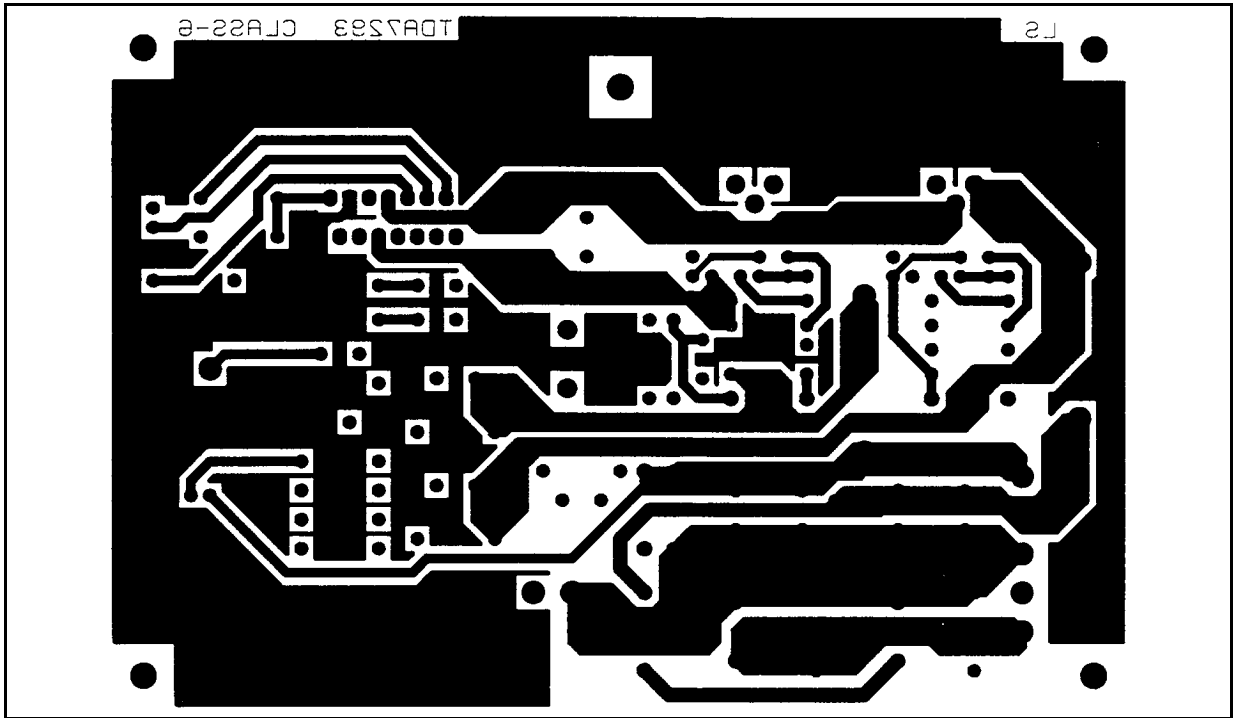**Figure 6b:** PCB - Solder Side of the fig. 6.

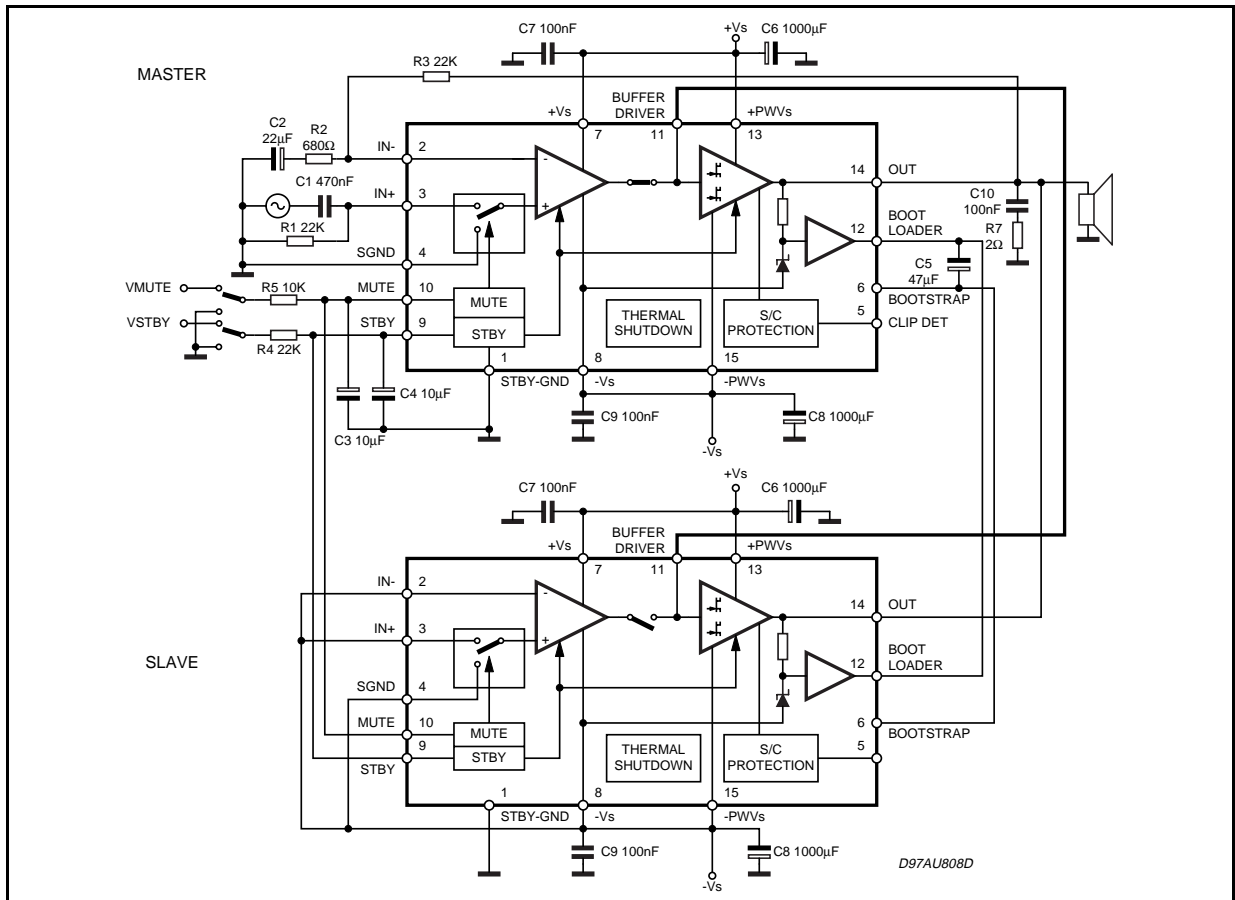**Figure 7:** Modular Application Circuit

Figure 8a: Modular Application P.C. Board and Component Layout (scale 1:1) (Component SIDE)
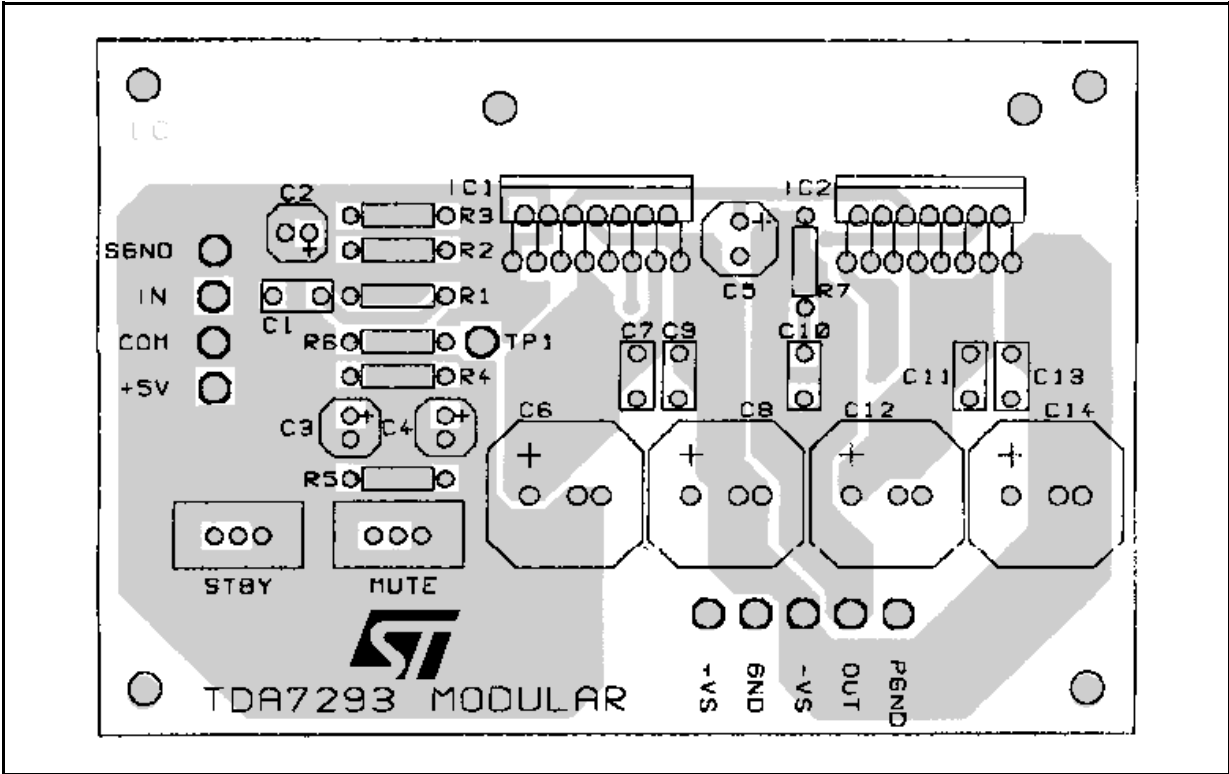

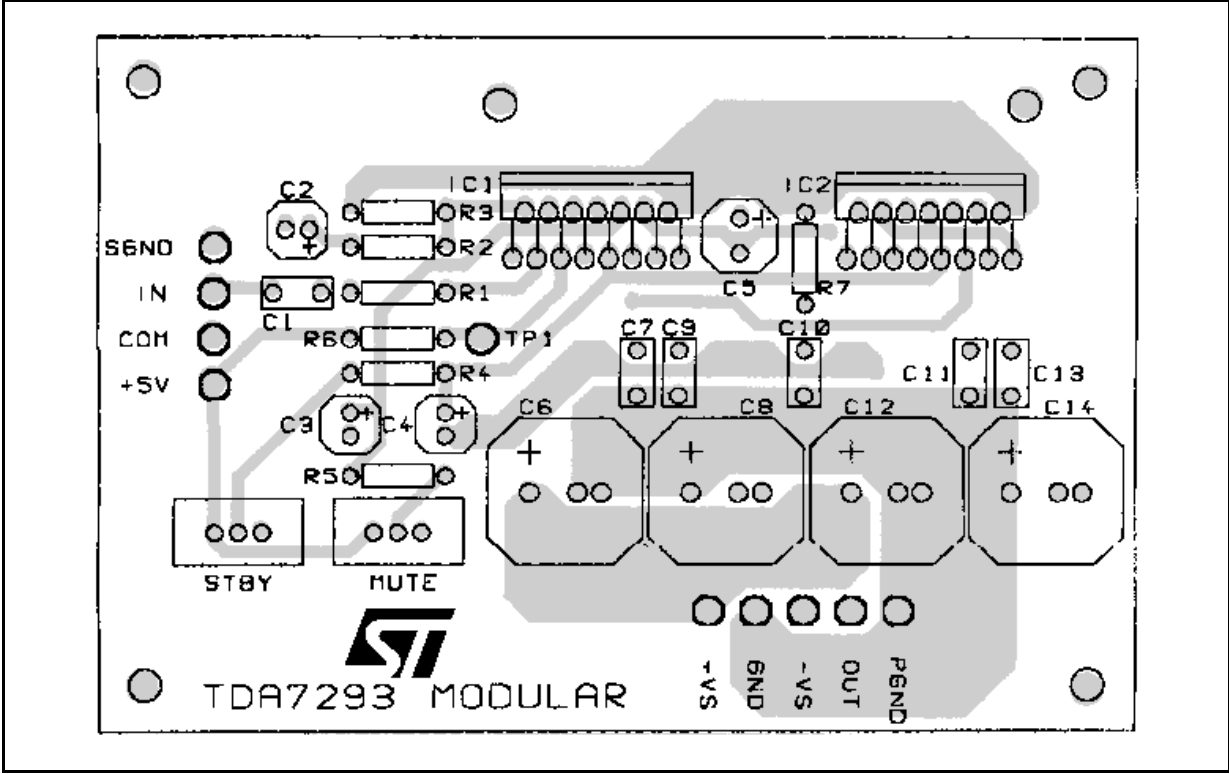**Figure 8b:** Modular Application P.C. Board and Component Layout (scale 1:1) (Solder SIDE)
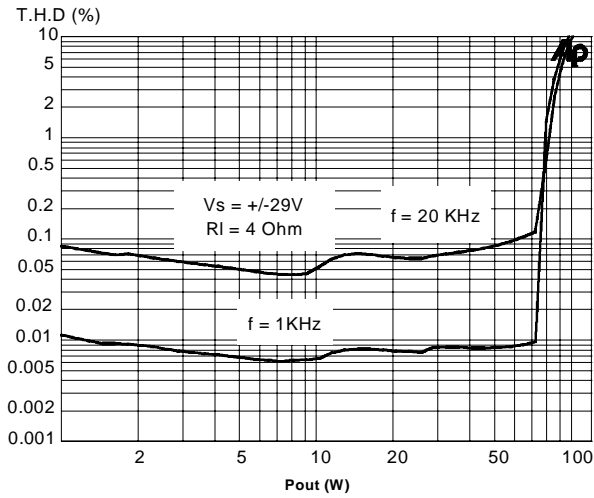
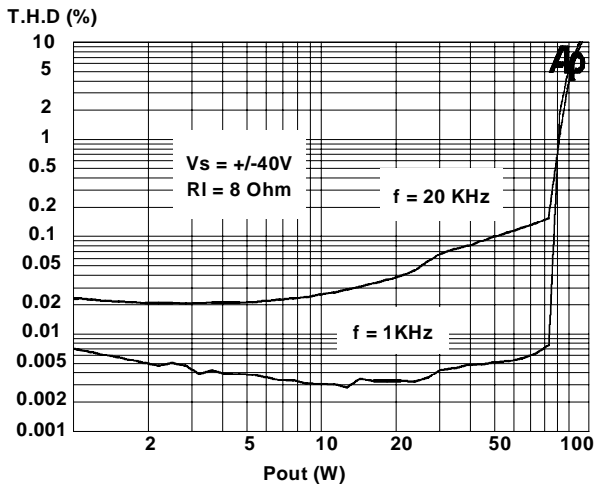**Figure 9:** Distortion vs Output Power

