

Univerza v Ljubljani  
Fakulteta za elektrotehniko

Boštjan Perko

## **Integrirani ojačevalnik 30W**

Seminarska naloga

pri predmetu  
Elektronska vezja

V Zalogu, maj 2008

## UVOD

Za izdelavo projekta integriranega ojačevalnika, sem se odločil zaradi zahteve pri predmetu Elektronska vezja in seveda tudi zaradi praktične uporabe. Saj je integrirano vezje TDA2005 zaradi kvalitetne reprodukcije uporabno tudi v Hi-Fi sistemih, pa čeprav je bilo v osnovi namenjeno za uporabo v avtoradijih.

Naš ojačevalnik nam da 30W sinusne moči, pri napajanju 18V in zvočnikih upornosti  $4\Omega$ .

Seveda pa je primerna tudi napetost 12-14V iz avtomobilskega akumulatorja.

Lahko pa uporabimo tudi zvočnike upornosti do  $8\Omega$  in manjše napajanje vse do 6V, ampak potem je tudi moč manjša.

## Delovanje vezja:

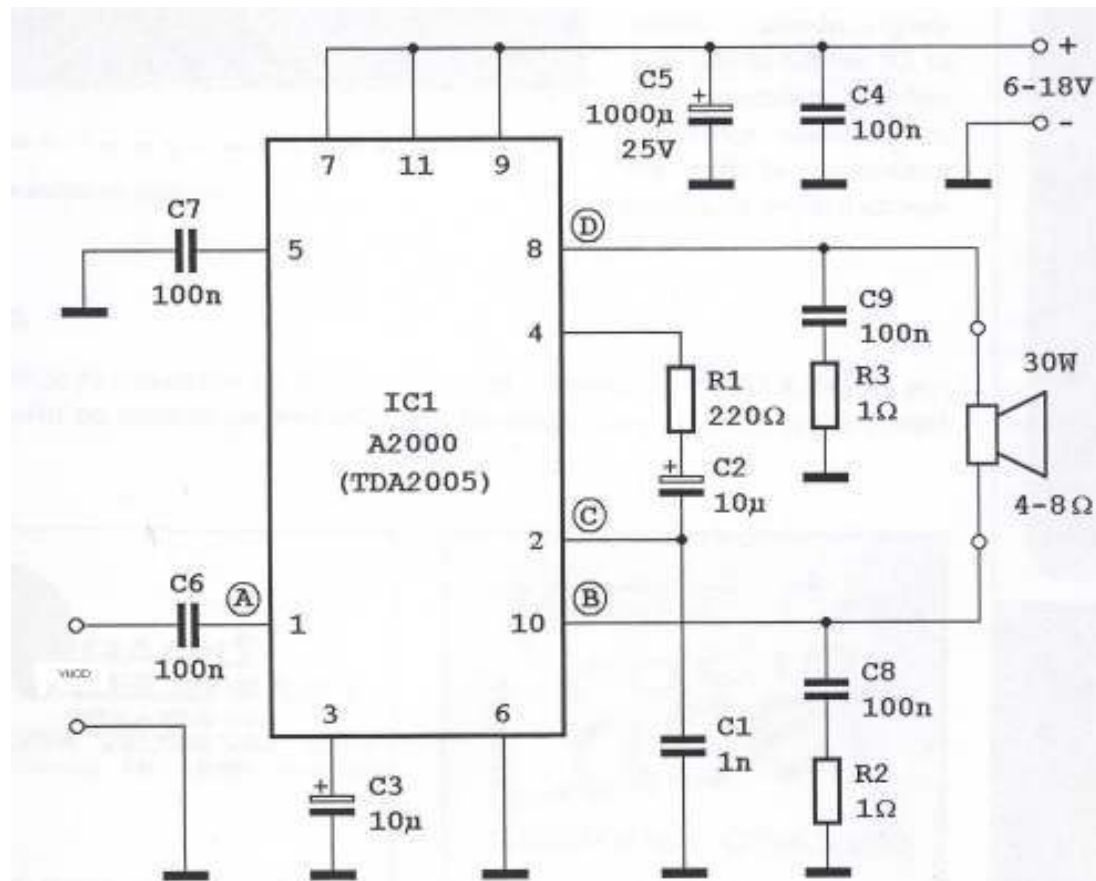
Na sliki 1 si lahko ogledate shemo integriranega ojačevalnika, z vsemi vrednostmi elementov, ki so bili uporabljeni.

Shema TDA2005 si lahko ogledate v datashetu. V datashetu so predstavljeni tudi še druge verzije uporabe integriranega vezja, kakor je tudi opisano delovanje samega integriranega vezja. Delovanje našega integriranega ojačevalnika je pa sledeče;

Ko na vhod pripeljemo naš vhodni signal, se nam v točki B pojavi izhodni signal, ki je v fazi z vhodnim, ki ga nato ponovno peljemo preko uporovnega delilnika na minus vhodno sponko našega integriranega vezja (točka C). V točki D se nam pojavi ojačan signal, ki ima obrnjeno fazo.

Torej, ko rase naš vhodni signal, rase signal tudi v točki B in obenem pada v točki D. Naš zvočnik je priključen med točkama B in D. Zato se s stališča zvočnika zdi da je izhodna napetost dvojna. Torej bi morali imeti na enem izhodu dvojno napetost, če bi eno sponko zvočnika priključili na maso.

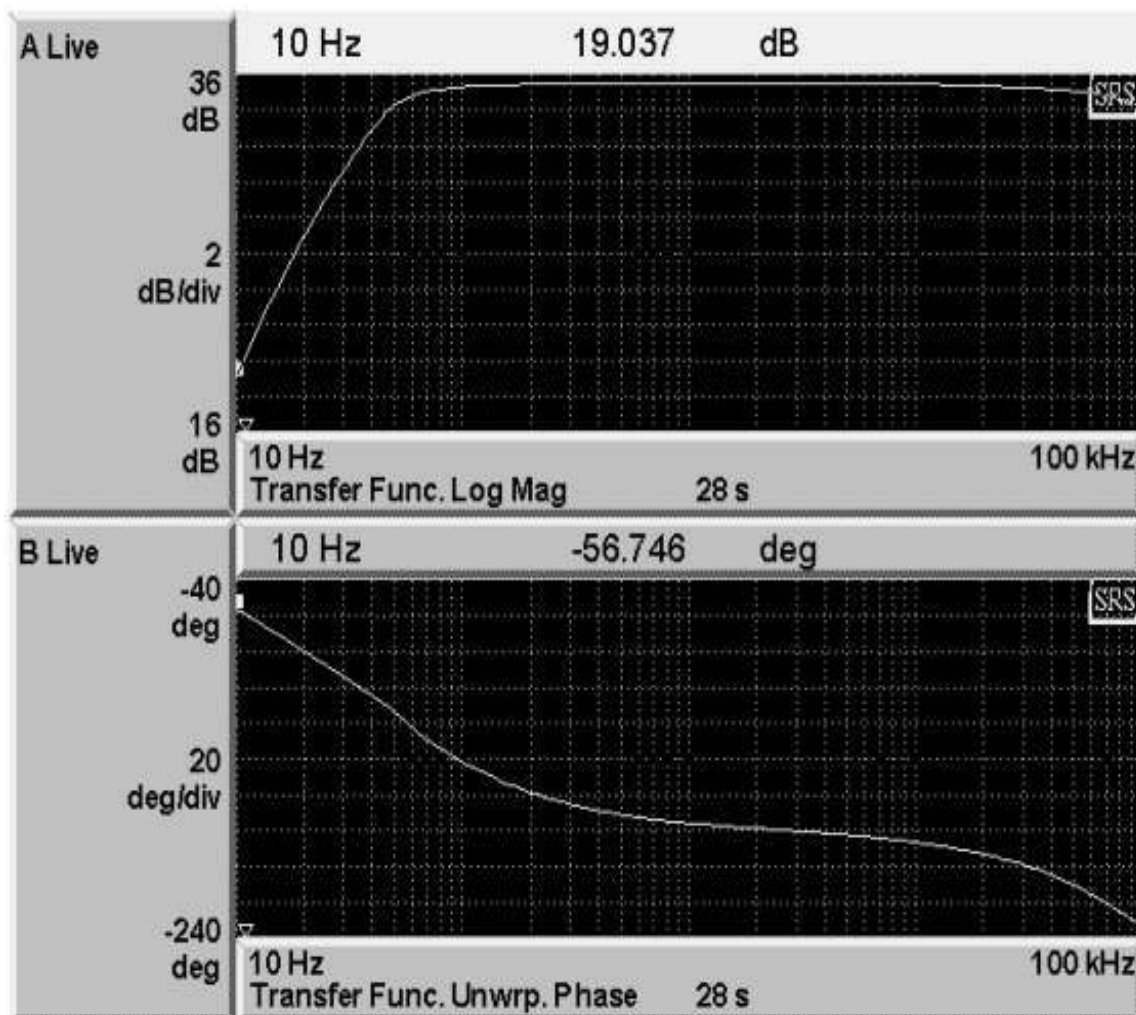
Za doseganje večjih moči je ta princip mostne vezave idealen pri nizkih napajalnih napetostih.



