

BIPOLAR ANALOG INTEGRATED CIRCUIT

μ PC2002

5.4W AUDIO FREQUENCY POWER AMPLIFIER

DISCRIPTION

The μ PC2002 is a silicon monolithic integrated circuit designed for use as an audio frequency power amplifier in a car radio and a car stereo.

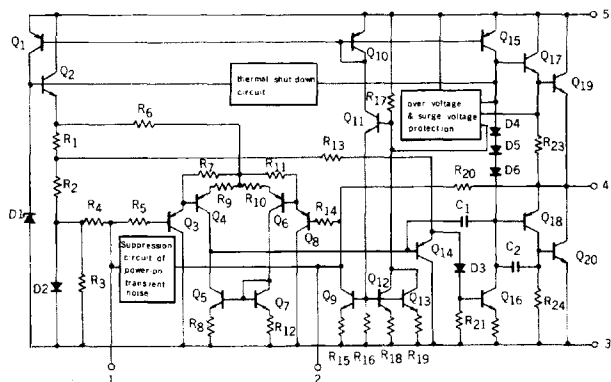
The device is packaged in five lead plastic power package, and designed for driving low impedance loads (down to 1.6Ω).

In addition, the device provides built-in protection against short circuit, over voltage and surge voltage of power supply.

FEATURES

- High output power. :
 $P_o = 5.4\text{ W}$ (at $R_L = 4\Omega$), $P_o = 9.0\text{ W}$ (at $R_L = 2\Omega$)
- Assembly ease and space saving.
- Low noise and low distortion. :
 $v_n = 0.6\text{ mVr.m.s.}$, T.H.D. = 0.05 %
- Low transient noise at power supply switch-on.
- Built-in over voltage and surge protection.
- Built-in short circuit protection.

EQUIVALENT CIRCUIT



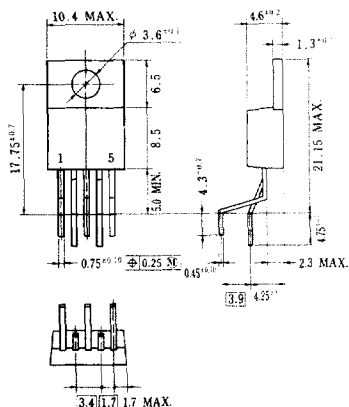
CONNECTION DIAGRAM



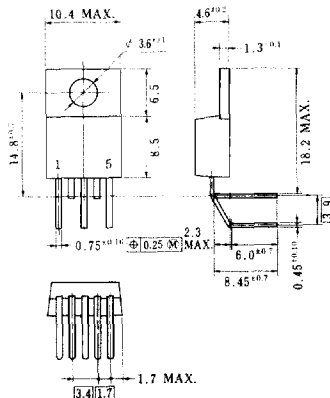
Pin No.	Electrical Connection
1	Non inverting input
2	Inverting input
3	Ground
4	Output
5	Power supply

PACKAGE DIMENSIONS (Unit: mm)

μPC2002V



μPC2002H



PSP-34002

PSP-34001

ABSOLUTE MAXIMUM RATINGS

Peak Supply Voltage (50 ms)	V_{CC1}	40	V
DC Supply Voltage (quiescent)	V_{CC2}	28	V
DC Supply Voltage (operational)	V_{CC3}	18	V
Output Peak Current (repetitive)	$I_{CC(peak)1}$	3.5	A
Output Peak Current (non repetitive)	$I_{CC(peak)2}$	4.5	A
Package Dissipation ($T_{case} = 90^{\circ}C$)	P_D	15	W
Operating Temperature	T_{opt}	-30 to 75	$^{\circ}C$
Storage Temperature	T_{stg}	-40 to 150	$^{\circ}C$

THERMAL DATA

Thermal Resistance junction-case	$R_{th(j-c)}$	4	$^{\circ}C/W$
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RECOMMENDED OPERATING CONDITION ($T_a = 25^{\circ}C$)