Figure 10: Distortion vs Output Power

Figure 11: Distortion vs Frequency
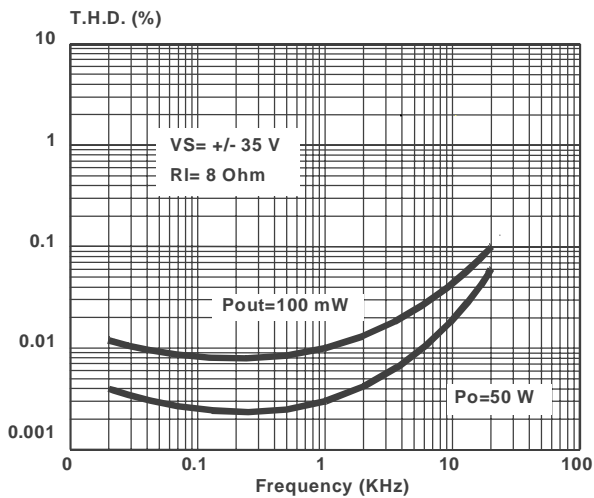
Figure 12: Modular Application Derating Rload vs Vsupply (ref. fig. 7)
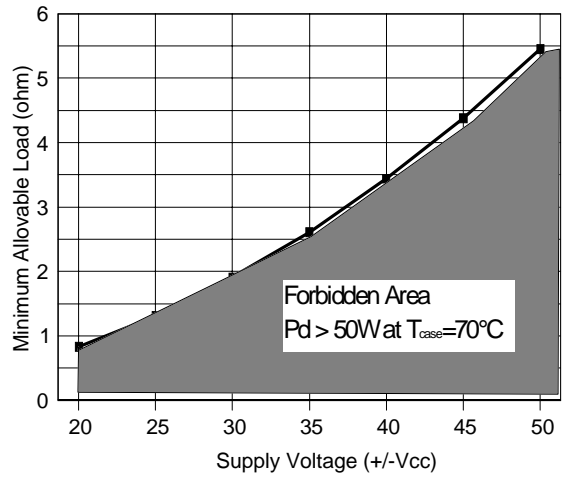

Figure 13: Modular Application Pd vs Vsupply (ref. fig. 7)
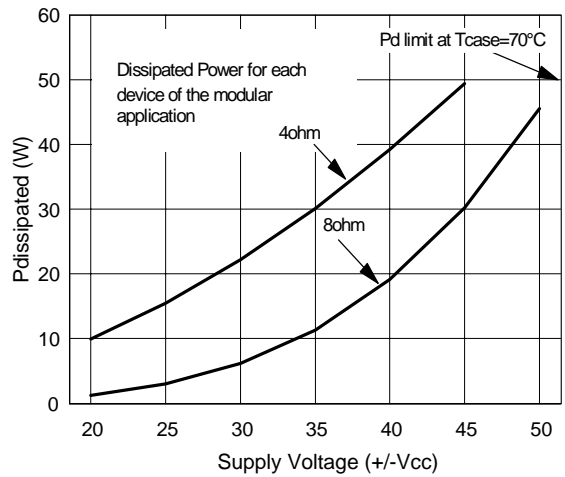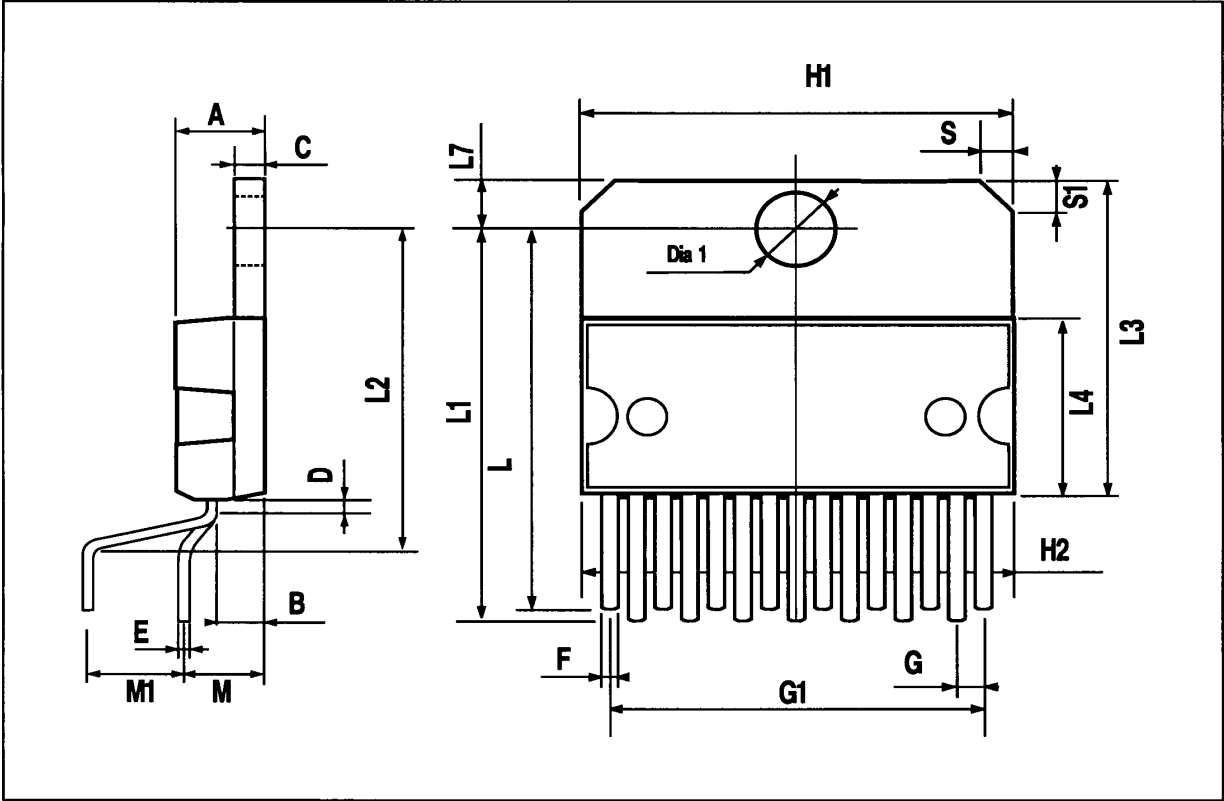

Figure 14: Output Power vs. Supply Voltage
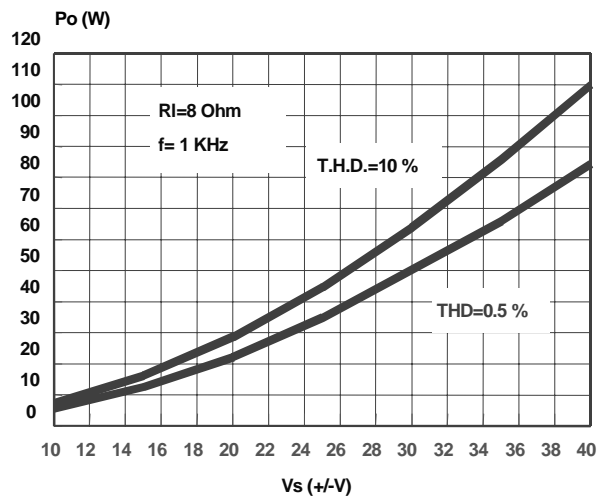
DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			5			0.197
B			2.65			0.104
C			1.6			0.063
D		1			0.039	
E	0.49		0.55	0.019		0.022
F	0.66		0.75	0.026		0.030
G	1.02	1.27	1.52	0.040	0.050	0.060
G1	17.53	17.78	18.03	0.690	0.700	0.710
H1	19.6			0.772		
H2			20.2			0.795
L	21.9	22.2	22.5	0.862	0.874	0.886
L1	21.7	22.1	22.5	0.854	0.870	0.886
L2	17.65		18.1	0.695		0.713
L3	17.25	17.5	17.75	0.679	0.689	0.699
L4	10.3	10.7	10.9	0.406	0.421	0.429
L7	2.65		2.9	0.104		0.114
M	4.25	4.55	4.85	0.167	0.179	0.191
M1	4.63	5.08	5.53	0.182	0.200	0.218
S	1.9		2.6	0.075		0.102
S1	1.9		2.6	0.075		0.102
Dia1	3.65		3.85	0.144		0.152

OUTLINE AND MECHANICAL DATA
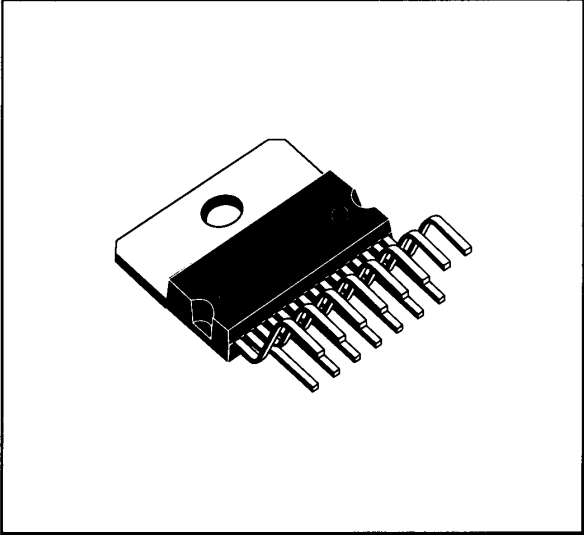
Multiwatt15 V

DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			5			0.197
B			2.65			0.104
C			1.6			0.063
E	0.49		0.55	0.019		0.022
F	0.66		0.75	0.026		0.030
G	1.14	1.27	1.4	0.045	0.050	0.055
G1	17.57	17.78	17.91	0.692	0.700	0.705
H1	19.6			0.772		
H2			20.2			0.795
L		20.57			0.810	
L1		18.03			0.710	
L2		2.54			0.100	
L3	17.25	17.5	17.75	0.679	0.689	0.699
L4	10.3	10.7	10.9	0.406	0.421	0.429
L5		5.28			0.208	
L6		2.38			0.094	
L7	2.65		2.9	0.104		0.114
S	1.9		2.6	0.075		0.102
S1	1.9		2.6	0.075		0.102
Dia1	3.65		3.85	0.144		0.152

**OUTLINE AND
MECHANICAL DATA**

Multiwatt15 H

National *Semiconductor*

LM124/LM224/LM324/LM2902
Low Power Quad Operational Amplifiers

General Description

The LM124 series consists of four independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to 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.

Application areas include transducer amplifiers, DC gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM124 series can be directly operated off of the standard +5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional ±15V power supplies.