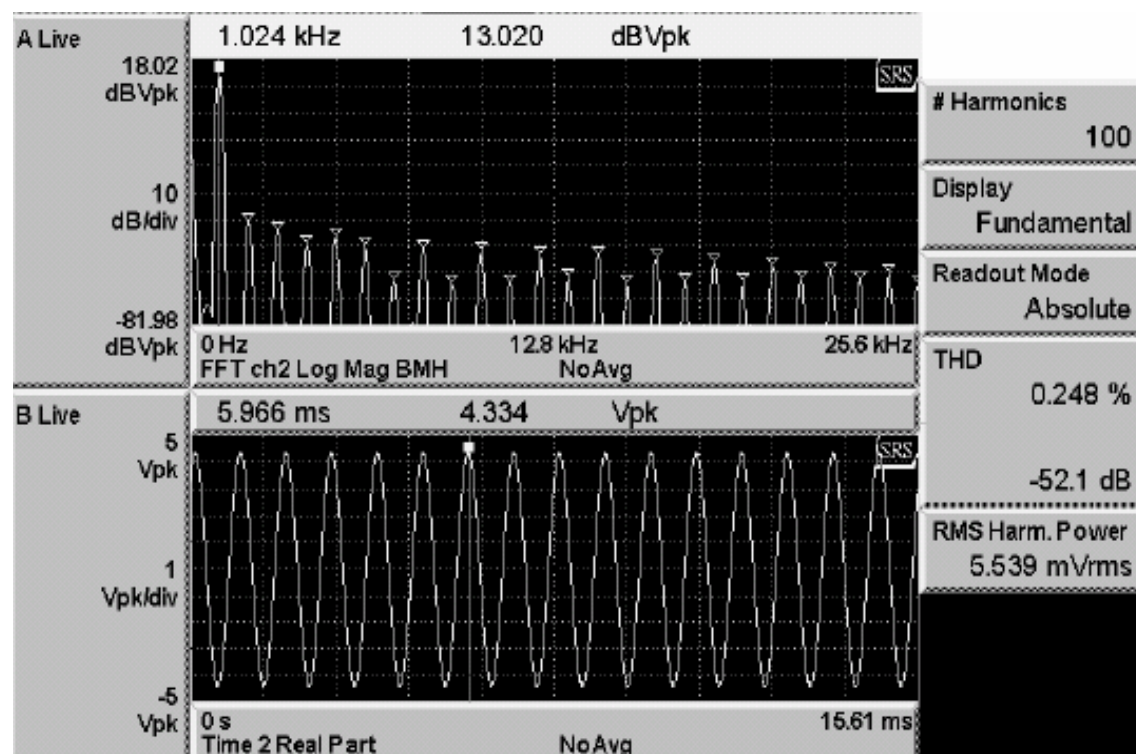
Slika 1: Shema integriranega ojačevalnika

### Izmerjene karakteristike:

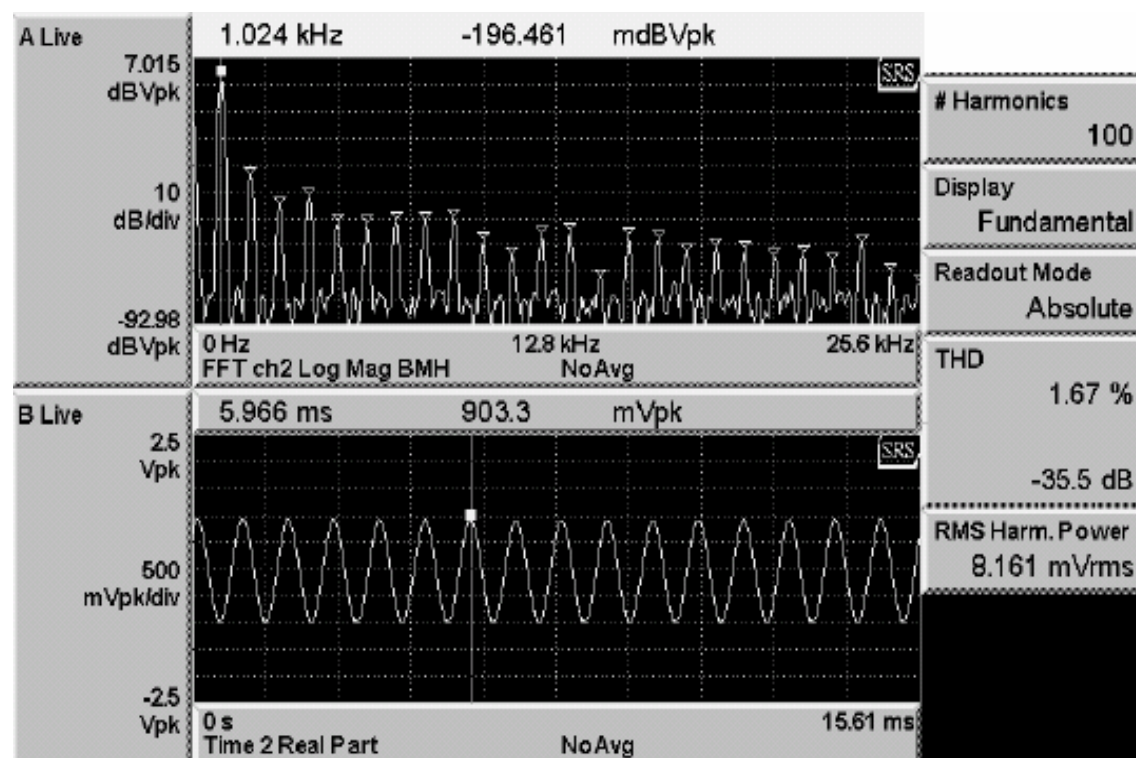
Karakteristike, ki so bile izmerjene so predstavljena na spodnjih slikah. Pri izpisu izrisanih karakteristik je bila uporabljena funkcije print screen. Na vseh slikah so tako vsi podatki oziroma rezultati, zato rezultati niso ponovno napisani pod vsako sliko.



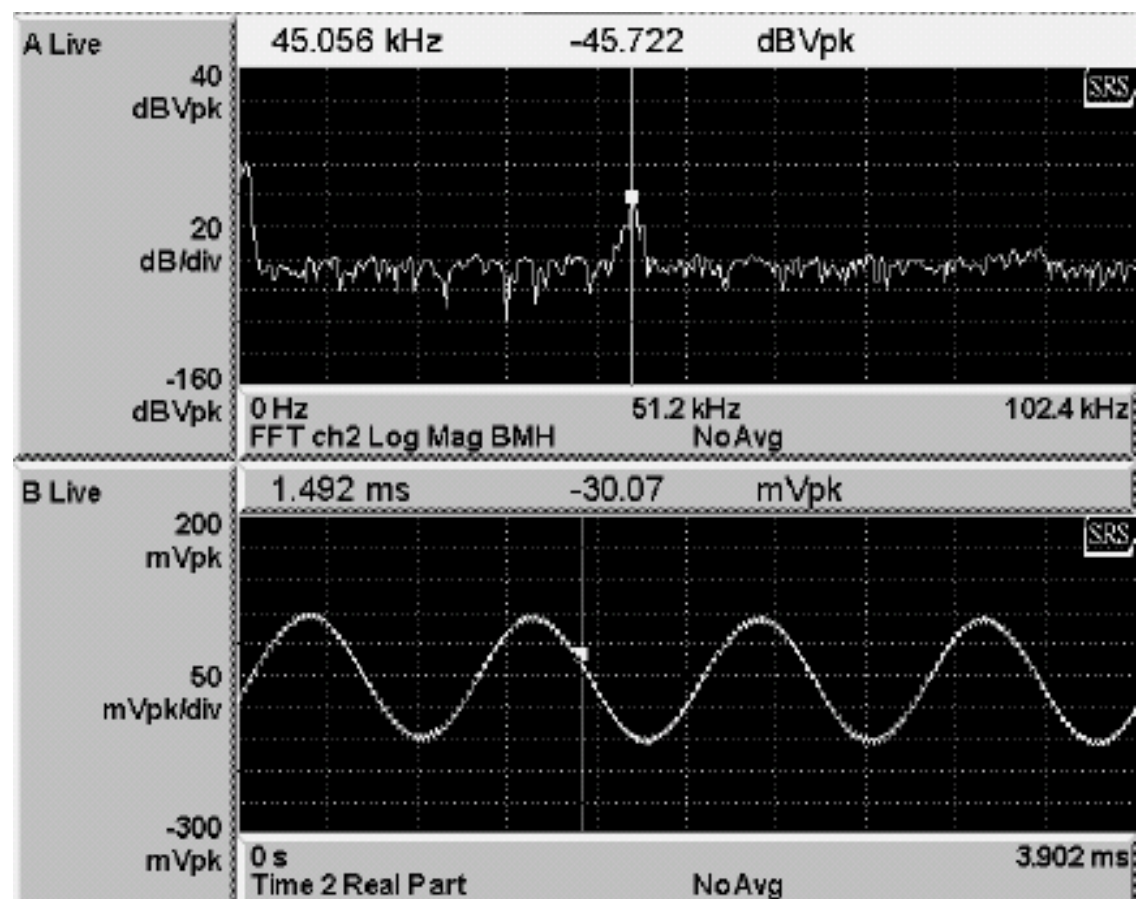
Slika 2: Prevajalna karakteristika



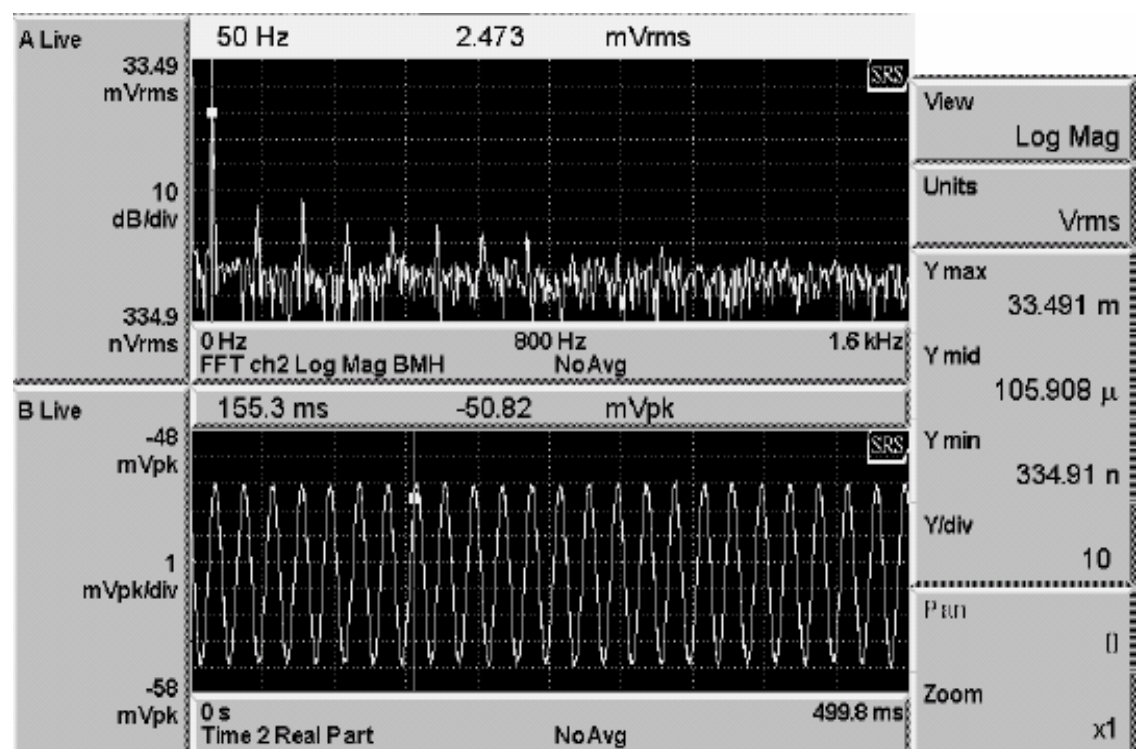
Slika 3: Popačenje pri 45mv.