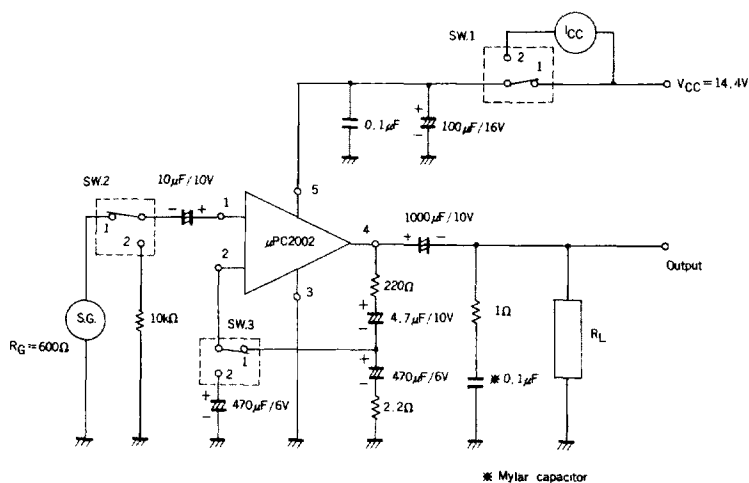
Operating Supply Voltage Range	V_{CC}	8 to 18	V
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ELECTRICAL CHARACTERISTICS

(Refer to the test circuit. : $T_a = 25^{\circ}\text{C}$, $R_L = 4\Omega$, $f = 1\text{kHz}$, using an aluminum heat sink $100 \times 100 \times 2 \text{ mm}$)

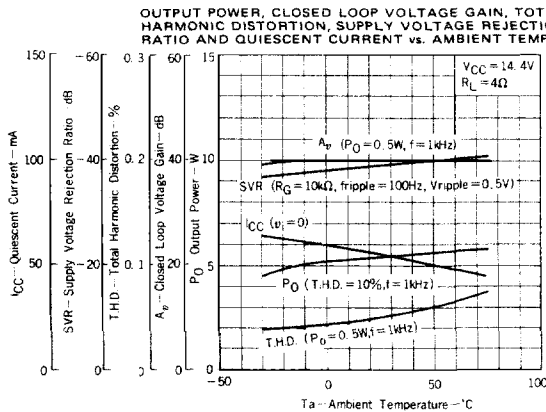
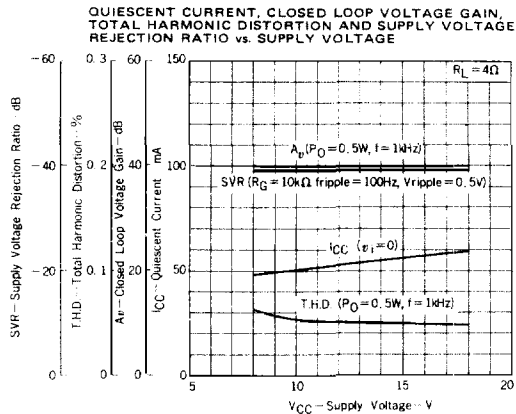
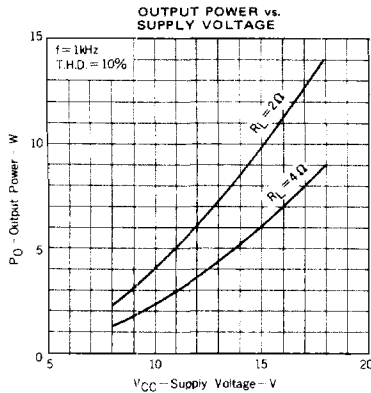
CHARACTERISTIC	SYMBOL	$V_{CC} = 14.4\text{V}$			$V_{CC} = 13.2\text{V}$	UNIT	TEST CONDITIONS
		MIN.	TYP.	MAX.	TYP.		
Quiescent Current	I_{CC}	35	55	85	54	mA	$V_i = 0$
Output Power	P_o	4.8	5.4		4.5	W	$R_L = 4\Omega$, T.H.D. = 10%
			9.0		7.5	W	$R_L = 2\Omega$, T.H.D. = 10%
Total Harmonic Distortion	T.H.D.		0.05	1.0	0.05	%	$R_L = 4\Omega$, $P_o = 0.5\text{W}$
			0.06	1.0	0.06	%	$R_L = 2\Omega$, $P_o = 1.0\text{W}$
Open Loop Voltage Gain	A_{VO}		78		78	dB	$P_o = 0.5\text{W}$
Closed Loop Voltage Gain	A_v	39.5	40	40.5	40	dB	$P_o = 0.5\text{W}$
Output Noise Voltage	V_n		0.6	3.0	0.6	mV r.m.s.	$R_G = 10\text{k}\Omega$
Input Resistance	R_i	70	150		150	$\text{k}\Omega$	
Supply Voltage Rejection Ratio	SVR	30	39		39	dB	$R_G = 10\text{k}\Omega$ $V_{\text{ripple}} = 0.5\text{V}$ $f_{\text{ripple}} = 100\text{Hz}$