Unique Characteristics

■ In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage

■ The unity gain cross frequency is temperature compensated

■ The input bias current is also temperature compensated

Advantages

■ Eliminates need for dual supplies
■ Four internally compensated op amps in a single package
■ Allows directly sensing near GND and V_{OUT} also goes to GND
■ Compatible with all forms of logic
■ Power drain suitable for battery operation

Features

■ Internally frequency compensated for unity gain
■ Large DC voltage gain   100 dB
■ Wide bandwidth (unity gain)   1 MHz (temperature compensated)
■ Wide power supply range:
  Single supply   3V to 32V
  or dual supplies   ±1.5V to ±16V
■ Very low supply current drain (700 µA) — essentially independent of supply voltage
■ Low input biasing current   45 nA (temperature compensated)
■ Low input offset voltage   2 mV and offset current: 5 nA
■ Input common-mode voltage range includes ground
■ Differential input voltage range equal to the power supply voltage
■ Large output voltage swing   0V to V^+ − 1.5V

Connection Diagram

Dual-In-Line Package

DS009299-1
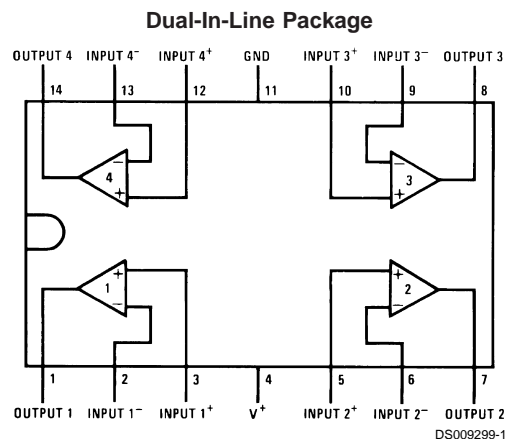
Top View
Order Number LM124J, LM124AJ, LM124J/883 (Note 2)**, LM124AJ/883** (Note 1)**, LM224J, LM224AJ, LM324J, LM324M, LM324MX, LM324AM, LM324AMX, LM2902M, LM2902MX, LM324N, LM324AN, LM324MT, LM324MTX or LM2902N LM124AJRQML and LM124AJRQMLV**(Note 3)
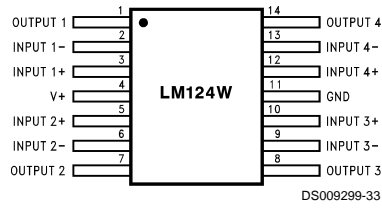**See NS Package Number J14A, M14A or N14A**

Note 1: LM124A available per JM38510/11006
**Note 2:** LM124 available per JM38510/11005

Connection Diagram (Continued)

Note 3: See STD Mil DWG 5962R99504 for Radiation Tolerant Device

OUTPUT 1 — 1	14 — OUTPUT 4
INPUT 1− — 2	13 — INPUT 4−
INPUT 1+ — 3	12 — INPUT 4+
V+ — 4	11 — GND
INPUT 2+ — 5	10 — INPUT 3+
INPUT 2− — 6	9 — INPUT 3−
OUTPUT 2 — 7	8 — OUTPUT 3

LM124W

DS009299-33

Order Number LM124AW/883, LM124AWG/883, LM124W/883 or LM124WG/883
LM124AWRQML and LM124AWRQMLV(Note 3)
See NS Package Number W14B
LM124AWGRQML and LM124AWGRQMLV(Note 3)
See NS Package Number WG14A

Schematic Diagram (Each Amplifier)
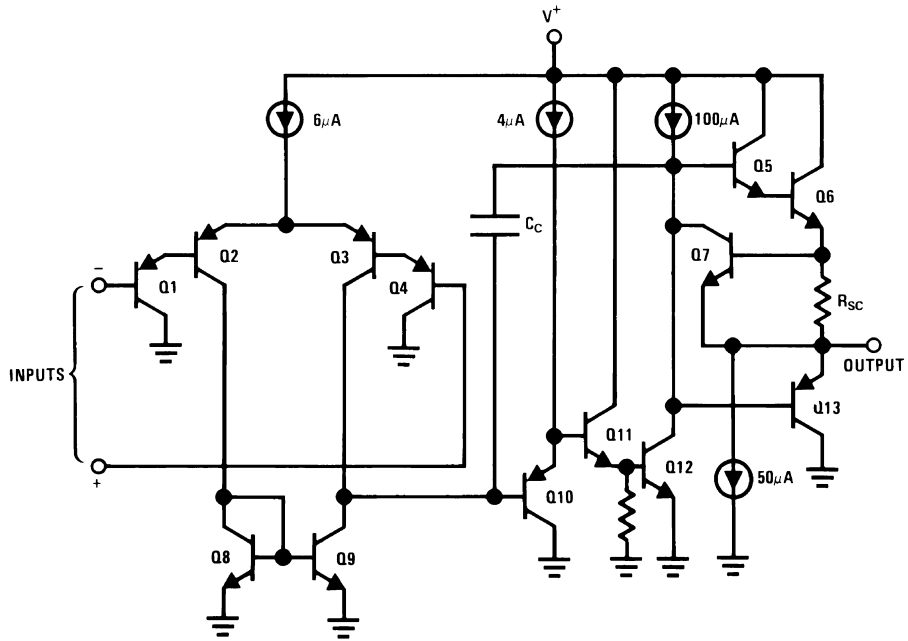
DS009299-2

Absolute Maximum Ratings (Note 12)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

	LM124/LM224/LM324 LM124A/LM224A/LM324A	LM2902
Supply Voltage, V^+	32V	26V
Differential Input Voltage	32V	26V
Input Voltage	−0.3V to +32V	−0.3V to +26V
Input Current		
($V_{IN} < -0.3V$) (Note 6)	50 mA	50 mA
Power Dissipation (Note 4)		
Molded DIP	1130 mW	1130 mW
Cavity DIP	1260 mW	1260 mW
Small Outline Package	800 mW	800 mW
Output Short-Circuit to GND		
(One Amplifier) (Note 5)		
$V^+ \leq 15V$ and $T_A = 25°C$	Continuous	Continuous
Operating Temperature Range		−40°C to +85°C
LM324/LM324A	0°C to +70°C	
LM224/LM224A	−25°C to +85°C	
LM124/LM124A	−55°C to +125°C	
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	260°C	260°C
Soldering Information		
Dual-In-Line Package		
Soldering (10 seconds)	260°C	260°C
Small Outline Package		
Vapor Phase (60 seconds)	215°C	215°C
Infrared (15 seconds)	220°C	220°C
See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.		
ESD Tolerance (Note 13)	250V	250V

Electrical Characteristics

$V^+ = +5.0V$, (Note 7), unless otherwise stated

Parameter	Conditions	LM124A			LM224A			LM324A			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	(Note 8) $T_A = 25°C$		1	2		1	3		2	3	mV
Input Bias Current (Note 9)	$I_{IN(+)}$ or $I_{IN(-)}$, $V_{CM} = 0V$, $T_A = 25°C$		20	50		40	80		45	100	nA
Input Offset Current	$I_{IN(+)}$ or $I_{IN(-)}$, $V_{CM} = 0V$, $T_A = 25°C$		2	10		2	15		5	30	nA
Input Common-Mode Voltage Range (Note 10)	$V^+ = 30V$, (LM2902, $V^+ = 26V$), $T_A = 25°C$	0		V^+−1.5	0		V^+−1.5	0		V^+−1.5	V
Supply Current	Over Full Temperature Range $R_L = \infty$ On All Op Amps										mA
	$V^+ = 30V$ (LM2902 $V^+ = 26V$)		1.5	3		1.5	3		1.5	3	
	$V^+ = 5V$		0.7	1.2		0.7	1.2		0.7	1.2	
Large Signal Voltage Gain	$V^+ = 15V$, $R_L \geq 2k\Omega$, ($V_O = 1V$ to $11V$), $T_A = 25°C$	50	100		50	100		25	100		V/mV
Common-Mode Rejection Ratio	DC, $V_{CM} = 0V$ to $V^+ - 1.5V$, $T_A = 25°C$	70	85		70	85		65	85		dB

LM124/LM224/LM324/LM2902

Electrical Characteristics (Continued)

V$^+$ = +5.0V, (Note 7), unless otherwise stated

Parameter		Conditions		LM124A			LM224A			LM324A			Units
				Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Power Supply Rejection Ratio		V$^+$ = 5V to 30V (LM2902, V$^+$ = 5V to 26V), T$_A$ = 25˚C		65	100		65	100		65	100		dB
Amplifier-to-Amplifier Coupling (Note 11)		f = 1 kHz to 20 kHz, T$_A$ = 25˚C (Input Referred)			−120			−120			−120		dB
Output Current	Source	V$_{IN}^+$ = 1V, V$_{IN}^-$ = 0V, V$^+$ = 15V, V$_O$ = 2V, T$_A$ = 25˚C		20	40		20	40		20	40		mA
	Sink	V$_{IN}^-$ = 1V, V$_{IN}^+$ = 0V, V$^+$ = 15V, V$_O$ = 2V, T$_A$ = 25˚C		10	20		10	20		10	20		
		V$_{IN}^-$ = 1V, V$_{IN}^+$ = 0V, V$^+$ = 15V, V$_O$ = 200 mV, T$_A$ = 25˚C		12	50		12	50		12	50		µA
Short Circuit to Ground		(Note 5) V$^+$ = 15V, T$_A$ = 25˚C			40	60		40	60		40	60	mA
Input Offset Voltage		(Note 8)				4			4			5	mV
V$_{OS}$ Drift		R$_S$ = 0Ω			7	20		7	20		7	30	µV/˚C
Input Offset Current		I$_{IN(+)}$ − I$_{IN(−)}$, V$_{CM}$ = 0V				30			30			75	nA
I$_{OS}$ Drift		R$_S$ = 0Ω			10	200		10	200		10	300	pA/˚C
Input Bias Current		I$_{IN(+)}$ or I$_{IN(−)}$			40	100		40	100		40	200	nA
Input Common-Mode Voltage Range (Note 10)		V$^+$ = +30V (LM2902, V$^+$ = 26V)		0		V$^+$−2	0		V$^+$−2	0		V$^+$−2	V
Large Signal Voltage Gain		V$^+$ = +15V (V$_O$Swing = 1V to 11V) R$_L$ ≥ 2 kΩ		25			25			15			V/mV
Output Voltage Swing	V$_{OH}$	V$^+$ = 30V (LM2902, V$^+$ = 26V)	R$_L$ = 2 kΩ	26			26			26			V
			R$_L$ = 10 kΩ	27	28		27	28		27	28		
	V$_{OL}$	V$^+$ = 5V, R$_L$ = 10 kΩ			5	20		5	20		5	20	mV
Output Current	Source	V$_O$ = 2V	V$_{IN}^+$ = +1V, V$_{IN}^-$ = 0V, V$^+$ = 15V	10	20		10	20		10	20		mA
	Sink		V$_{IN}^-$ = +1V, V$_{IN}^+$ = 0V, V$^+$ = 15V	10	15		5	8		5	8		

Electrical Characteristics

V$^+$ = +5.0V, (Note 7), unless otherwise stated

Parameter	Conditions	LM124/LM224			LM324			LM2902			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	(Note 8) T$_A$ = 25˚C		2	5		2	7		2	7	mV
Input Bias Current (Note 9)	I$_{IN(+)}$ or I$_{IN(−)}$, V$_{CM}$ = 0V, T$_A$ = 25˚C		45	150		45	250		45	250	nA
Input Offset Current	I$_{IN(+)}$ or I$_{IN(−)}$, V$_{CM}$ = 0V, T$_A$ = 25˚C		3	30		5	50		5	50	nA
Input Common-Mode Voltage Range (Note 10)	V$^+$ = 30V, (LM2902, V$^+$ = 26V), T$_A$ = 25˚C	0		V$^+$−1.5	0		V$^+$−1.5	0		V$^+$−1.5	V
Supply Current	Over Full Temperature Range R$_L$ = ∞ On All Op Amps V$^+$ = 30V (LM2902 V$^+$ = 26V)		1.5	3		1.5	3		1.5	3	mA
	V$^+$ = 5V		0.7	1.2		0.7	1.2		0.7	1.2	
Large Signal Voltage Gain	V$^+$ = 15V, R$_L$≥ 2kΩ, (V$_O$ = 1V to 11V), T$_A$ = 25˚C	50	100		25	100		25	100		V/mV
Common-Mode Rejection Ratio	DC, V$_{CM}$ = 0V to V$^+$ − 1.5V, T$_A$ = 25˚C	70	85		65	85		50	70		dB
Power Supply Rejection Ratio	V$^+$ = 5V to 30V (LM2902, V$^+$ = 5V to 26V),	65	100		65	100		50	100		dB

Electrical Characteristics (Continued)