Slika 4: Popačenje pri 10mv



Slika 5: Popačenje pri 1mV in pojav oscilacij pri frekvenci 50Hz



Slika 6: Šum pri kratkem stiku na vhodu.

## ZAKLJUČEK

Pri izdelavi integriranega ojačevalnika ni prišlo do nobenih posebnih težav. V veliki meri je to tudi zasluga vira, ki je bil izbran. Seveda pa je pri izdelavi še vedno potrebno vsaj osnovno znanje elektrotehnike.

Osebnostno se nisem odločil za izdelavo tiskanine. To seveda potegne za seboj malo več spajkanja, zato je priporočljiva kakšna izkušnja. No ja ampak nekje se je potrebno naučiti, sam mogoče bo to učenje vzelo malo več časa.

Ojačevalnik glede na karakteristike svoje delo opravlja. Problem bi se lahko pojavil pri izvoru napajanja z veliko notranjo upornostjo – popačenje zvoka. Za ta problem je tudi predvidena rešitev z dodatnim elektrolitskim kondenzatorjem na vhodu.

V primeru, da ne bi imeli izvora signala z vgrajeno regulacijo glasnosti, je pa možnost tudi nadgradnje z dodatnim potenciometrom za regulacijo glasnosti.

VIRI:

Svet Elektronike številka 150

Datasheet TDA2005 povezava: <http://kitsrus.com/pdf/tda2005.pdf>







## TDA2005

### 20W BRIDGE AMPLIFIER FOR CAR RADIO

**High output power :**  $P_O = 10 + 10\text{ W@}R_L = 2\Omega$ ,  
 $d = 10\%$  ;  $P_O = 20\text{ W@}R_L = 4\Omega$ ,  $d = 1\%$ .

**High reliability** of the chip and package with additional complete safety during operation thanks to protection against:

- OUTPUT DC AND AC SHORT CIRCUIT TO GROUND
- OVERRATING CHIP TEMPERATURE
- LOAD DUMP VOLTAGE SURGE
- FORTUITOUS OPEN GROUND
- VERY INDUCTIVE LOADS

**Flexibility in use :** bridge or stereo booster amplifiers with or without bootstrap and with programmable gain and bandwidth.

**Space and cost saving :** very low number of external components, very simple mounting system with no electrical isolation between the package and the heatsink (one screw only).

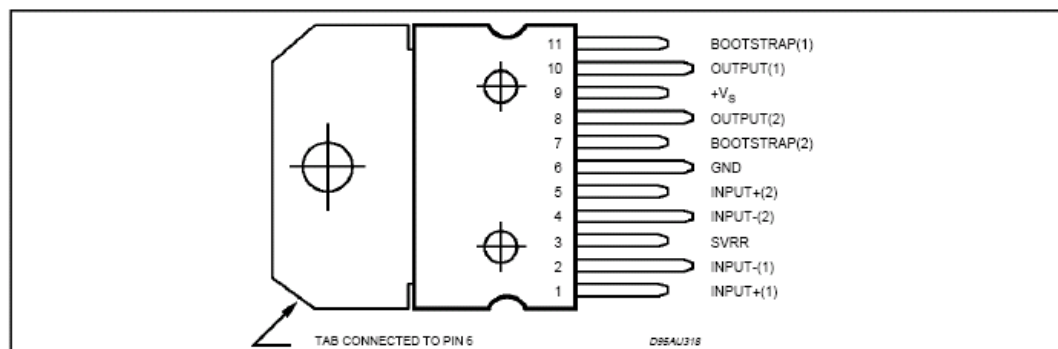
In addition, the circuit offers **loudspeaker protection** during short circuit for one wire to ground.

#### ABSOLUTE MAXIMUM RATINGS

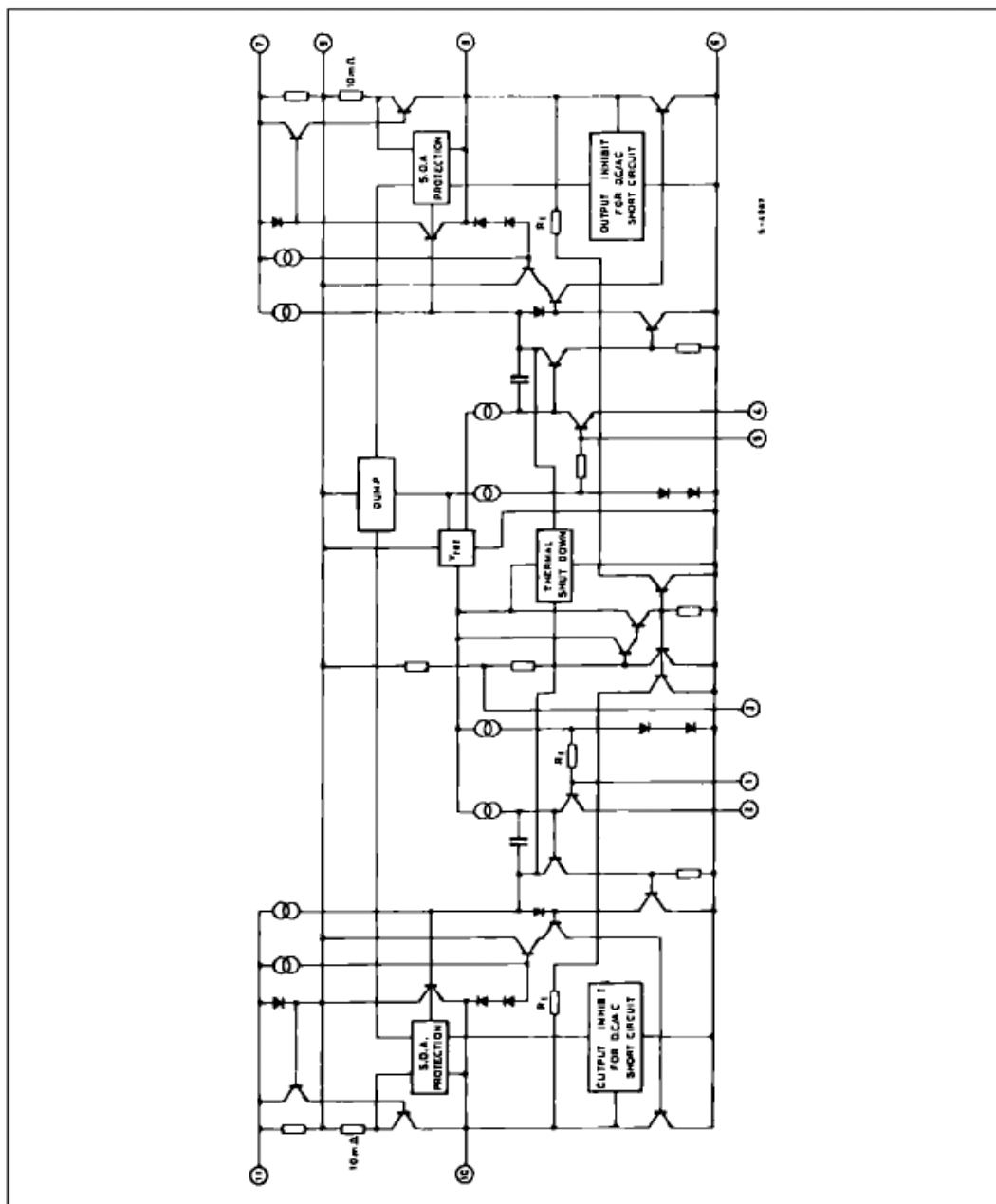
Symbol	Parameter	Value	Unit
$V_S$	Operating Supply Voltage	18	V
$V_S$	DC Supply Voltage	28	V
$V_S$	Peak Supply Voltage (for 50 ms)	40	V
$I_O$ (*)	Output Peak Current (non repetitive $t = 0.1\text{ ms}$ )	4.5	A
$I_O$ (*)	Output Peak Current (repetitive $f \geq 10\text{ Hz}$ )	3.5	A
$P_{tot}$	Power Dissipation at $T_{case} = 60^\circ\text{C}$	30	W
$T_{stg}, T_J$	Storage and Junction Temperature	- 40 to 150	$^\circ\text{C}$

(\*) The max. output current is internally limited.