TEST CIRCUIT



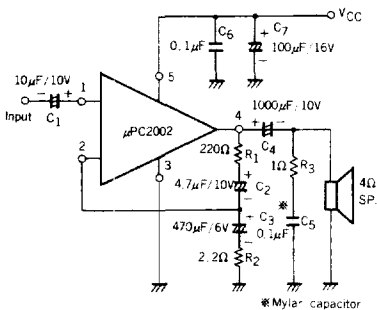
Switch position

Item SW.	I_{CC}	P_o	T.H.D.	A_{VO}	A_v	V_n	SVR
SW.1	2	1	1	1	1	1	1
SW.2	2	1	1	1	1	2	2
SW.3	1	1	1	2	1	1	1

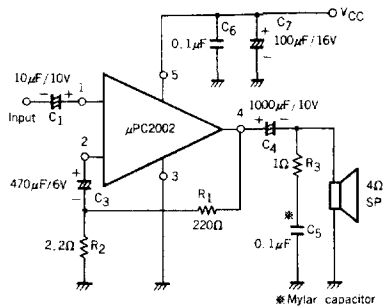


TYPICAL APPLICATIONS

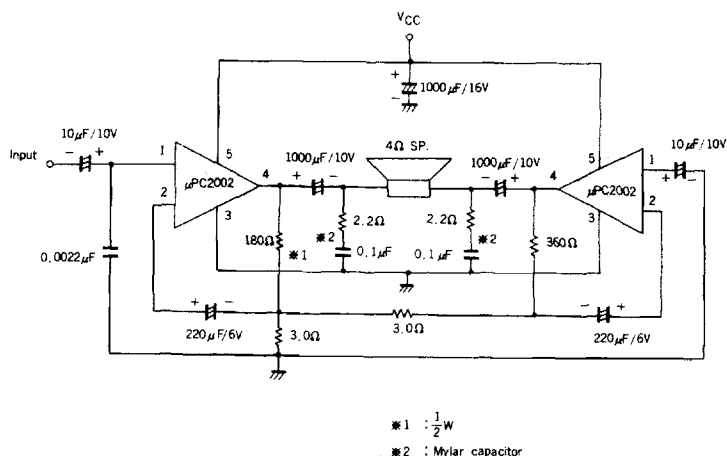
Circuit example 1.



Circuit example 2.

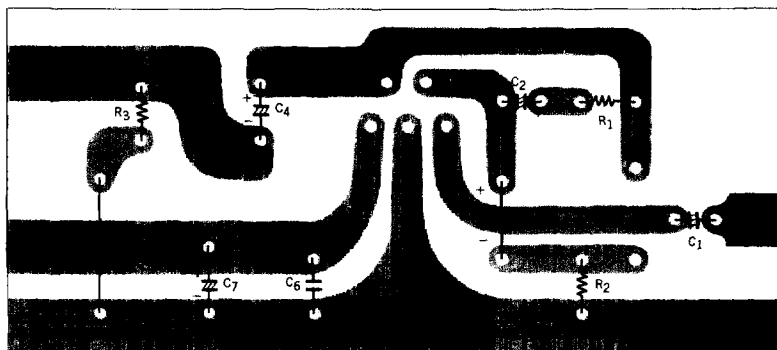


Circuit example 3. (Bridge configuration)



Typical printed circuit board and components layout for the circuit of example 1 and 2.