V^+ = +5.0V, (Note 7), unless otherwise stated

Parameter		Conditions		LM124/LM224			LM324			LM2902			Units
				Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
		T_A = 25˚C											
Amplifier-to-Amplifier Coupling (Note 11)		f = 1 kHz to 20 kHz, T_A = 25˚C (Input Referred)			−120			−120			−120		dB
Output Current	Source	V_{IN}^+ = 1V, V_{IN}^- = 0V, V^+ = 15V, V_O = 2V, T_A = 25˚C		20	40		20	40		20	40		mA
	Sink	V_{IN}^- = 1V, V_{IN}^+ = 0V, V^+ = 15V, V_O = 2V, T_A = 25˚C		10	20		10	20		10	20		
		V_{IN}^- = 1V, V_{IN}^+ = 0V, V^+ = 15V, V_O = 200 mV, T_A = 25˚C		12	50		12	50		12	50		µA
Short Circuit to Ground		(Note 5) V^+ = 15V, T_A = 25˚C			40	60		40	60		40	60	mA
Input Offset Voltage		(Note 8)				7			9			10	mV
V_{OS} Drift		R_S = 0Ω			7			7			7		µV/˚C
Input Offset Current		$I_{IN(+)} - I_{IN(-)}$, V_{CM} = 0V				100			150		45	200	nA
I_{OS} Drift		R_S = 0Ω			10			10			10		pA/˚C
Input Bias Current		$I_{IN(+)}$ or $I_{IN(-)}$			40	300		40	500		40	500	nA
Input Common-Mode Voltage Range (Note 10)		V^+ = +30V (LM2902, V^+ = 26V)		0		V^+−2	0		V^+−2	0		V^+−2	V
Large Signal Voltage Gain		V^+ = +15V (V_OSwing = 1V to 11V) $R_L \geq$ 2 kΩ		25			15			15			V/mV
Output Voltage Swing	V_{OH}	V^+ = 30V (LM2902, V^+ = 26V)	R_L = 2 kΩ	26			26			22			V
			R_L = 10 kΩ	27	28		27	28		23	24		
	V_{OL}	V^+ = 5V, R_L = 10 kΩ			5	20		5	20		5	100	mV
Output Current	Source	V_O = 2V	V_{IN}^+ = +1V, V_{IN}^- = 0V, V^+ = 15V	10	20		10	20		10	20		mA
	Sink		V_{IN}^- = +1V, V_{IN}^+ = 0V, V^+ = 15V	5	8		5	8		5	8		

Note 4: For operating at high temperatures, the LM324/LM324A/LM2902 must be derated based on a +125˚C maximum junction temperature and a thermal resistance of 88˚C/W which applies for the device soldered in a printed circuit board, operating in a still air ambient. The LM224/LM224A and LM124/LM124A can be derated based on a +150˚C maximum junction temperature. The dissipation is the total of all four amplifiers — use external resistors, where possible, to allow the amplifier to saturate of to reduce the power which is dissipated in the integrated circuit.

Note 5: Short circuits from the output to V^+ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of V^+. At values of supply voltage in excess of +15V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

Note 6: This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the op amps to go to the V^+voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than −0.3V (at 25˚C).

Note 7: These specifications are limited to −55˚C ≤ T_A ≤ +125˚C for the LM124/LM124A. With the LM224/LM224A, all temperature specifications are limited to −25˚C ≤ T_A ≤ +85˚C, the LM324/LM324A temperature specifications are limited to 0˚C ≤ T_A ≤ +70˚C, and the LM2902 specifications are limited to −40˚C ≤ T_A ≤ +85˚C.

Note 8: V_O ≈ 1.4V, R_S = 0Ω with V^+ from 5V to 30V; and over the full input common-mode range (0V to V^+ − 1.5V) for LM2902, V^+ from 5V to 26V.

Note 9: The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.

Note 10: The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3V (at 25˚C). The upper end of the common-mode voltage range is V^+ − 1.5V (at 25˚C), but either or both inputs can go to +32V without damage (+26V for LM2902), independent of the magnitude of V^+.
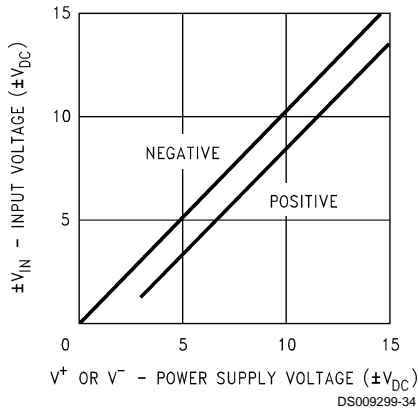
Note 11: Due to proximity of external components, insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitance increases at higher frequencies.

Note 12: Refer to RETS124AX for LM124A military specifications and refer to RETS124X for LM124 military specifications.
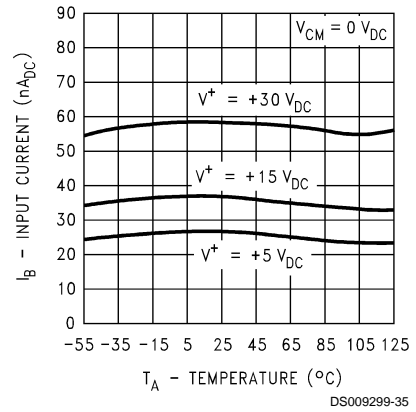
Note 13: Human body model, 1.5 kΩ in series with 100 pF.
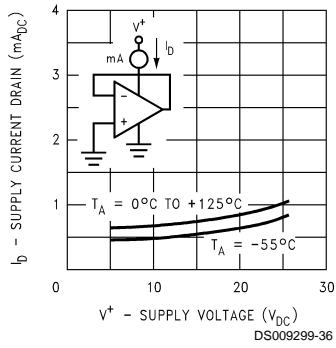
Typical Performance Characteristics
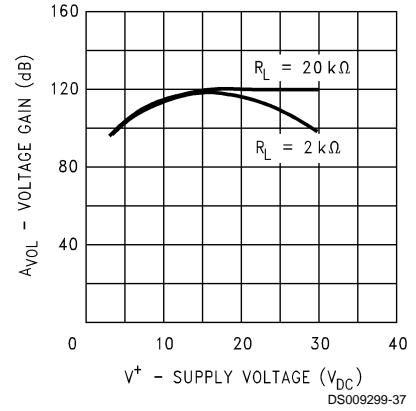
Input Voltage Range

DS009299-34

Input Current

DS009299-35

Supply Current

DS009299-36

Voltage Gain

DS009299-37

Open Loop Frequency Response

DS009299-38

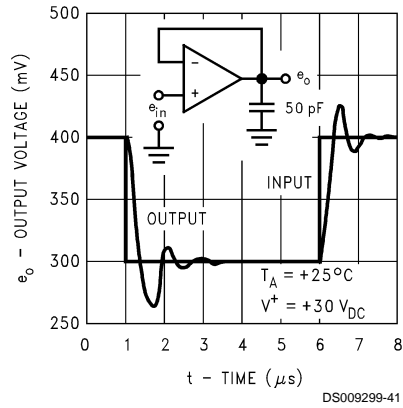**Common Mode Rejection Ratio**

DS009299-39
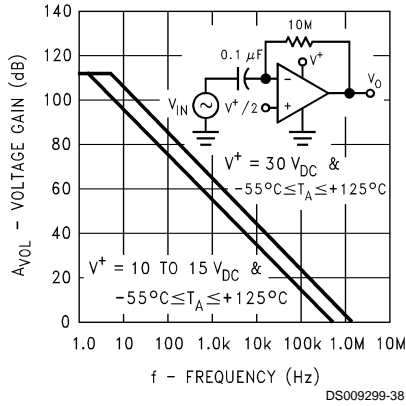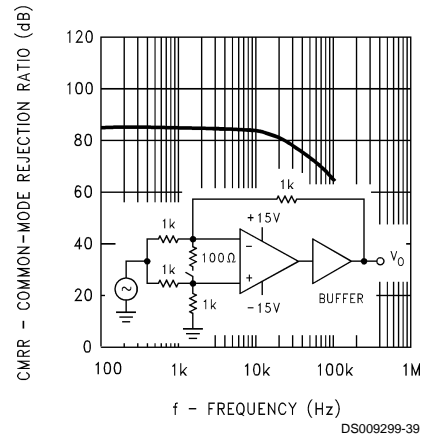
Typical Performance Characteristics (Continued)

Voltage Follower Pulse Response

DS009299-40
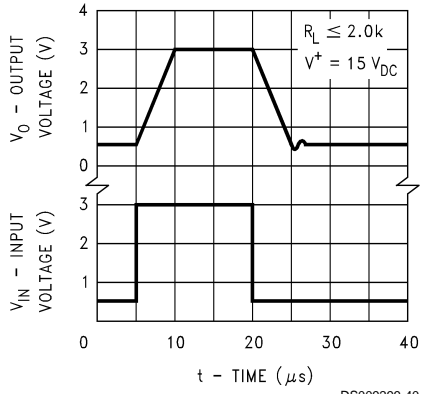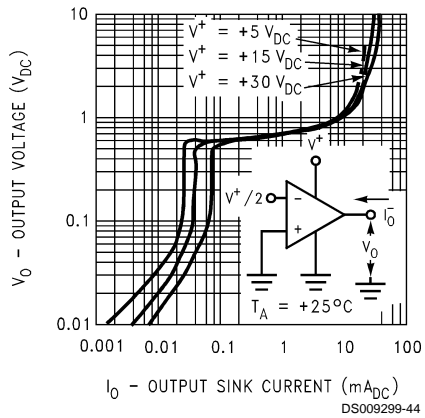
Voltage Follower Pulse Response (Small Signal)

DS009299-41

Large Signal Frequency Response

DS009299-42
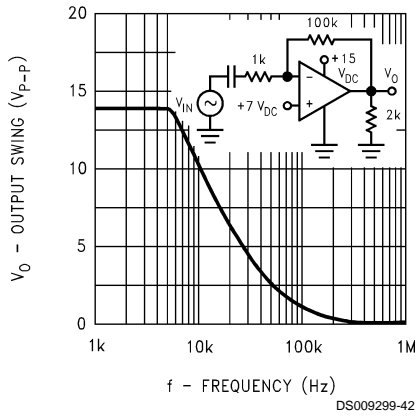
Output Characteristics Current Sourcing

DS009299-43
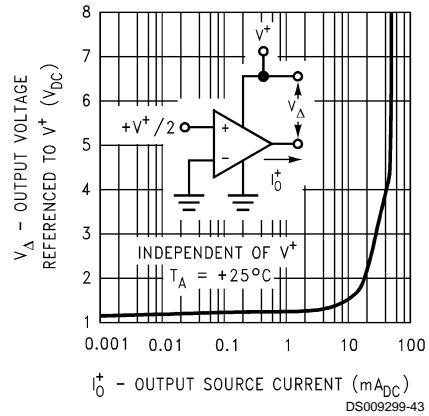
Output Characteristics Current Sinking

DS009299-44

Current Limiting

DS009299-45
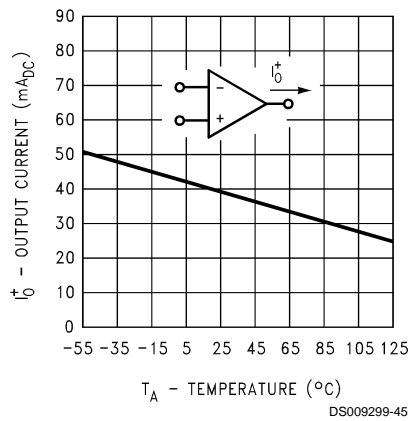
Typical Performance Characteristics (Continued)

Input Current (LM2902 only)

DS009299-46
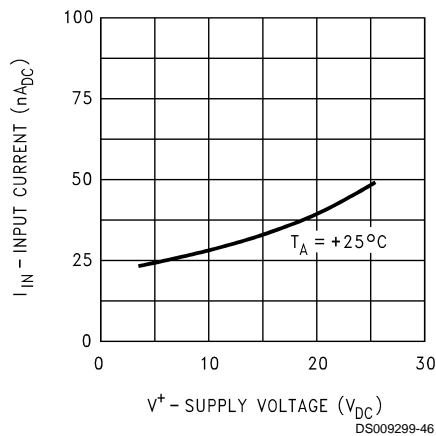
Voltage Gain (LM2902 only)

DS009299-47
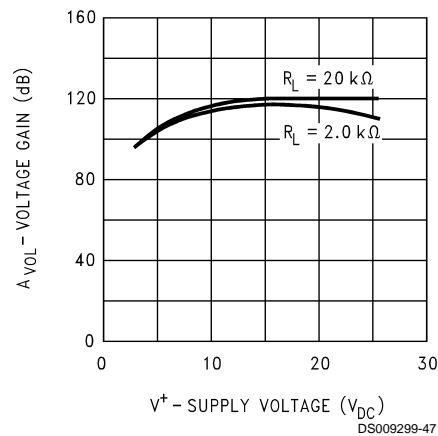
Application Hints

The LM124 series are op amps which operate with only a single power supply voltage, have true-differential inputs, and remain in the linear mode with an input common-mode voltage of 0 V_{DC}. These amplifiers operate over a wide range of power supply voltage with little change in performance characteristics. At 25°C amplifier operation is possible down to a minimum supply voltage of 2.3 V_{DC}.

The pinouts of the package have been designed to simplify PC board layouts. Inverting inputs are adjacent to outputs for all of the amplifiers and the outputs have also been placed at the corners of the package (pins 1, 7, 8, and 14).

Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a test socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

Large differential input voltages can be easily accommodated and, as input differential voltage protection diodes are not needed, no large input currents result from large differential input voltages. The differential input voltage may be larger than V^+ without damaging the device. Protection should be provided to prevent the input voltages from going negative more than −0.3 V_{DC} (at 25°C). An input clamp diode with a resistor to the IC input terminal can be used.