#### PIN CONNECTION



## SCHEMATIC DIAGRAM



## THERMAL DATA

Symbol	Parameter	Value	Unit
$R_{th(j-case)}$	Thermal Resistance Junction-case	Max. 3	$^{\circ}\text{C/W}$

## BRIDGE AMPLIFIER APPLICATION (TDA2005M)

Figure 1 : Test and Application Circuit (Bridge amplifier)

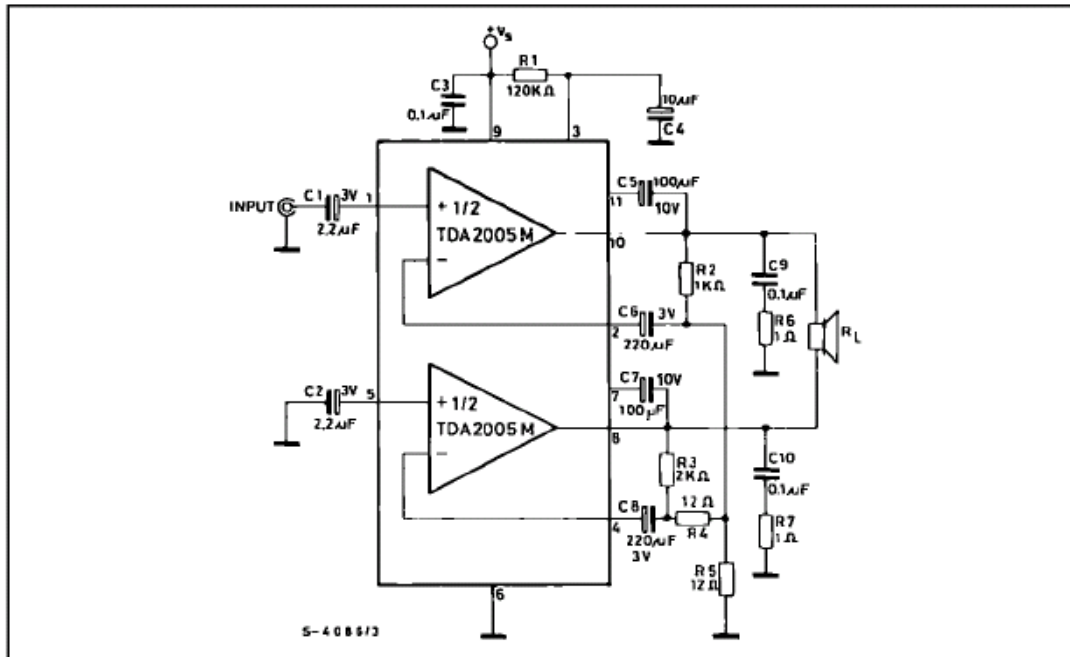
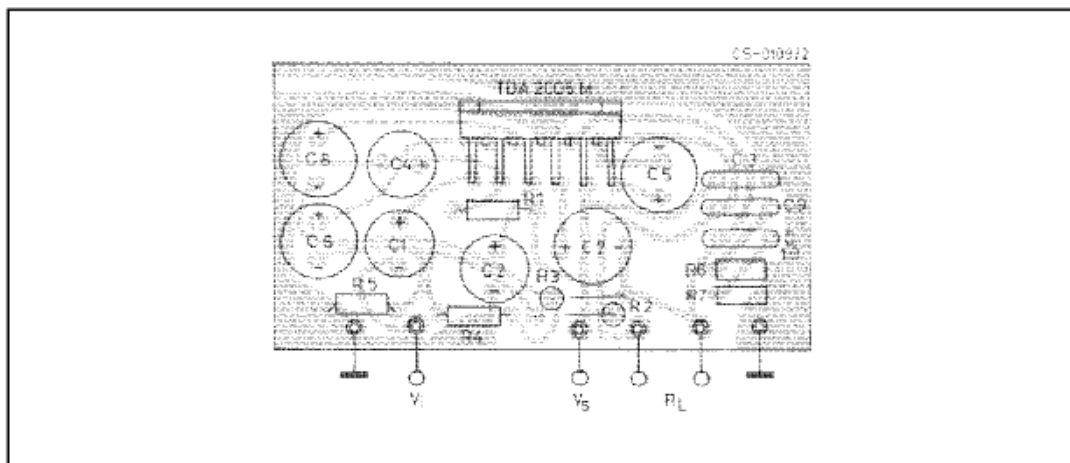


Figure 2 : P.C. Board and Components Layout of Figure 1 (1:1 scale)



## TDA2005

**ELECTRICAL CHARACTERISTICS** (refer to the **Bridge** application circuit,  $T_{amb} = 25^{\circ}\text{C}$ ,  $G_V = 50\text{dB}$ ,  $R_{th}(\text{heatsink}) = 4^{\circ}\text{C/W}$ , unless otherwise specified)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
$V_S$	Supply Voltage		8		18	V
$V_{OS}$	Output Offset Voltage (1) (between pin 8 and pin 10)	$V_S = 14.4\text{V}$ $V_S = 13.2\text{V}$			150 150	mV mV
$I_d$	Total Quiescent Drain Current	$V_S = 14.4\text{V}$ $R_L = 4\Omega$ $V_S = 13.2\text{V}$ $R_L = 3.2\Omega$		75 70	150 160	mA mA
$P_o$	Output Power	$d = 10\%$ $f = 1\text{Hz}$ $V_S = 14.4\text{V}$ $R_L = 4\Omega$ $V_S = 13.2\text{V}$ $R_L = 3.2\Omega$	18 20 17	20 22 19		W
$d$	Distortion	$f = 1\text{kHz}$ $V_S = 14.4\text{V}$ $R_L = 4\Omega$ $P_o = 50\text{mW to } 15\text{W}$ $V_S = 13.2\text{V}$ $R_L = 3.2\Omega$ $P_o = 50\text{mW to } 13\text{W}$			1 1	% %
$V_i$	Input Sensitivity	$f = 1\text{kHz}$ $P_o = 2\text{W}$ $R_L = 4\Omega$ $P_o = 2\text{W}$ $R_L = 3.2\Omega$		9 8		mV mV
$R_i$	Input Resistance	$f = 1\text{kHz}$	70			k $\Omega$
$f_L$	Low Frequency Roll Off (– 3dB)	$R_L = 3.2\Omega$			40	Hz
$f_H$	High Frequency Roll Off (– 3dB)	$R_L = 3.2\Omega$	20			kHz
$G_V$	Closed Loop Voltage Gain	$f = 1\text{kHz}$		50		dB
$e_N$	Total Input Noise Voltage	$R_g = 10\text{k}\Omega$ (2)		3	10	$\mu\text{V}$
SVR	Supply Voltage Rejection	$R_g = 10\text{k}\Omega$ , $C_4 = 10\mu\text{F}$ $f_{\text{ripple}} = 100\text{Hz}$ , $V_{\text{ripple}} = 0.5\text{V}$	45	55		dB
$\eta$	Efficiency	$V_S = 14.4\text{V}$ , $f = 1\text{kHz}$ $P_o = 20\text{W}$ $R_L = 4\Omega$ $P_o = 22\text{W}$ $R_L = 3.2\Omega$ $V_S = 13.2\text{V}$ , $f = 1\text{kHz}$ $P_o = 19\text{W}$ $R_L = 3.2\Omega$		60 60 58		% % %
$T_J$	Thermal Shut-down Junction Temperature	$V_S = 14.4\text{V}$ , $R_L = 4\Omega$ $f = 1\text{kHz}$ , $P_{\text{tot}} = 13\text{W}$		145		$^{\circ}\text{C}$
$V_{OSH}$	Output Voltage with one Side of the Speaker connected to ground	$V_S = 14.4\text{V}$ $R_L = 4\Omega$ $V_S = 13.2\text{V}$ $R_L = 3.2\Omega$			2	V

Notes : 1. ~~Speaker Impedance~~  
2. Bandwidth Filter : 22Hz to 22kHz.

Figure 3 : Output Offset Voltage versus Supply Voltage

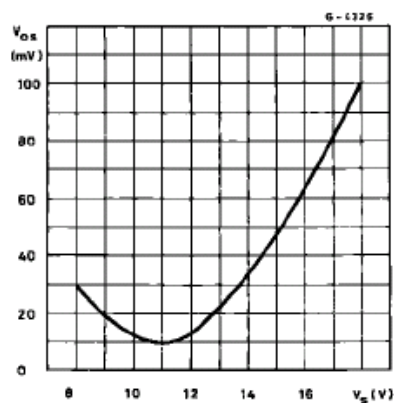


Figure 4 : Distortion versus Output Power (bridge amplifier)

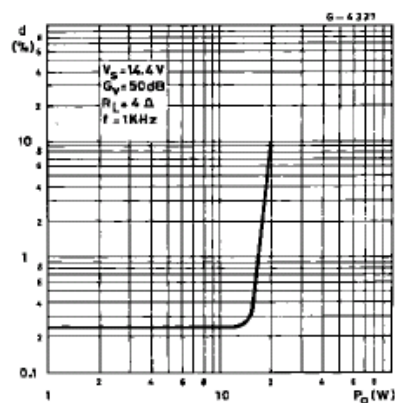
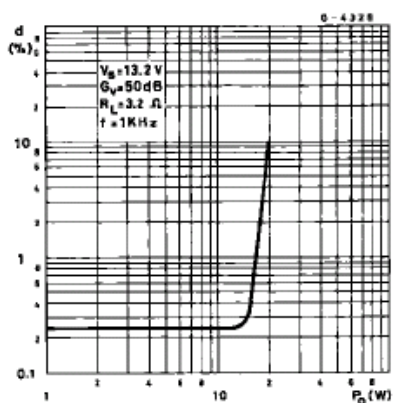


Figure 5 : Distortion versus Output Power (bridge amplifier)



### BRIDGE AMPLIFIER DESIGN

The following considerations can be useful when designing a bridge amplifier.

Parameter		Single Ended	Bridge
$V_{O \max}$	Peak Output Voltage (before clipping)	$\frac{1}{2} (V_S - 2 V_{CE \text{ sat}})$	$V_S - 2 V_{CE \text{ sat}}$
$I_{O \max}$	Peak Output Current (before clipping)	$\frac{1}{2} \frac{V_S - 2 V_{CE \text{ sat}}}{R_L}$	$\frac{V_S - 2 V_{CE \text{ sat}}}{R_L}$
$P_{O \max}$	RMS Output Power (before clipping)	$\frac{1}{4} \frac{(V_S - 2 V_{CE \text{ sat}})^2}{2 R_L}$	$\frac{(V_S - 2 V_{CE \text{ sat}})^2}{2 R_L}$

Where :  $V_{CE \text{ sat}}$  = output transistors saturation voltage  
 $V_S$  = allowable supply voltage  
 $R_L$  = load impedance

## TDA2005

Voltage and current swings are twice for a bridge amplifier in comparison with single ended amplifier. In other words, with the same  $R_L$  the bridge configuration can deliver an output power that is four times the output power of a single ended amplifier, while, with the same max output current the bridge configuration can deliver an output power that is twice the output power of a single ended amplifier. Care must be taken when selecting  $V_S$  and  $R_L$  in order to avoid an output peak current above the absolute maximum rating.