Bottom View



SETTING CLOSED LOOP VOLTAGE GAIN

The closed loop voltage gain (A_V) for μ PC2002 can be set up in three manners as shown in Figs. 1 to 3. Simple formulas for calculating A_V are given in Table 1.

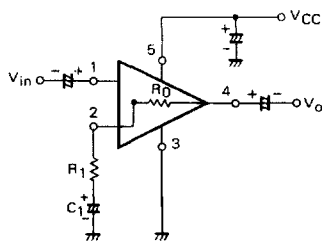


Fig. 1 Circuit A

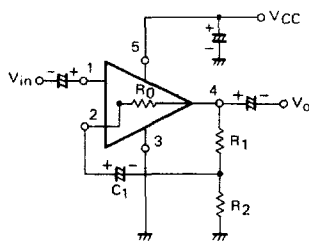


Fig. 2 Circuit B

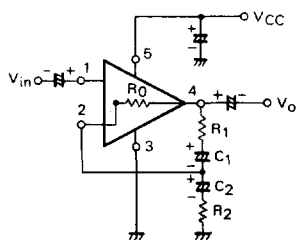


Fig. 3 Circuit C

Table 1 Simple Formulas for Calculating Closed Loop Voltage Gain A_v

Circuit A	Circuit B	Circuit C
$A_v \doteq \frac{R_0}{\sqrt{R_1^2 + \left(\frac{1}{\omega C_1}\right)^2}}$ $\left(R_0 \gg \sqrt{R_1^2 + \left(\frac{1}{\omega C_1}\right)^2}\right)$	$A_v \doteq \frac{R_1}{R_2}$ $(R_0 \gg R_1, R_1 \gg R_2)$	$A_v \doteq \frac{\sqrt{R_1^2 + \left(\frac{1}{\omega C_1}\right)^2}}{\sqrt{R_2^2 + \left(\frac{1}{\omega C_2}\right)^2}}$ $\left(R_0 \gg \sqrt{R_1^2 + \left(\frac{1}{\omega C_1}\right)^2} \gg \sqrt{R_2^2 + \left(\frac{1}{\omega C_2}\right)^2}\right)$

(Note) The design typical value for diffused resistor R_0 built in the IC is 14.5 kΩ.

- (1) Circuit A is advantageous in that the circuit can be made up of less external parts, but disadvantageous in that the value of R_1 is high and the IC is susceptible to ripple of power source. In addition, being dependent on the feedback resistance R_0 contained in the IC, the gain disperses to a great extent.
- (2) In circuit B, the drawbacks of circuit A are eliminated. The dispersion of gain can be reduced by selecting the value of R_1 which is much lower than R_0 . In addition, it is possible to decrease the effect of power source ripple by selecting the low value of R_2 . Fig. 4 shows the closed loop voltage gain vs. frequency characteristic in the case of circuit B.
- (3) Circuit C is basically the same as circuit B. Only difference is that capacitors C_1 and C_2 are connected in series to R_1 and R_2 which determine the gain.

In order to make flat the low frequency characteristic of the gain, the resistance and capacitance should be selected so that $R_1 \cdot C_1 = R_2 \cdot C_2$. If $R_1 \cdot C_1 < R_2 \cdot C_2$, it is possible to correct the decrease of gain in low frequency.

Fig. 5 shows the closed loop voltage gain vs. frequency characteristic in the case of circuit C.