To reduce the power supply drain, the amplifiers have a class A output stage for small signal levels which converts to class B in a large signal mode. This allows the amplifiers to both source and sink large output currents. Therefore both NPN and PNP external current boost transistors can be used to extend the power capability of the basic amplifiers. The output voltage needs to raise approximately 1 diode drop above ground to bias the on-chip vertical PNP transistor for output current sinking applications.

For ac applications, where the load is capacitively coupled to the output of the amplifier, a resistor should be used, from the output of the amplifier to ground to increase the class A bias current and prevent crossover distortion.

Where the load is directly coupled, as in dc applications, there is no crossover distortion.

Capacitive loads which are applied directly to the output of the amplifier reduce the loop stability margin. Values of 50 pF can be accommodated using the worst-case non-inverting unity gain connection. Large closed loop gains or resistive isolation should be used if larger load capacitance must be driven by the amplifier.

The bias network of the LM124 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from 3 V_{DC} to 30 V_{DC}.

Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fusing, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive junction temperatures. Putting direct short-circuits on more than one amplifier at a time will increase the total IC power dissipation to destructive levels, if not properly protected with external dissipation limiting resistors in series with the output leads of the amplifiers. The larger value of output source current which is available at 25°C provides a larger output current capability at elevated temperatures (see typical performance characteristics) than a standard IC op amp.

The circuits presented in the section on typical applications emphasize operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op amp circuits can be used. In general, introducing a pseudo-ground (a bias voltage reference of $V^+/2$) will allow operation above and below this value in single power supply systems. Many application circuits are shown which take advantage of the wide input common-mode voltage range which includes ground. In most cases, input biasing is not required and input voltages which range to ground can easily be accommodated.

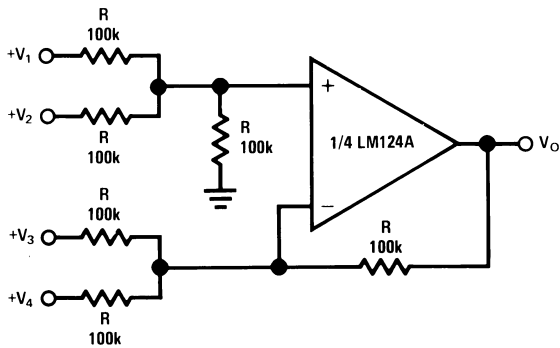# Typical Single-Supply Applications (V$^+$ = 5.0 V$_{DC}$)

Non-Inverting DC Gain (0V Input = 0V Output)

+V$_{IN}$

1/4 LM124A

+V$_O$

R2 1M

R1 10k
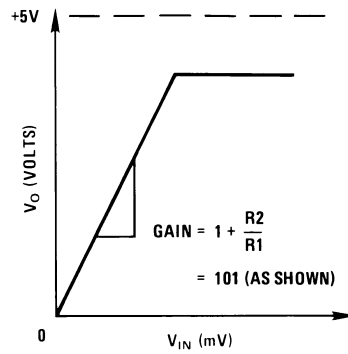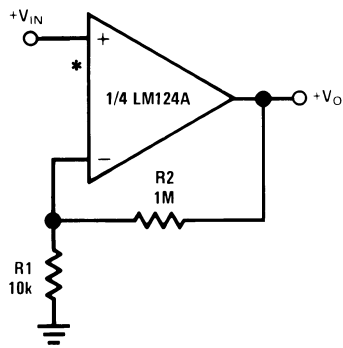
*R not needed due to temperature independent I$_{IN}$

GAIN = 1 + $\frac{R2}{R1}$

= 101 (AS SHOWN)

V$_O$ (VOLTS)

V$_{IN}$ (mV)

DS009299-5

DC Summing Amplifier
(V$_{IN'S}$ ≥ 0 V$_{DC}$ and V$_O$ ≥ V$_{DC}$)

+V$_1$ R 100k
+V$_2$ R 100k
R 100k
1/4 LM124A
V$_O$
+V$_3$ R 100k
+V$_4$ R 100k
R 100k

DS009299-6

Where: V$_0$ = V$_1$ + V$_2$ − V$_3$ − V$_4$
(V$_1$ + V$_2$) ≥ (V$_3$ + V$_4$) to keep V$_O$ > 0 V$_{DC}$

Power Amplifier
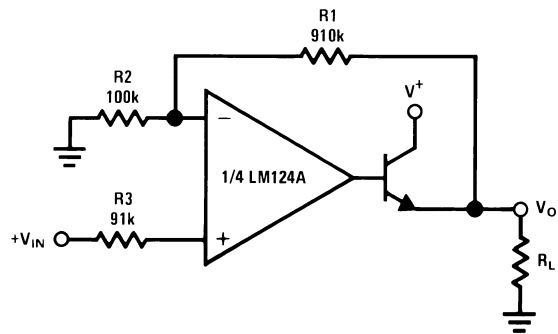
R1 910k
R2 100k
R3 91k
+V$_{IN}$
1/4 LM124A
V$^+$
V$_O$
R$_L$

DS009299-7

V$_0$ = 0 V$_{DC}$ for V$_{IN}$ = 0 V$_{DC}$
A$_V$ = 10

LM124/LM224/LM324/LM2902

Typical Single-Supply Applications (V^+ = 5.0 V_{DC}) (Continued)

LED Driver
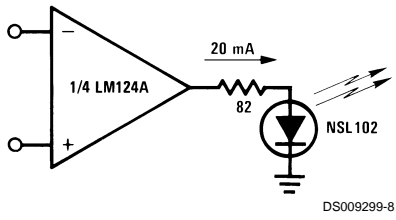
DS009299-8

"BI-QUAD" RC Active Bandpass Filter
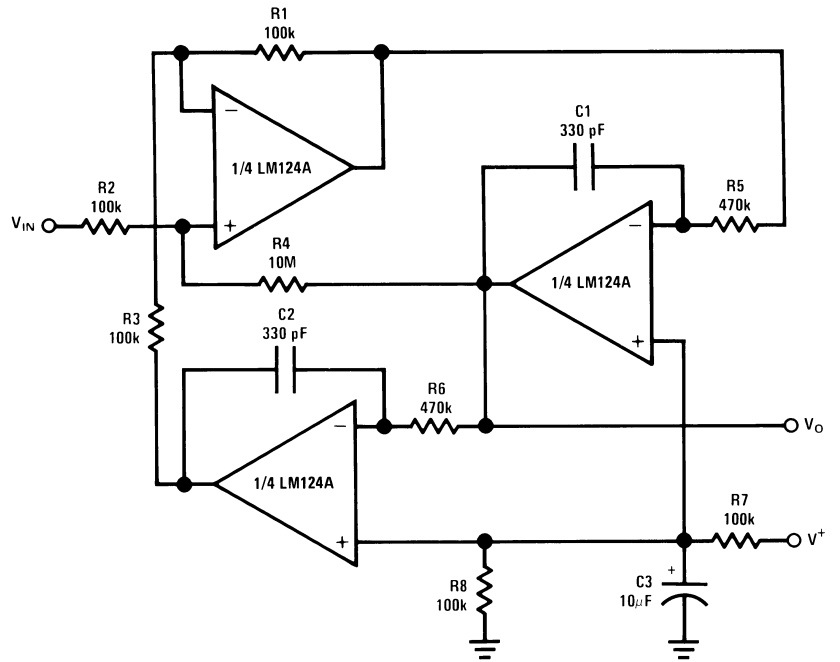
DS009299-9

f_o = 1 kHz
Q = 50
A_V = 100 (40 dB)

Fixed Current Sources
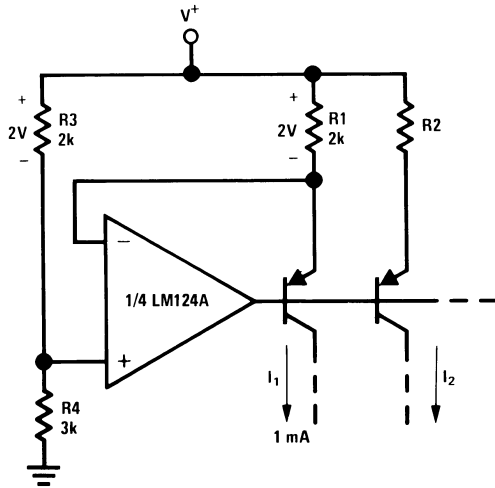
DS009299-10

$$I_2 = \left(\frac{R1}{R2}\right) I_1$$

Lamp Driver

DS009299-11

Typical Single-Supply Applications (V$^+$ = 5.0 V$_{DC}$) (Continued)

Current Monitor
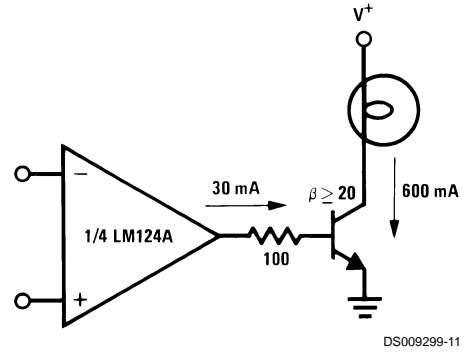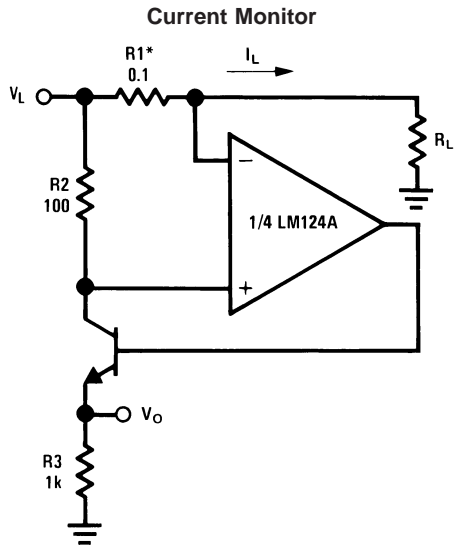
DS009299-12

$$V_O = \frac{1V(I_L)}{1A}$$

$$V_L \leq V^+ - 2V$$

*(Increase R1 for I$_L$ small)

Driving TTL

DS009299-13

Voltage Follower
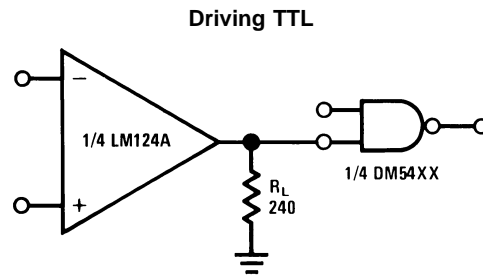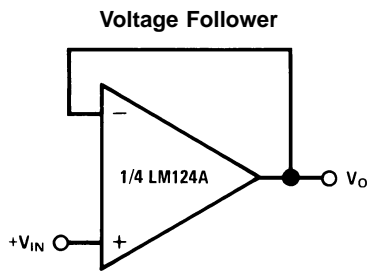
DS009299-14
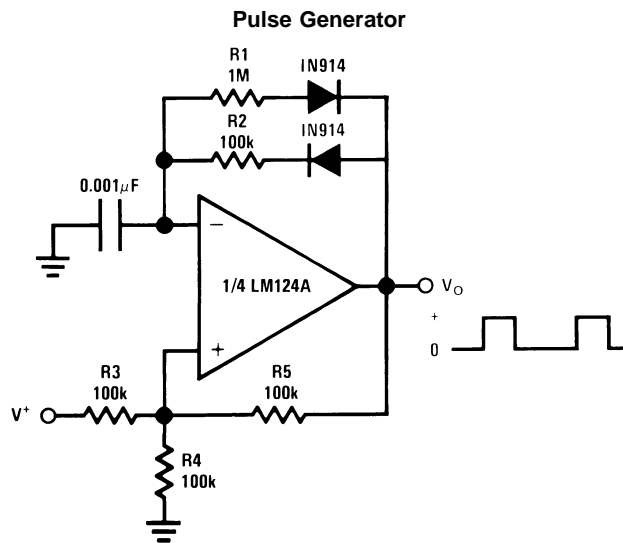
Pulse Generator

DS009299-15

Typical Single-Supply Applications (V$^+$ = 5.0 V$_{DC}$) (Continued)