From the expression for  $I_{Omax}$ , assuming  $V_S = 14.4V$  and  $V_{CEsat} = 2V$ , the minimum load that can be driven by TDA2005 in bridge configuration is :

$$R_{Lmin} = \frac{V_S - 2 V_{CEsat}}{I_{Omax}} = \frac{14.4 - 4}{3.5} = 2.97\Omega$$

The voltage gain of the bridge configuration is given by (see Figure 34) :

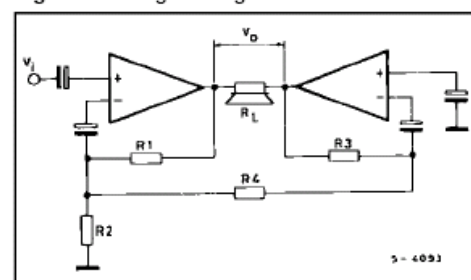
$$G_V = \frac{V_0}{V_1} = 1 + \left( \frac{R_1}{R_2 + R_4} \right) + \frac{R_3}{R_4}$$

For sufficiently high gains (40 to 50dB) it is possible to put  $R_2 = R_4$  and  $R_3 = 2 R_1$ , simplifying the formula in :

$$G_V = 4 \frac{R_1}{R_2}$$

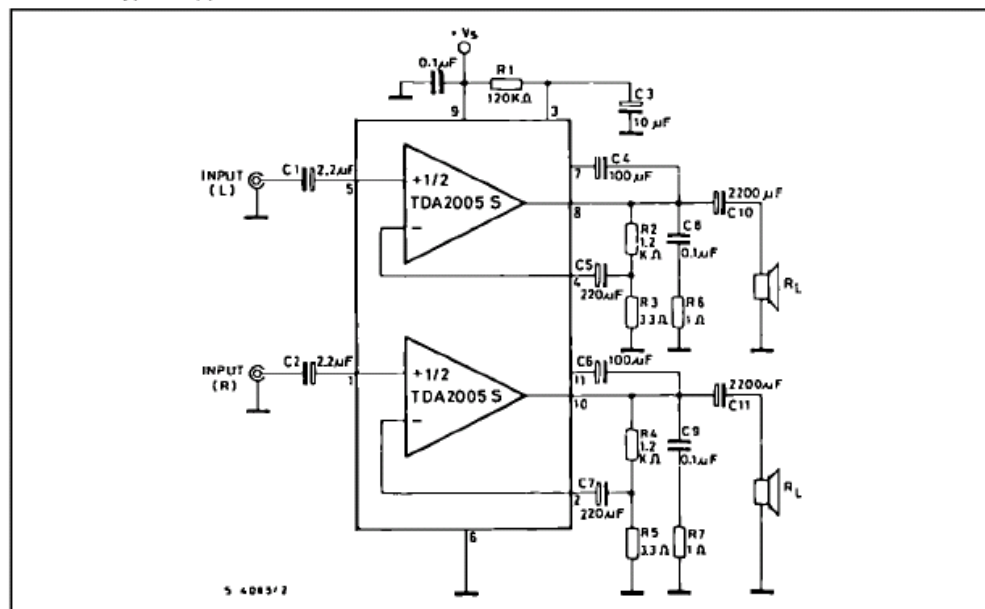
$G_V$ (dB)	$R_1$ ( $\Omega$ )	$R_2 = R_4$ ( $\Omega$ )	$R_3$ ( $\Omega$ )
40	1000	39	2000
50	1000	12	2000

Figure 6 : Bridge Configuration



## STEREO AMPLIFIER APPLICATION (TDA2005S)

Figure 7 : Typical Application Circuit



**ELECTRICAL CHARACTERISTICS** (refer to the Stereo application circuit,  $T_{amb} = 25^{\circ}\text{C}$ ,  $G_V = 50\text{dB}$ ,  $R_{th}(\text{heatsink}) = 4^{\circ}\text{C/W}$ , unless otherwise specified)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
$V_S$	Supply Voltage		8		18	V
$V_O$	Quiescent Output Voltage	$V_S = 14.4\text{V}$ $V_S = 13.2\text{V}$	6.6 6	7.2 6.6	7.8 7.2	V
$I_d$	Total Quiescent Drain Current	$V_S = 14.4\text{V}$ $V_S = 13.2\text{V}$		65 62	120 120	mA
$P_O$	Output Power (each channel)	$f = 1\text{kHz}$ , $d = 10\%$ $V_S = 14.4\text{V}$ $R_L = 4\Omega$ $R_L = 3.2\Omega$ $R_L = 2\Omega$ $R_L = 1.6\Omega$ $V_S = 13.2\text{V}$ $R_L = 3.2\Omega$ $R_L = 1.6\Omega$ $V_S = 16\text{V}$ $R_L = 2\Omega$	6 7 9 10 6 9	6.5 8 10 11 6.5 10 12		W
$d$	Distortion (each channel)	$f = 1\text{kHz}$ $V_S = 14.4\text{V}$ , $R_L = 4\Omega$ $P_O = 50\text{mW}$ to $4\text{W}$ $V_S = 14.4\text{V}$ , $R_L = 2\Omega$ $P_O = 50\text{mW}$ to $6\text{W}$ $V_S = 13.2\text{V}$ , $R_L = 3.2\Omega$ $P_O = 50\text{mW}$ to $3\text{W}$ $V_S = 13.2\text{V}$ , $R_L = 1.6\Omega$ $P_O = 40\text{mW}$ to $6\text{W}$		0.2 0.3 0.2 0.3	1 1 1 1	%
CT	Cross Talk (1)	$V_S = 14.4\text{V}$ , $V_O = 4\text{V}_{RMS}$ $R_L = 4\Omega$ , $R_g = 5\text{k}\Omega$ $f = 1\text{kHz}$ $f = 10\text{kHz}$		60 45		dB
$V_I$	Input Saturation Voltage		300			mV
$V_I$	Input Sensitivity	$f = 1\text{kHz}$ , $P_O = 1\text{W}$ $R_L = 4\Omega$ $R_L = 3.2\Omega$		6 5.5		mV
$R_i$	Input Resistance	$f = 1\text{kHz}$	70	200		$\text{k}\Omega$
$f_L$	Low Frequency Roll Off ( $-3\text{dB}$ )	$R_L = 2\Omega$			50	Hz
$f_H$	High Frequency Roll Off ( $-3\text{dB}$ )	$R_L = 2\Omega$	15			kHz
$G_V$	Voltage Gain (open loop)	$f = 1\text{kHz}$		90		dB
$G_V$	Voltage Gain (closed loop)	$f = 1\text{kHz}$	48	50	51	dB
$\Delta G_V$	Closed Loop Gain Matching			0.5		dB
$e_N$	Total Input Noise Voltage	$R_g = 10\text{k}\Omega$ (2)		1.5	5	$\mu\text{V}$
SVR	Supply Voltage Rejection	$R_g = 10\text{k}\Omega$ , $C_3 = 10\mu\text{F}$ $f_{\text{ripple}} = 100\text{Hz}$ , $V_{\text{ripple}} = 0.5\text{V}$	35	45		dB
$\eta$	Efficiency	$V_S = 14.4\text{V}$ , $f = 1\text{kHz}$ $P_O = 6.5\text{W}$ , $R_L = 4\Omega$ $P_O = 10\text{W}$ , $R_L = 2\Omega$ $V_S = 13.2\text{V}$ , $f = 1\text{kHz}$ $P_O = 6.5\text{W}$ , $R_L = 3.2\Omega$ $P_O = 100\text{W}$ , $R_L = 1.6\Omega$		70 60 70 60		%

Notes : 1. For TDA2005M only  
2. Bandwidth Filter : 22Hz to 22kHz.

Figure 8 : Quiescent Output Voltage versus Supply Voltage (Stereo amplifier)

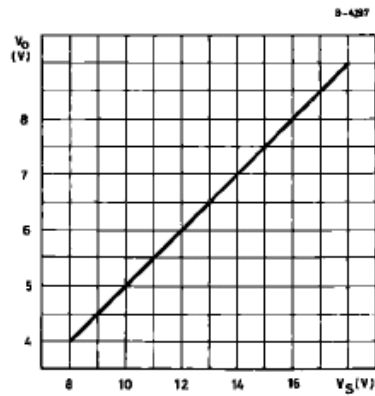


Figure 9 : Quiescent Drain Current versus Supply Voltage (Stereo amplifier)

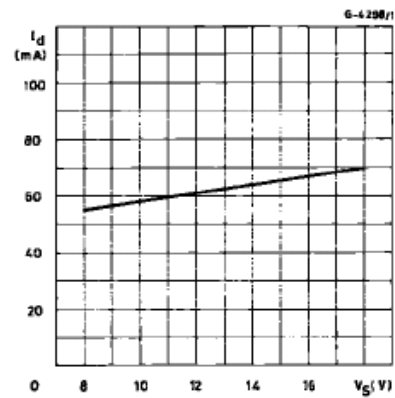


Figure 10 : Distortion versus Output Power (Stereo amplifier)

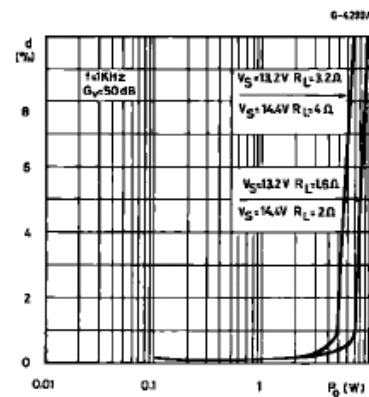


Figure 11 : Output Power versus Supply Voltage (Stereo amplifier)

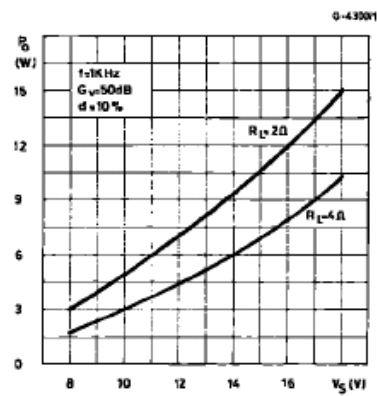


Figure 12 : Output Power versus Supply Voltage (Stereo amplifier)

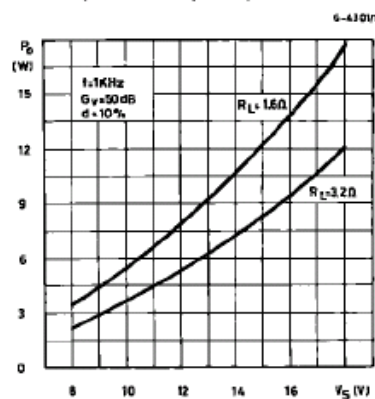


Figure 13 : Distortion versus Frequency (Stereo amplifier)