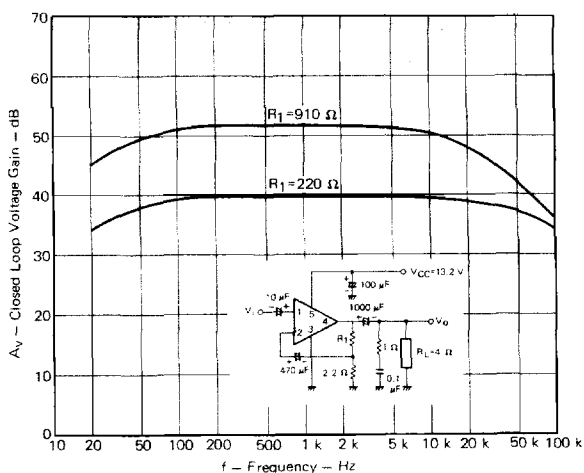


Fig. 4 Closed Loop Voltage Gain vs. Frequency Characteristic

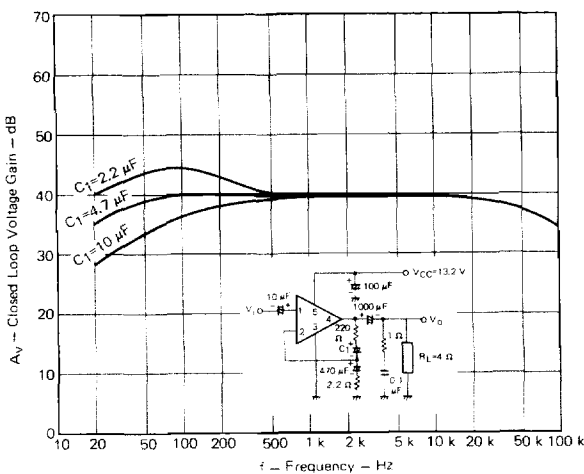


Fig. 5 Closed Loop Voltage Gain vs. Frequency Characteristic

VOLTAGE GAIN VS. FREQUENCY CHARACTERISTIC

Fig. 6 shows the voltage gain vs. frequency characteristic of μPC2002. The open loop voltage gain (A_{VO}) of low frequency is determined by capacitance $C_1 = 470 \mu F$ and IC-contained feedback resistance R_O . A_{VO} of high frequency is determined by the phase compensation constant.

Lower and higher cut-off frequencies in circuit B (mentioned in Section 1) are described below.

(1) Lower cut-off frequency (f_L)

This frequency is determined by the time constants of the following three combinations.

- Input DC decoupling capacitance ($10 \mu F$) and IC input resistance ($150 k\Omega$ typ).
- External capacitance ($470 \mu F$) and IC-contained feedback resistance R_O ($14.5 k\Omega$ typ).
- Output DC decoupling capacitance ($1000 \mu F$) and load resistance R_L (4Ω)

The time constants of (a) and (b) are negligibly great as compared with that of (c). Thus, f_L (-3 dB point) can be expressed by equation (1).

$$f_L = \frac{1}{2\pi \cdot C_O \cdot R_L} \text{ (Hz)} \quad (1)$$

C_O : Output DC decoupling capacitance

R_L : Load resistance

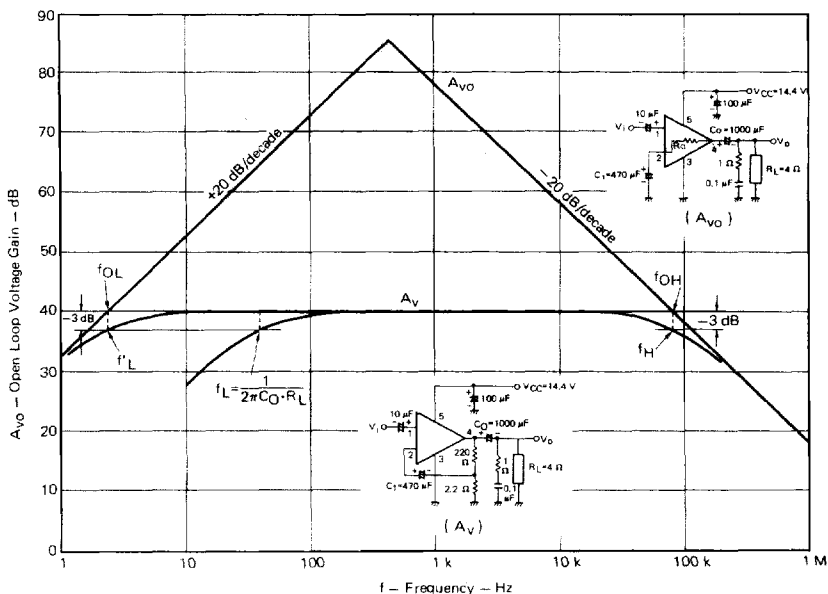


Fig. 6 Voltage Gain vs. Frequency Characteristic

(2) Higher cut-off frequency f_H

This frequency is determined by the area of -20 dB/decade of A_{VO} . This area is determined by the phase compensating constant in the IC, and the slope of voltage gain is constant.