Squarewave Oscillator
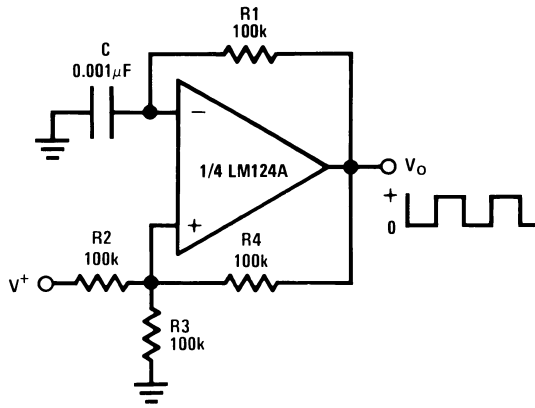
DS009299-16

Pulse Generator
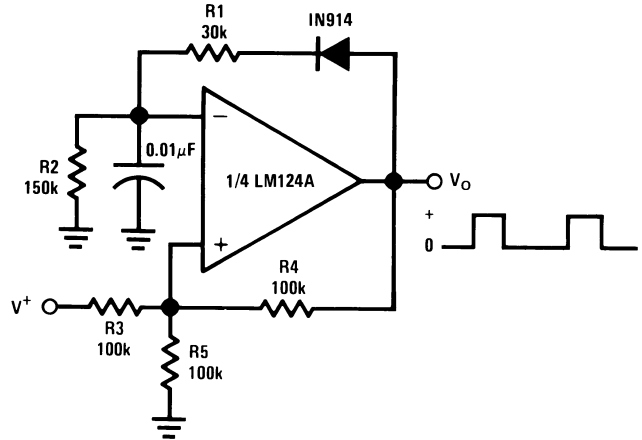
DS009299-17

High Compliance Current Sink
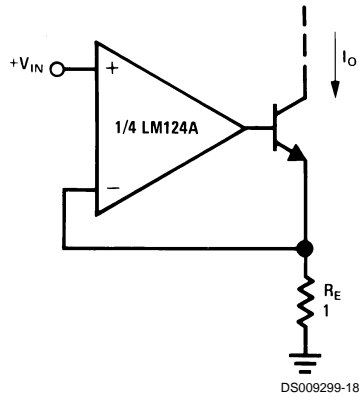
DS009299-18

I$_O$ = 1 amp/volt V$_{IN}$
(Increase R$_E$ for I$_o$ small)

Typical Single-Supply Applications (V+ = 5.0 V_DC) (Continued)

Low Drift Peak Detector
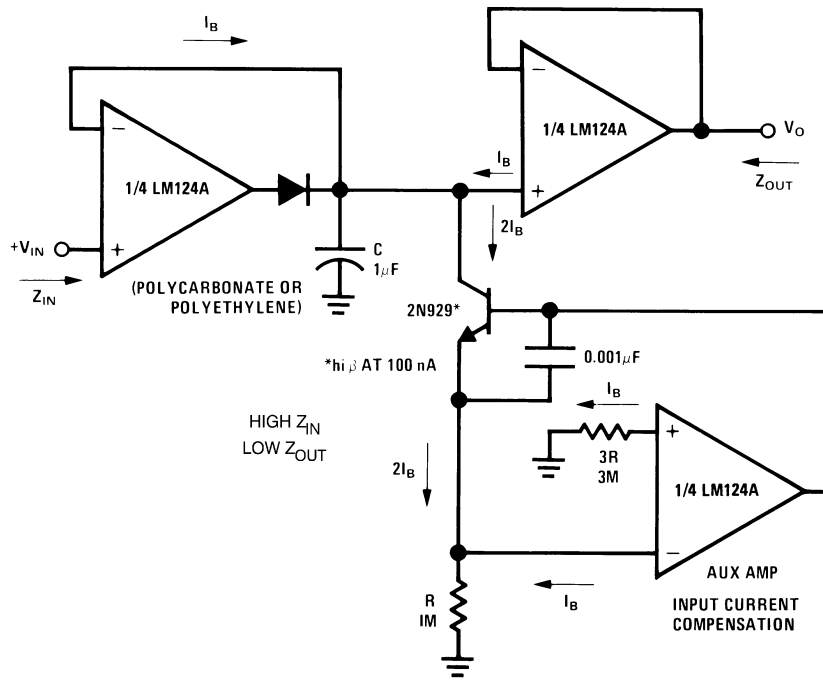
DS009299-19

Comparator with Hysteresis
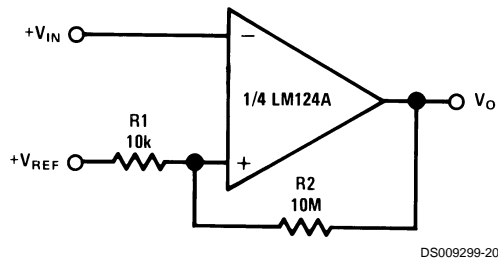
DS009299-20

Ground Referencing a Differential Input Signal

DS009299-21

$V_O = V_R$
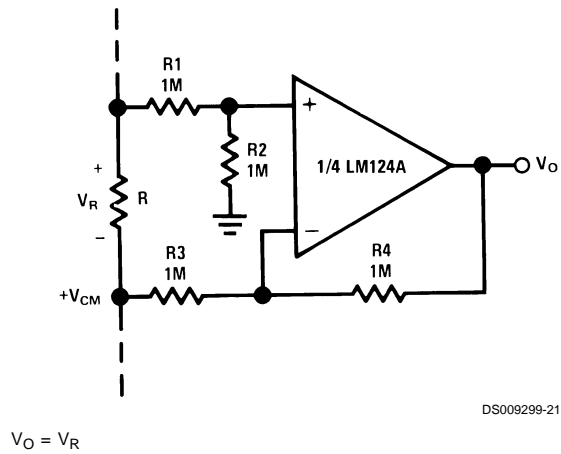
Typical Single-Supply Applications (V$^+$ = 5.0 V$_{DC}$) (Continued)

Voltage Controlled Oscillator Circuit
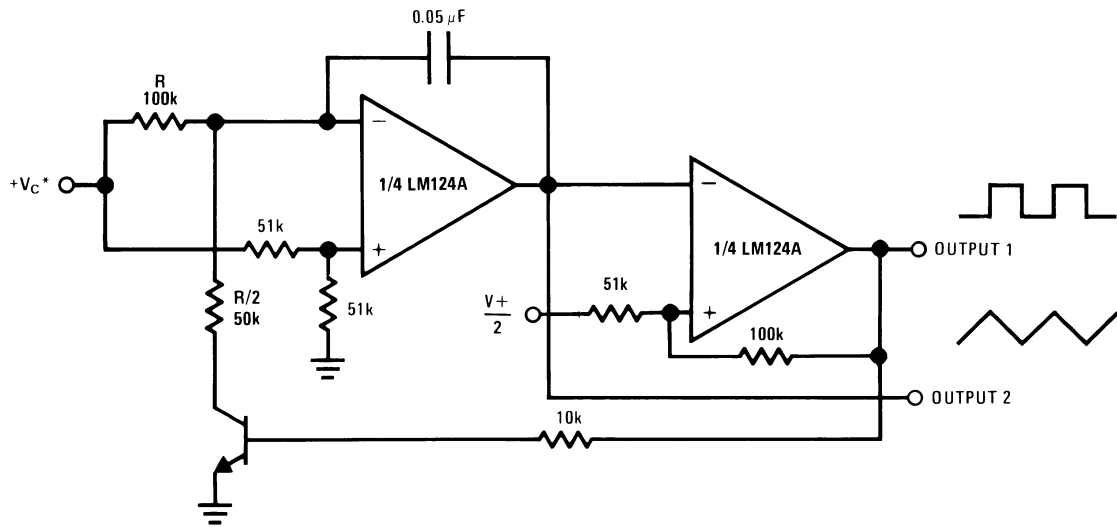
DS009299-22

*Wide control voltage range: 0 V$_{DC}$ ≤ V$_C$ ≤ 2 (V$^+$ −1.5 V$_{DC}$)

Photo Voltaic-Cell Amplifier
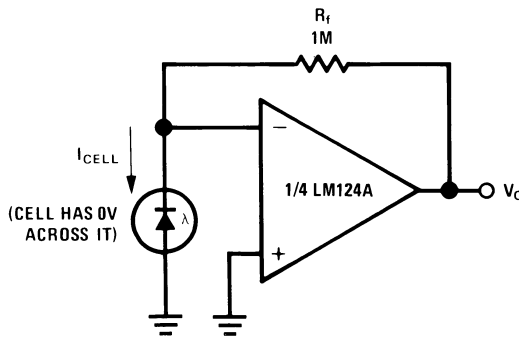
DS009299-23

AC Coupled Inverting Amplifier
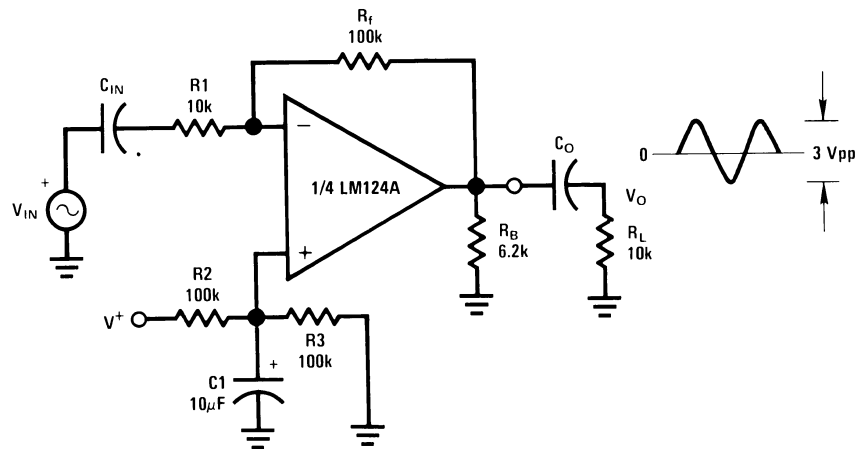
DS009299-24

$A_V = \dfrac{R_f}{R1}$ (As shown, A_V = 10)
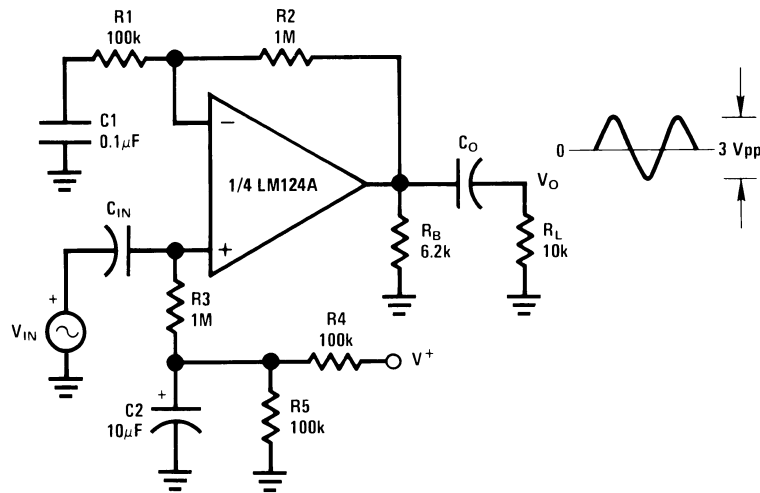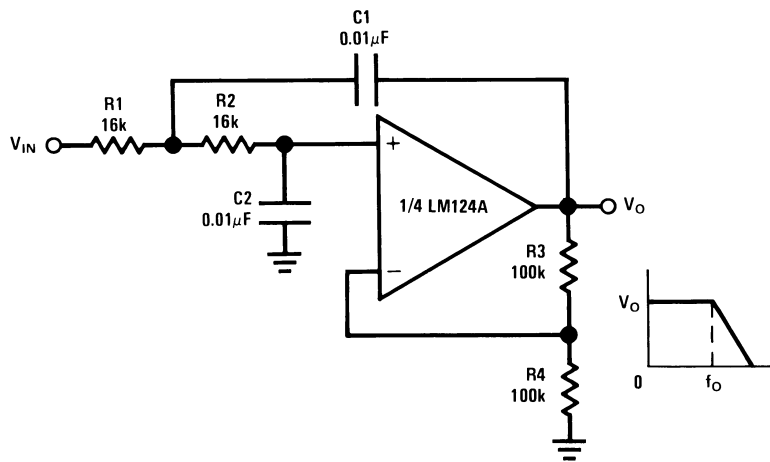
Typical Single-Supply Applications (V$^+$ = 5.0 V$_{DC}$) (Continued)

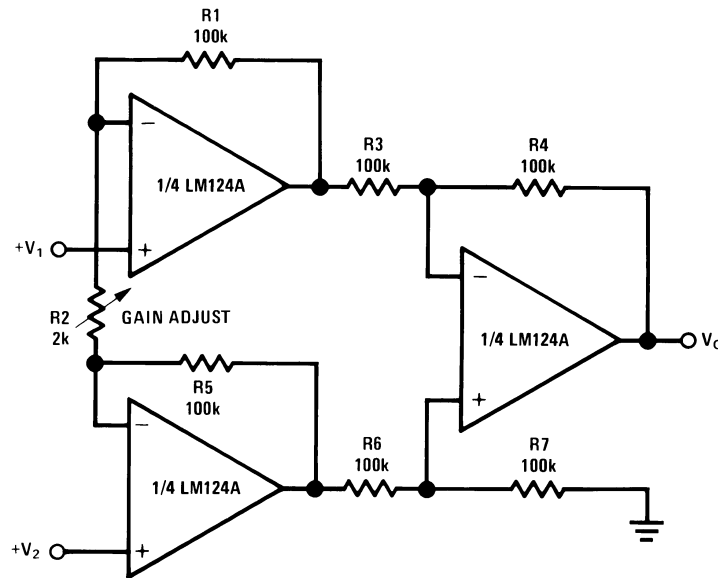**High Input Z, DC Differential Amplifier**
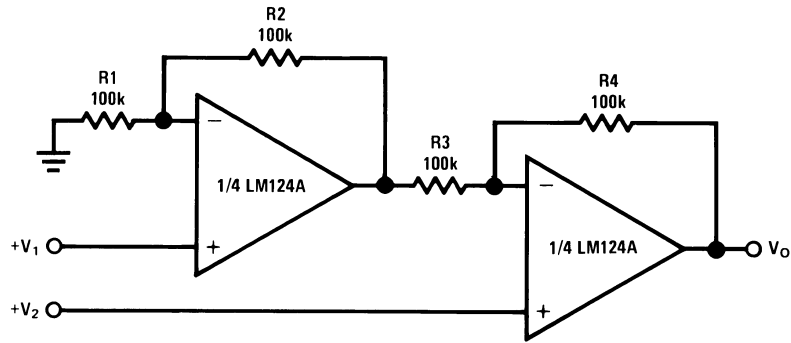
DS009299-27