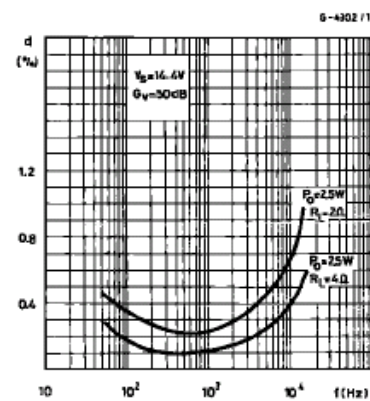




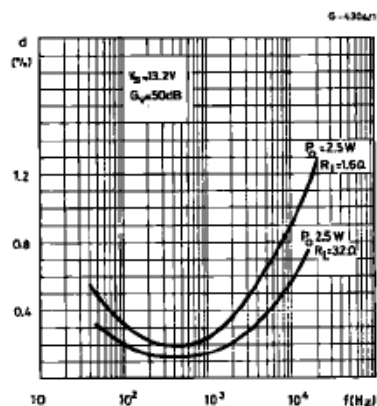
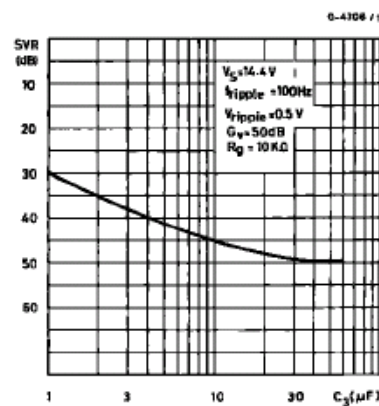
Figure 14 : Distortion versus Frequency  
(Stereo amplifier)Figure 15 : Supply Voltage Rejection versus C3  
(Stereo amplifier)

Figure 16 : Supply Voltage Rejection versus Frequency (Stereo amplifier)

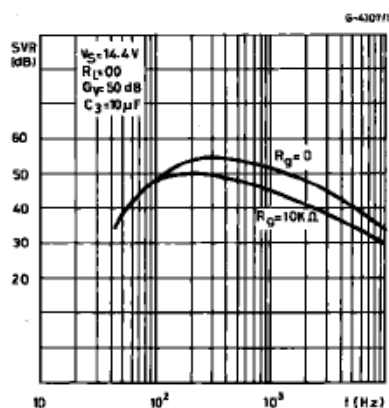


Figure 17 : Supply Voltage Rejection versus C2 and C3 (Stereo amplifier)

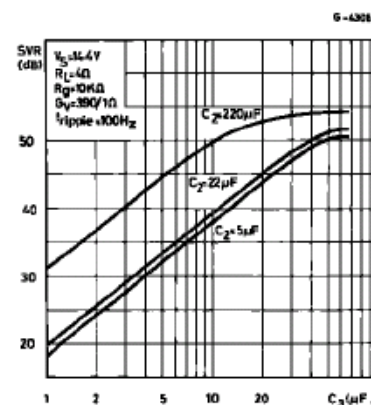


Figure 18 : Supply Voltage Rejection versus C2 and C3 (Stereo amplifier)

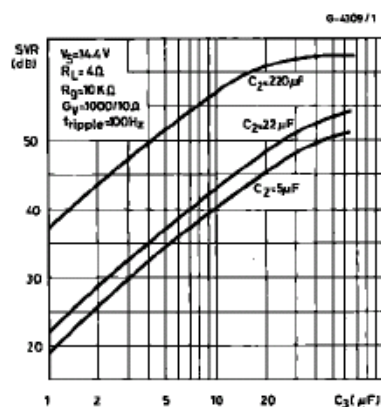


Figure 19 : Gain versus Input Sensitivity (Stereo amplifier)

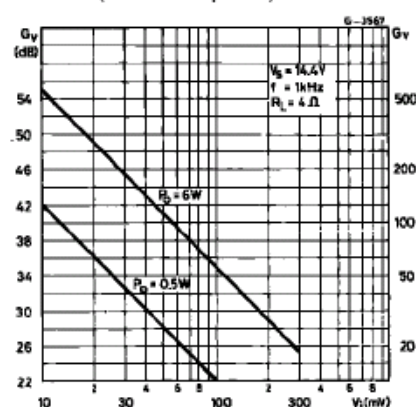
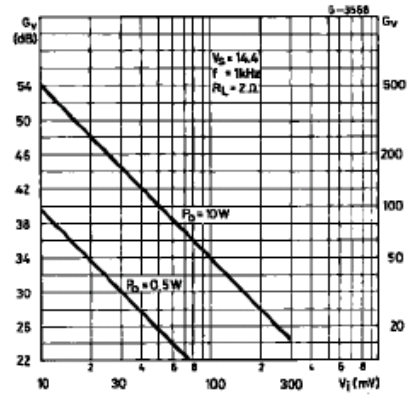
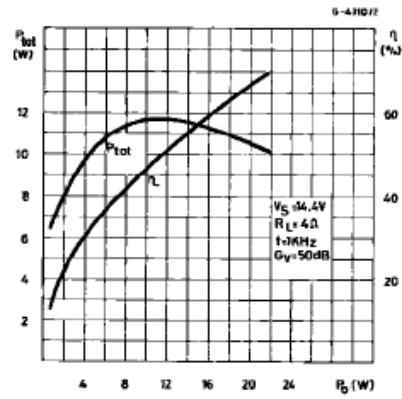
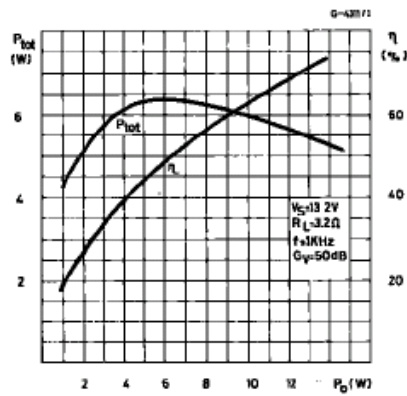


Figure 20 : Gain versus Input Sensitivity  
(Stereo amplifier)Figure 21 : Total Power Dissipation and Efficiency versus Output Power  
(Bridge amplifier)Figure 22 : Total Power Dissipation and Efficiency versus Output Power  
(Stereo amplifier)

**APPLICATION SUGGESTION**

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

Comp.	Recom. Value	Purpose	Larger Than	Smaller Than
R <sub>1</sub>	120 kΩ	Optimization of the Output Symmetry	Smaller P <sub>o max</sub>	Smaller P <sub>o max</sub>
R <sub>2</sub>	1kΩ			
R <sub>3</sub>	2 kΩ			
R <sub>4</sub> , R <sub>5</sub>	12 Ω	Closed Loop Gain Setting (see Bridge Amplifier Design) (*)		
R <sub>6</sub> , R <sub>7</sub>	1 Ω	Frequency Stability	Danger of Oscillation at High Frequency with Inductive Loads	
C <sub>1</sub>	2.2 μF	Input DC Decoupling		
C <sub>2</sub>	2.2 μF	Optimization of Turn on Pop and Turn on Delay	High Turn on Delay	Higher Turn on Pop, Higher Low Frequency Cut-off, Increase of Noise
C <sub>3</sub>	0.1 μF	Supply by Pass		Danger of Oscillation
C <sub>4</sub>	10 μF	Ripple Rejection	Increase of SVR, Increase of the Switch-on Time	Degradation of SVR.
C <sub>5</sub> , C <sub>7</sub>	100 μF	Bootstrapping		Increase of Distortion at low Frequency
C <sub>6</sub> , C <sub>8</sub>	220 μF	Feedback Input DC Decoupling, Low Frequency Cut-off		Higher Low Frequency Cut-off
C <sub>9</sub> , C <sub>10</sub>	0.1 μF	Frequency Stability		Danger of Oscillation

(\*) The closed loop gain must be higher than 32dB.

## TDA2005

### APPLICATION INFORMATION

Figure 23 : Bridge Amplifier without Bootstrap

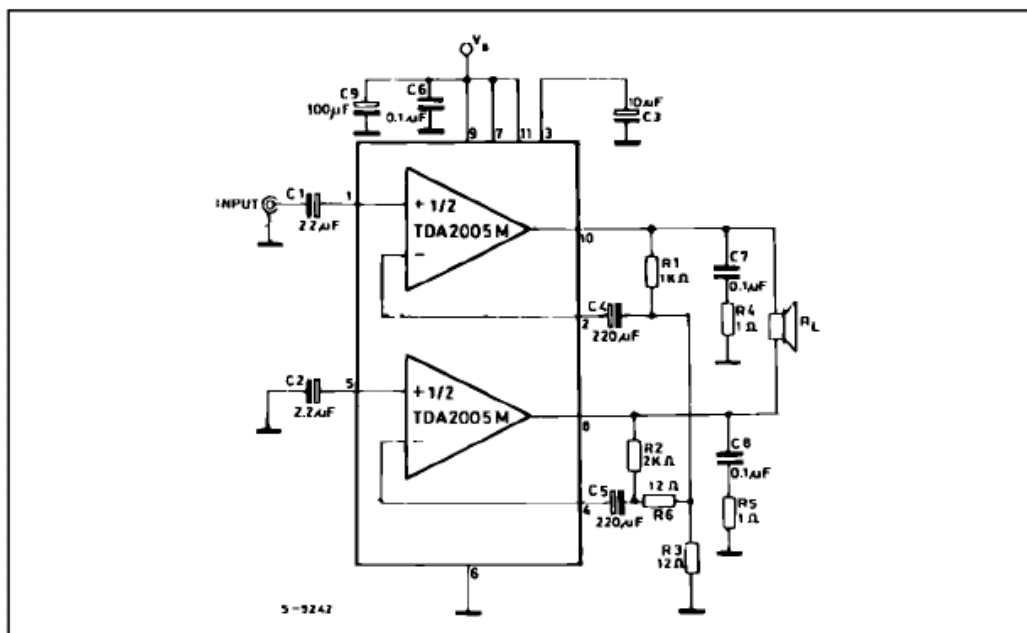
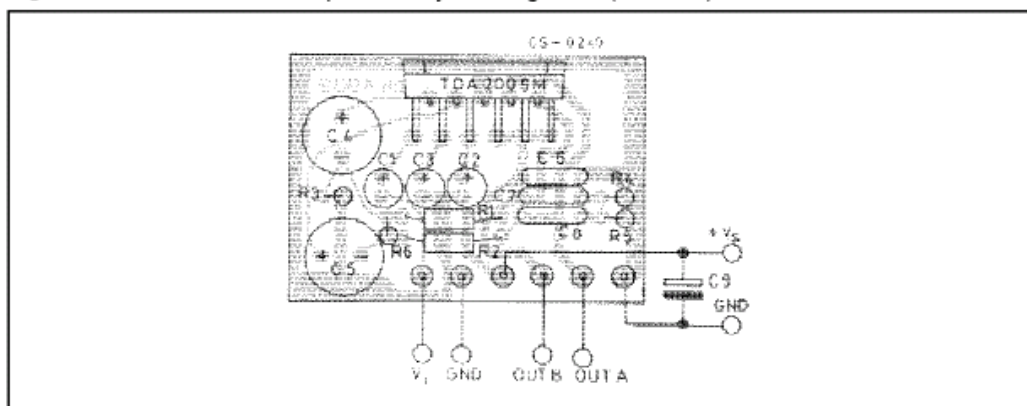


Figure 24 : P.C. Board and Components Layout of Figure 23 (1:1 scale)



## APPLICATION INFORMATION (continued)

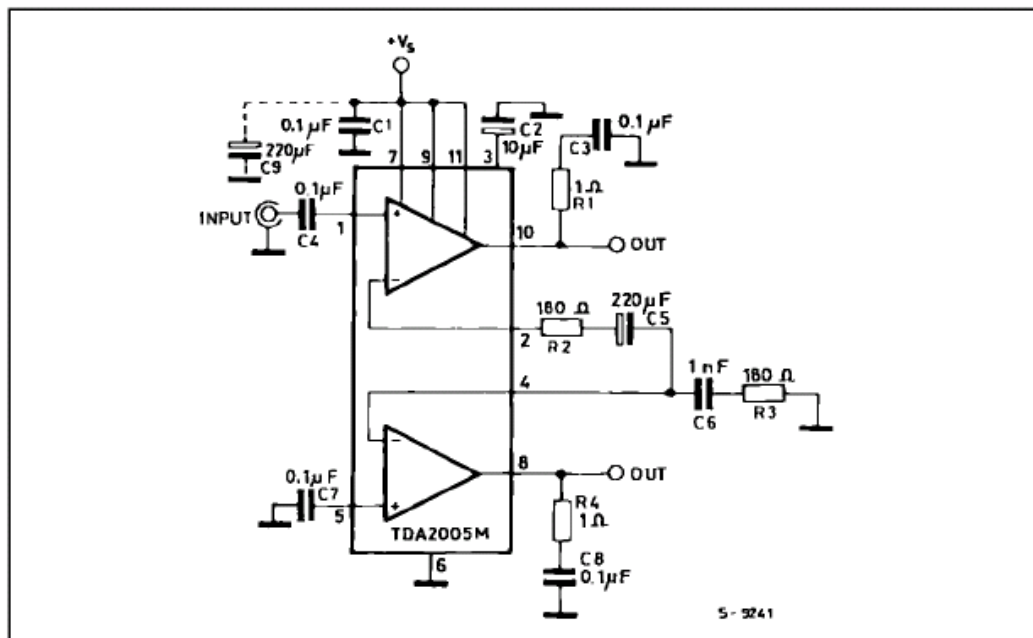
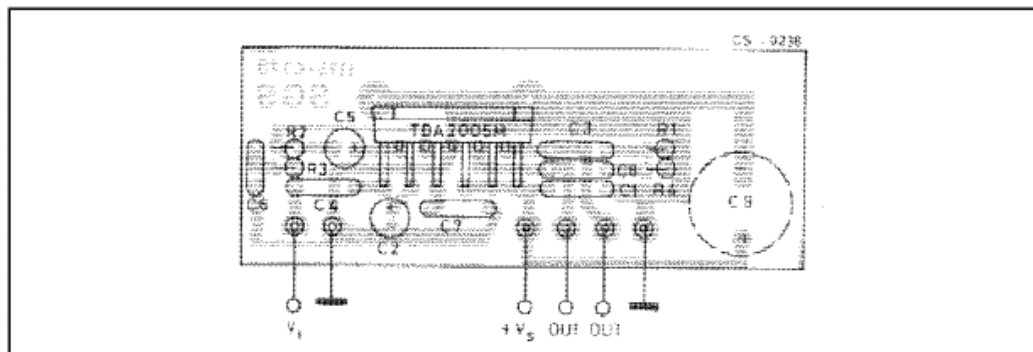
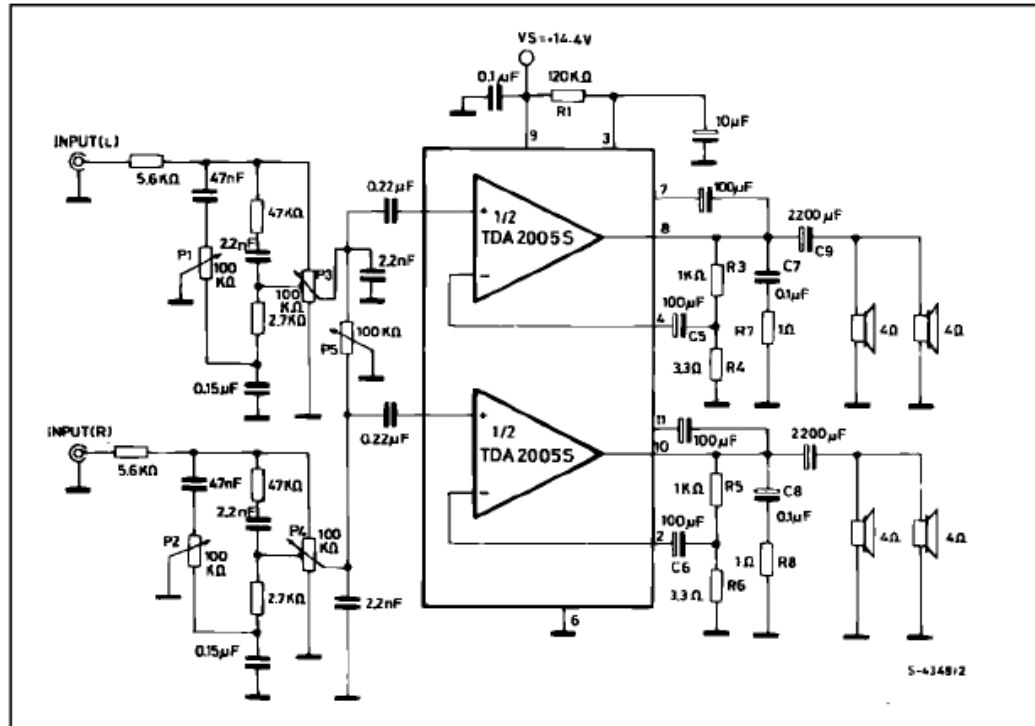
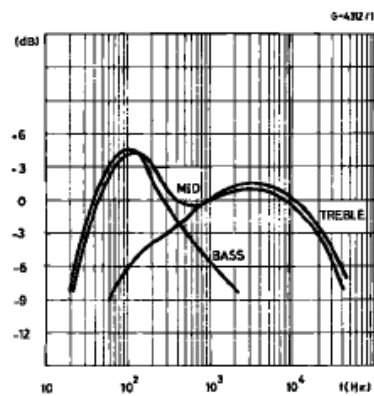
Figure 25 : Low Cost Bridge Amplifier ( $G_V = 42\text{dB}$ )

Figure 26 : P.C. Board and Components Layout of Figure 25 (1:1 scale)



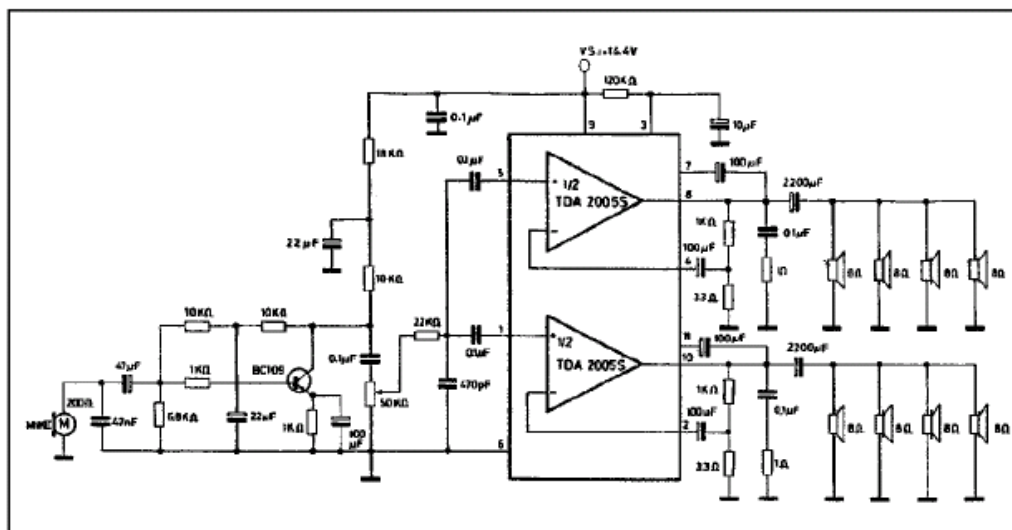
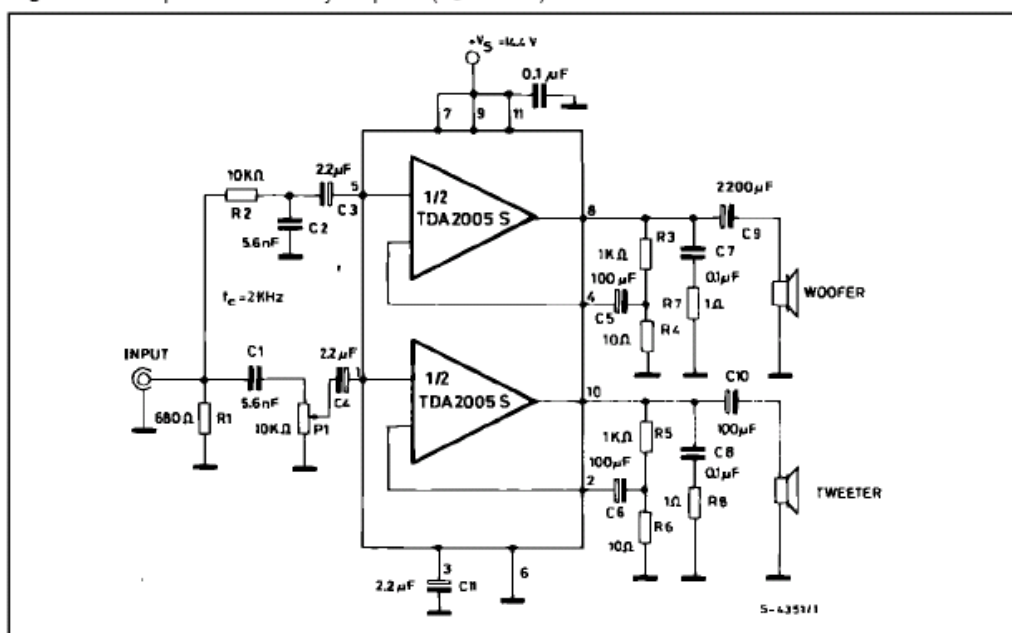
## APPLICATION INFORMATION (continued)