For $\dfrac{R1}{R2} = \dfrac{R4}{R3}$ (CMRR depends on this resistor ratio match)

$V_O = 1 + \dfrac{R4}{R3}(V_2 - V_1)$

As shown: $V_O = 2(V_2 - V_1)$

**High Input Z Adjustable-Gain
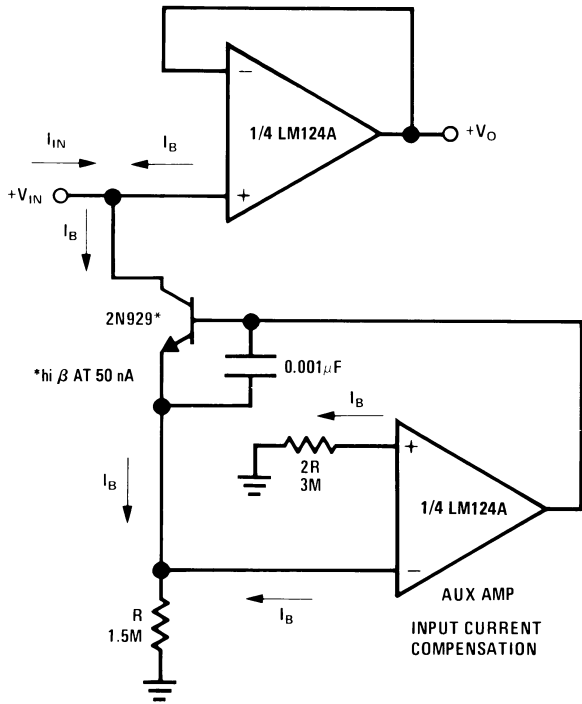DC Instrumentation Amplifier**

DS009299-28

If R1 = R5 & R3 = R4 = R6 = R7 (CMRR depends on match)

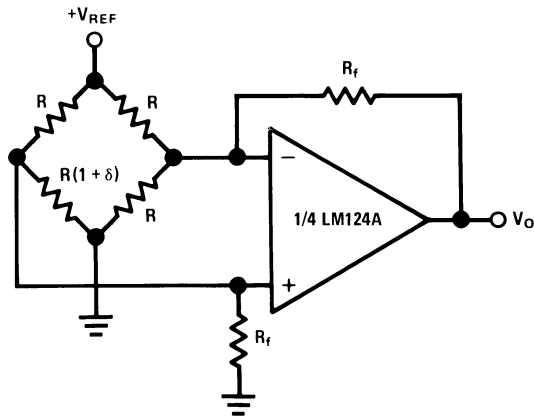$V_O = 1 + \dfrac{2R1}{R2}(V_2 - V_1)$

As shown $V_O = 101\,(V_2 - V_1)$

Typical Single-Supply Applications (V$^+$ = 5.0 V$_{DC}$) (Continued)

Using Symmetrical Amplifiers to Reduce Input Current (General Concept)
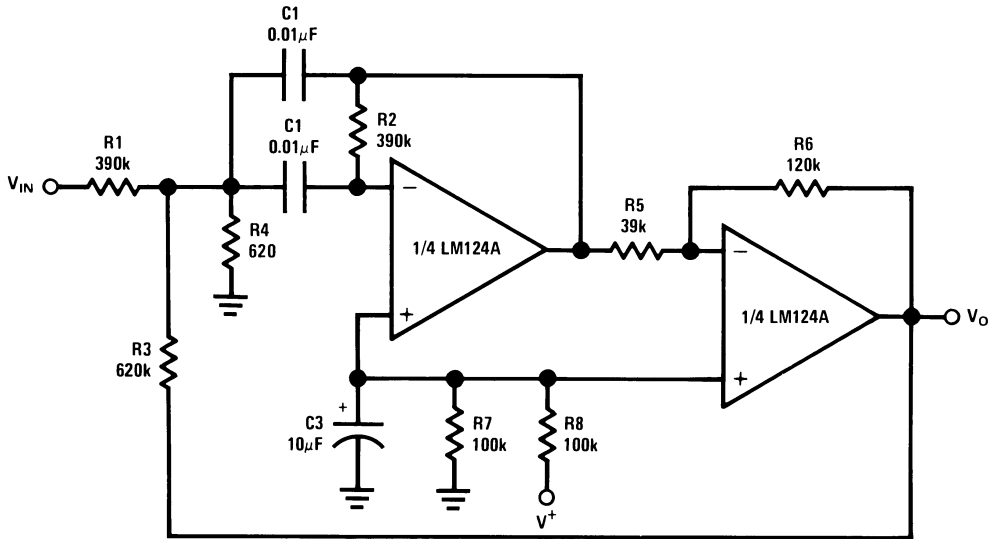

DS009299-29

Bridge Current Amplifier

DS009299-30

For $\delta << 1$ and $R_f >> R$

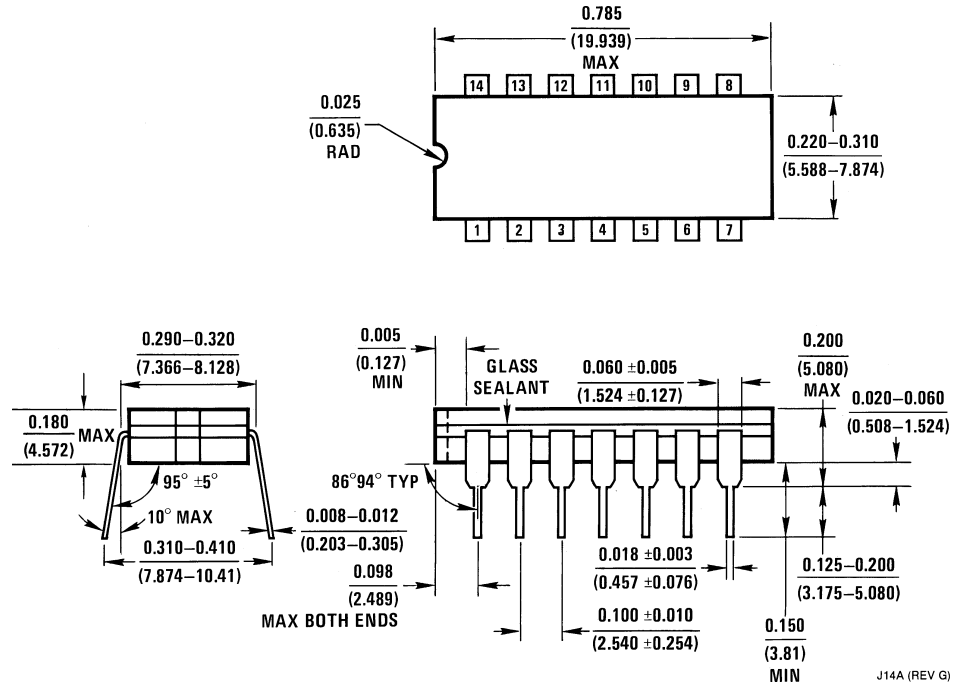$$V_O \simeq V_{REF} \left(\frac{\delta}{2} \right) \frac{R_f}{R}$$
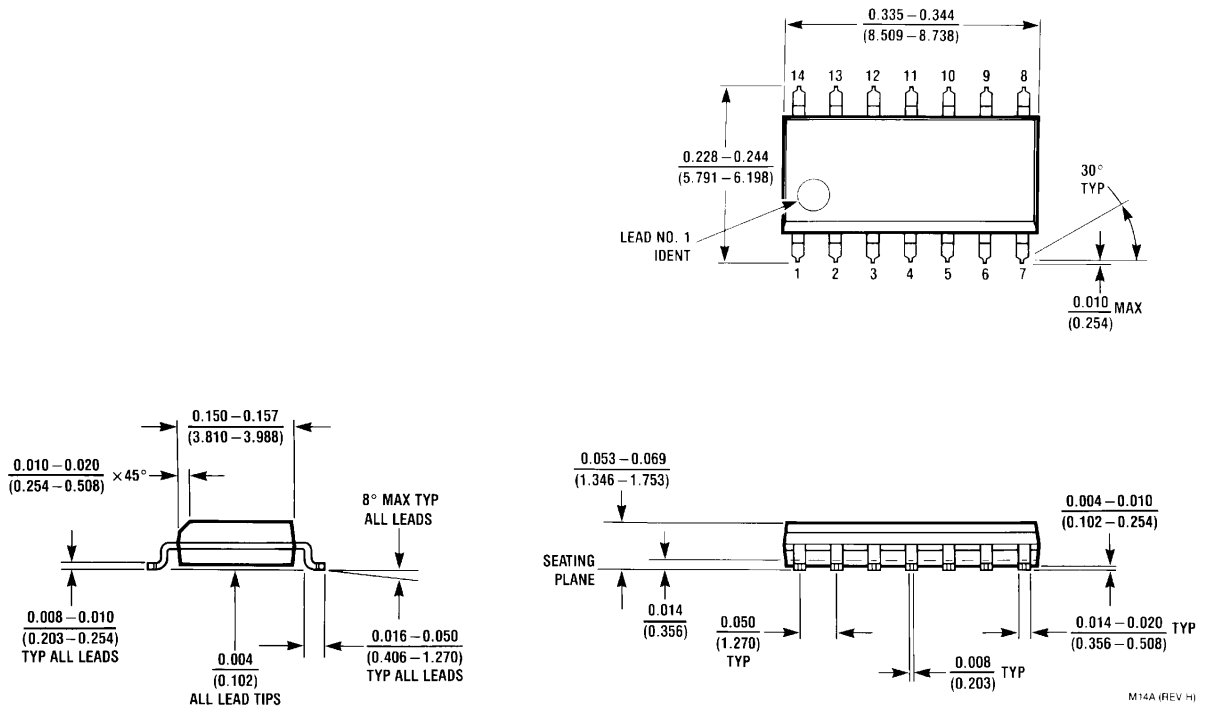
Bandpass Active Filter

DS009299-31

f$_O$ = 1 kHz
Q = 25

Physical Dimensions inches (millimeters) unless otherwise noted

0.785
(19.939)
MAX

0.025
(0.635)
RAD

0.220–0.310
(5.588–7.874)

0.290–0.320
(7.366–8.128)

0.180
(4.572)
MAX

95° ±5°

10° MAX

0.310–0.410
(7.874–10.41)

0.005
(0.127)
MIN

GLASS
SEALANT

0.008–0.012
(0.203–0.305)

0.098
(2.489)
MAX BOTH ENDS

86°94° TYP

0.060 ±0.005
(1.524 ±0.127)

0.018 ±0.003
(0.457 ±0.076)

0.100 ±0.010
(2.540 ±0.254)

0.200
(5.080)
MAX

0.020–0.060
(0.508–1.524)

0.125–0.200
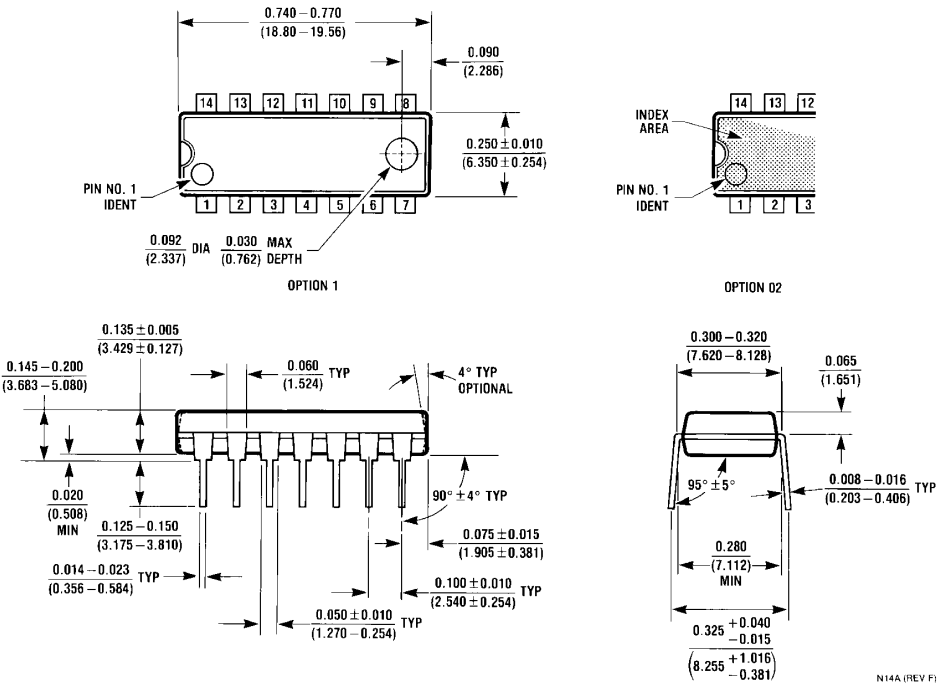(3.175–5.080)