Figure 27 : 10 + 10 W Stereo Amplifier with Tone Balance and Loudness Control

Figure 28 : Tone Control Response  
(circuit of Figure 29)

## APPLICATION INFORMATION (continued)

Figure 29 : 20W Bus Amplifier

Figure 30 : Simple 20W Two Way Amplifier ( $F_c = 2\text{kHz}$ )

## BUILT-IN PROTECTION SYSTEMS

### Load Dump Voltage Surge

The TDA2005 has a circuit which enables it to withstand a voltage pulse train, on Pin 9, of the type shown in Figure 34.

If the supply voltage peaks to more than 40V, then an LC filter must be inserted between the supply and pin 9, in order to assure that the pulses at pin 9 will be held within the limits shown.

A suggested LC network is shown in Figure 33. With this network, a train of pulses with amplitude up to 120V and width of 2ms can be applied at point A. This type of protection is ON when the supply voltage (pulse or DC) exceeds 18V. For this reason the maximum operating supply voltage is 18V.

Figure 33

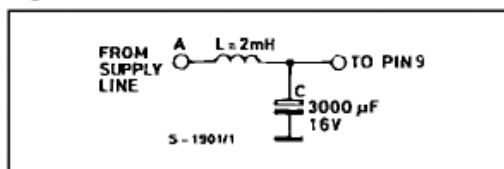
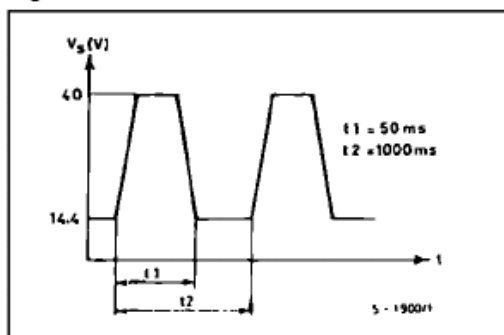


Figure 34



### Short Circuit (AC and DC conditions)

The TDA2005 can withstand a permanent short-circuit on the output for a supply voltage up to 16V.

### Polarity Inversion

High current (up to 10A) can be handled by the device with no damage for a longer period than the blow-out time of a quick 2A fuse (normally connected in series with the supply). This feature is added to avoid destruction, if during fitting to the car, a mistake on the connection of the supply is made.



### Open Ground

When the ratio is in the ON condition and the ground is accidentally opened, a standard audio amplifier will be damaged. On the TDA2005 protection diodes are included to avoid any damage.

### Inductive Load

A protection diode is provided to allow use of the TDA2005 with inductive loads.

### DC Voltage

The maximum operating DC voltage for the TDA2005 is 18V.

However the device can withstand a DC voltage up to 28V with no damage. This could occur during winter if two batteries are series connected to crank the engine.

### Thermal Shut-down

The presence of a thermal limiting circuit offers the following advantages:

- 1) an overload on the output (even if it is permanent), or an excessive ambient temperature can be easily withstood.
- 2) the heatsink can have a smaller factor of safety compared with that of a conventional circuit. There is no device damage in the case of excessive junction temperature: all that happens is that  $P_O$  (and therefore  $P_{tot}$ ) and  $I_d$  are reduced.

The maximum allowable power dissipation depends upon the size of the external heatsink (i.e. its thermal resistance); Figure 35 shows the dissippable power as a function of ambient temperature for different thermal resistance.

### Loudspeaker Protection

The circuit offers loudspeaker protection during short circuit for one wire to ground.



Figure 35 : Maximum Allowable Power Dissipation versus Ambient Temperature

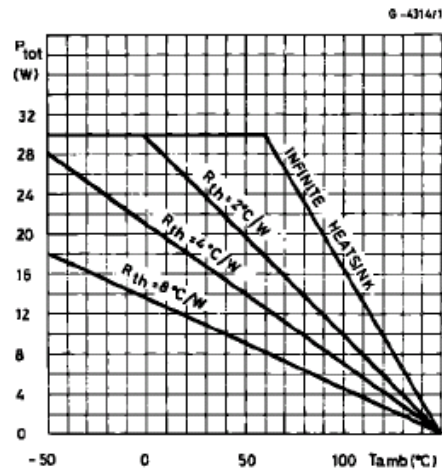


Figure 36 : Output Power and Drain Current versus Case Temperature

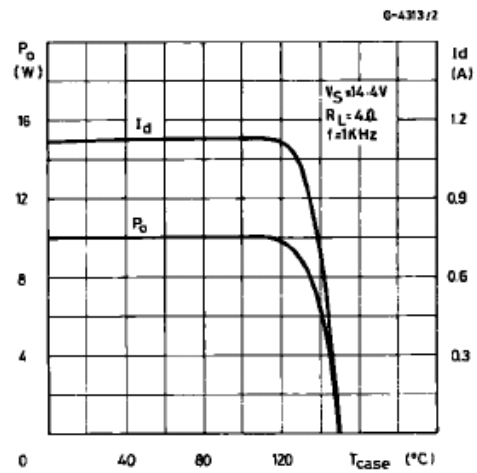


Figure 37 : Output Power and Drain Current versus Case Temperature

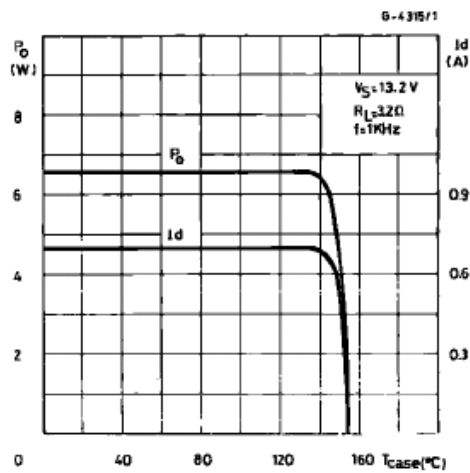


Figure 35 : Maximum Allowable Power Dissipation versus Ambient Temperature

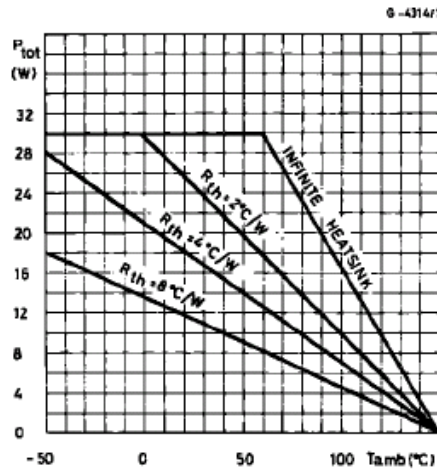


Figure 36 : Output Power and Drain Current versus Case Temperature

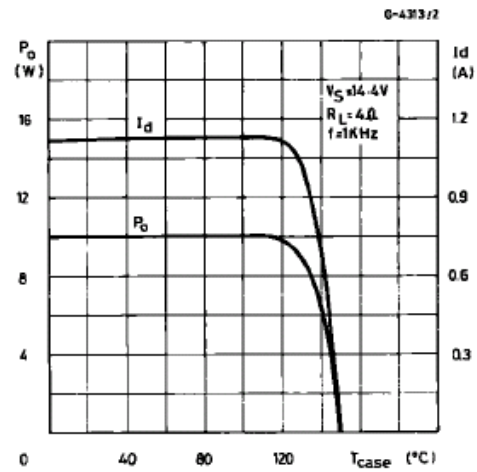
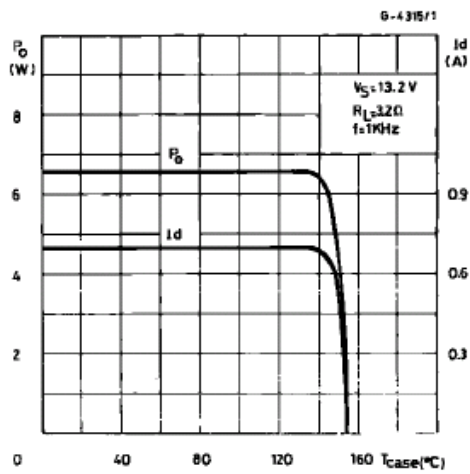


Figure 37 : Output Power and Drain Current versus Case Temperature



Information furnished is believed to be accurate and reliable. However, STMicroelectronics assumes no responsibility for the consequences of use of such information nor for any infringement of patents or other rights of third parties which may result from its use. No license is granted by implication or otherwise under any patent or patent rights of STMicroelectronics. Specification mentioned in this publication are subject to change without notice. This publication supersedes and replaces all information previously supplied. STMicroelectronics products are not authorized for use as critical components in life support devices or systems without express written approval of STMicroelectronics.

The ST logo is a registered trademark of STMicroelectronics  
© 1998 STMicroelectronics – Printed in Italy – All Rights Reserved

STMicroelectronics GROUP OF COMPANIES

Australia - Brazil - Canada - China - France - Germany - Italy - Japan - Korea - Malaysia - Malta - Mexico - Morocco - The Netherlands -  
Singapore - Spain - Sweden - Switzerland - Taiwan - Thailand - United Kingdom - U.S.A.  
<http://www.st.com>