0.150
(3.81)
MIN

J14A (REV G)

Ceramic Dual-In-Line Package (J)
Order Number JL124ABCA, JL124BCA, JL124ASCA, JL124SCA, LM124J,
**LM124AJ, LM124AJ/883, LM124J/883, LM224J, LM224AJ or LM324J**
NS Package Number J14A

0.335–0.344
(8.509–8.738)

0.228–0.244
(5.791–6.198)

LEAD NO. 1
IDENT

30°
TYP

0.010
(0.254) MAX

0.150–0.157
(3.810–3.988)

0.010–0.020
(0.254–0.508) ×45°

8° MAX TYP
ALL LEADS

0.008–0.010
(0.203–0.254)
TYP ALL LEADS

0.004
(0.102)
ALL LEAD TIPS

0.016–0.050
(0.406–1.270)
TYP ALL LEADS

0.053–0.069
(1.346–1.753)

0.004–0.010
(0.102–0.254)

SEATING
PLANE

0.014
(0.356)

0.050
(1.270)
TYP

0.008
(0.203) TYP

0.014–0.020
(0.356–0.508) TYP

M14A (REV H)

MX S.O. Package (M)
Order Number LM324M, LM324MX, LM324AM, LM324AMX, LM2902M or LM2902MX
NS Package Number M14A

OPTION 1

OPTION 02

N14A (REV F)

Molded Dual-In-Line Package (N)
Order Number LM324N, LM324AN or LM2902N
NS Package Number N14A

DETAIL A

W14B (REV J)
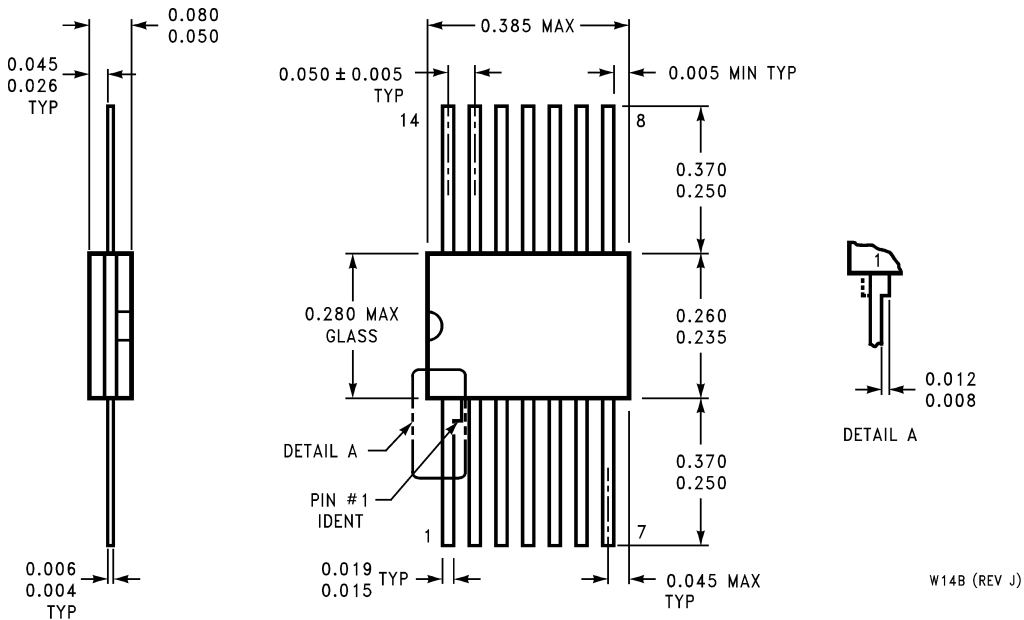
Ceramic Flatpak Package
Order Number JL124ABDA, JL124ABZA, JL124ASDA, JL124BDA, JL124BZA,
JL124SDA, LM124AW/883, LM124AWG/883, LM124W/883 or LM124WG/883
NS Package Number W14B

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)

LAND PATTERN RECOMMENDATION

DIMENSIONS ARE IN MILLIMETERS

DETAIL A
TYPICAL, SCALE: 40X

MTC14 (REV C)
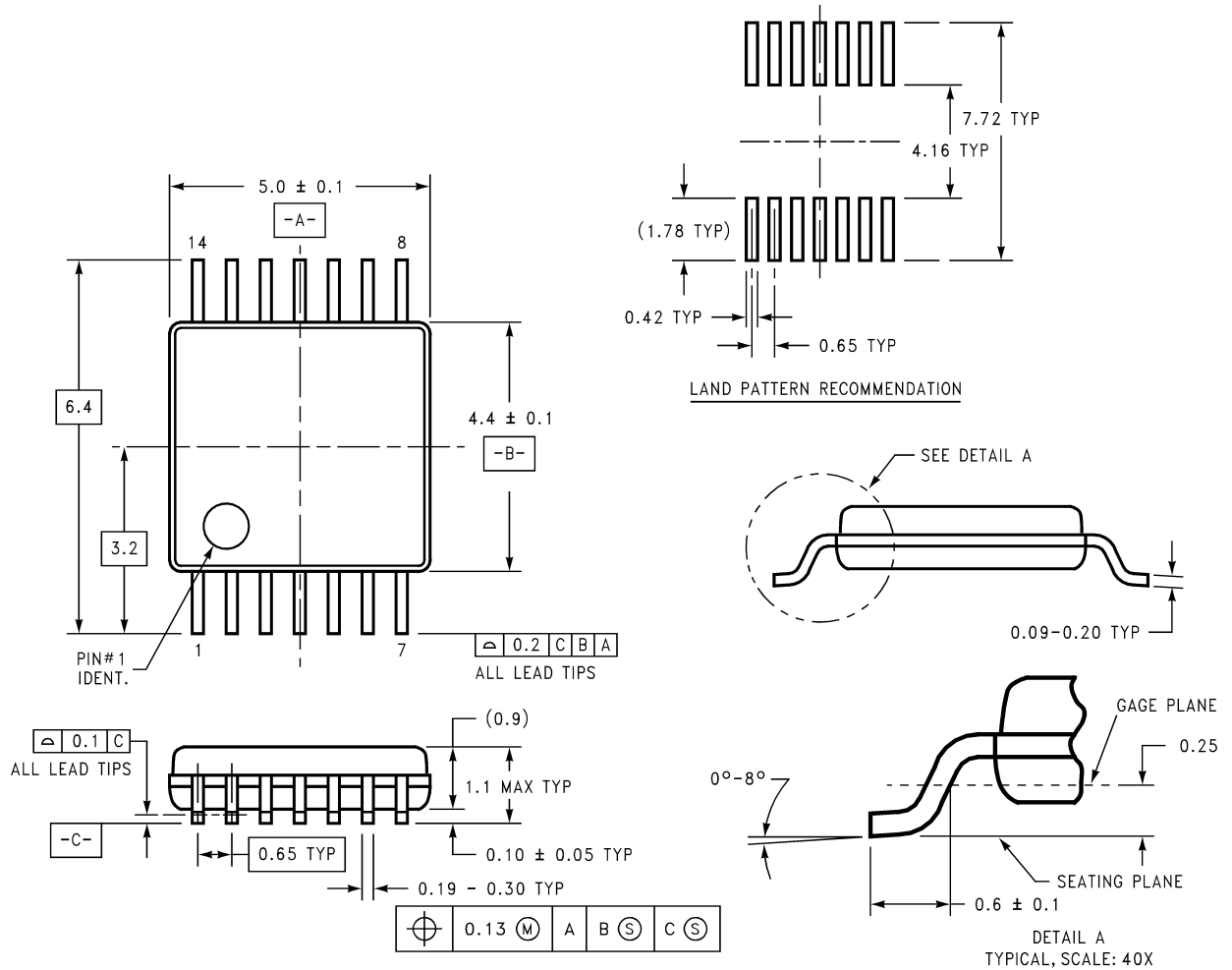
14-Pin TSSOP
Order NumberLM324MT or LM324MTX
NS Package Number MTC14

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.

2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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EXPLODED VIEWS PARTS LIST

NOTE : THE COMPONENTS IDENTIFIED BY THE MARK
! ARE CRITICAL FOR RISK OF FIRE AND
ELECTRIC SHOCK. REPLACE ONLY WITH PART
NUMBER SPECIFIED.

REF. NO.	PART NAME	DESCRIPTION	Q'TY	PART NO. (SN)	MARK
SKW-320X : POWERED SUBWOOFER					
SP01	CABINET ASS'Y	SKW-320X	1	ANK8S404S-BM10	
SP02	PLASTIC FOOT	D87.5 x D37.5 x H50 HIPS	4	BPE8000040001	
SP03	STAND BOARD	---	1	ANF860005-BM10	
SP04	LOGO PLATE	SKW-320X / ONKYO NAME PLATE	1	BPL800155-0001	
SP05	WOOD SCREW	D8 x D4 x L75 PAN HEAD (FOR FOOT)	8	NST8550514750	
SP06	WOOD SCREW	4STT+20A (FOR AMPLIFIER / SP)	18	NST8550518201 or	
	WOOD SCREW	4STT+20A (FOR AMPLIFIER / SP)	(18)	837440204	
SP08	WOOFER SPEAKER	20cm 4ohm 50W	1	FSB82A080-0404 or	
	WOOFER SPEAKER	20cm 4ohm 50W	(1)	W20178A	
A01	REAR PANEL	"SKW-320X" SPCC 190 x 120 x T2.0mm	1	GSE400175-0007	
A02	AC CORD	LINE CORD 2P 1800mm BLK POLARIZE	1	VPA0040120010	!
A03	BUSHING	AC LINE BUSHING	1	DBU001002-0011	!
A04	POWER TRANSFORMER	DC30V, DC2.3A, 120V / 60Hz 100W	1	TTI1120010120	!
A05	SCREW	M4.0 x P0.7 x L25mm (FOR TRANS)	4	HSD1431033250	
F902	FUSE	4A / 250V SLOW WALT	1	KSA0204000011	!
F903	FUSE	4A / 250V SLOW WALT	1	KSA0204000011	!
U01	MAIN PC BOARD ASS'Y	MAIN PC BOARD ASS'Y	1	APE4012115001	
<Note>					
U01 : MAIN PC BOARD ASS'Y = PCB BRACKET + HEAT SINK + ALL PARTS FOR MAIN PC BOARD					
U02	INPUT PC BOARD ASS'Y	INPUT PC BOARD ASS'Y	1	APE4012125001	
<Note>					
U02 : INPUT PC BOARD ASS'Y = INPUT PC BOARD with RCA JACK + CORD ASS'Y					
U03	VR / LED PC BOARD ASS'Y	VR / LED PC BOARD ASS'Y	1	APE4012135001	
<Note>					
U03 : VR / LED PC BOARD ASS'Y = VR / LED PC BOARD with VR / LED / CORD ASS'Y etc.					
SKF-320F : FRONT SPEAKERS (L / R)					
SP10	COMPLETE UNIT	"SKF-320F (L)"	1	ASL8M404S-BM10	
SP11	BACK LABEL (L)	without serial numbering	1	YLB810009-FL10	
SP12	COMPLETE UNIT	"SKF-320F (R)"	1	ASL8M404S-BM11	
SP13	BACK LABEL (R)	without serial numbering	1	YLB810009-FR10	
SKC-320C : CENTER SPEAKER					
SP14	COMPLETE UNIT	"SKC-320C"	1	ASL8C404S-BM10	
SP15	BACK LABEL	without serial numbering	1	YLB810009-C010	
SKM-320S : SURROUND SPEAKERS (L / R)					
SP16	COMPLETE UNIT	"SKM-320S (L)"	1	ASL8S404S-BM10	
SP17	BACK LABEL (L)	without serial numbering	1	YLB810009-SL10	
SP18	COMPLETE UNIT	"SKM-320S (R)"	1	ASL8S404S-BM11	
SP19	BACK LABEL (R)	without serial numbering	1	YLB810009-SR10	

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PRINTED CIRCUIT BOARD PARTS LIST

	CIRCUIT NO.	PART NAME	DESCRIPTION	Q'TY	PART NO. (SN)	MARK
PWB	IC501	POWER IC	IC 15 PIN TDA7293	1	RHI007293-0001	
PWB	DB901	DIODE	RS402L 4A 100V	1	RHD2040100011	!

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