In general, the frequency characteristic of the closed loop voltage gain (A_V) is expressed by equation (2).

$$A_V(f) = A_V \cdot \frac{1}{1 + j \frac{f}{f_{OH}}} \cdot \frac{1}{1 - j \frac{f_{OL}}{f}} \quad \dots\dots\dots (2)$$

f_{OH} : High frequency at which A_{VO} equals A_V .

f_{OL} : Low frequency at which A_{VO} equals A_V .

It follows from equation (2) that the higher cut-off frequency f_H (-3 dB point) is frequency f_{OH} at which A_{VO} equals A_V . The f_{OH} is dependent on the dispersion of A_{VO} .

(3) In the case where band limiting circuit is used

Conceivable for S/N improvement is the band limiting circuit employing resistance R_X and capacitance C_X .

This circuit has the higher cut-off frequency f'_H (-3 dB point) represented by equation (3).

$$f'_H = \frac{1}{2\pi \cdot C_X \cdot R_1} \quad \dots\dots\dots (3) \quad (\text{where } f'_H \ll f_{OH})$$

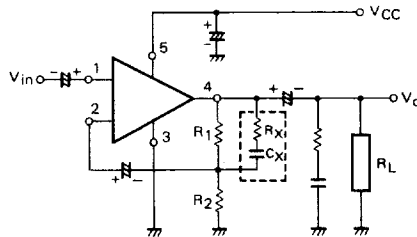


Fig. 7 Band Limiting Circuit

Resistance R_X is intended to prevent the oscillation due to excess phase rotation of feedback circuit. It should be set up at about 20 times of R_2 .

EFFECT OF POWER SUPPLY RIPPLE

Fig. 8 shows a part of equivalent circuit of μ PC2002.

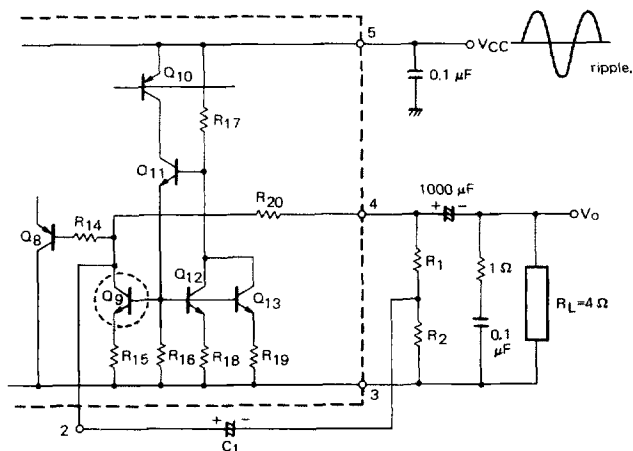


Fig. 8 Part of Equivalent Circuit of μ PC2002

The stability of the amplifier against power source ripple is expressed by the supply voltage rejection ratio (SVR). This is defined by the ratio in dB of the ripple voltage (including noise voltage) that appears at the output terminal of the amplifier, to the ripple voltage on the source line.

SVR is greatly dependent on C_1 and R_2 connected between the #2 terminal and the #3 terminal (GND) and the closed loop voltage gain. In Fig. 8, the lower the impedance of C_1 and R_2 which are the load of transistor Q_9 , the smaller the fluctuation of the initial differential amplifier (base of transistor Q_9) and the fluctuation of the output terminal. In designing the gain, C_1 and R_2 should be selected in the ranges of 220 to 470 μ F and 1 to 3 Ω , respectively.

Fig. 9 shows the relation of SVR and C_1 , and Fig. 10 shows the relation of SVR and R_1 . Fig. 11 shows the frequency characteristic of SVR.

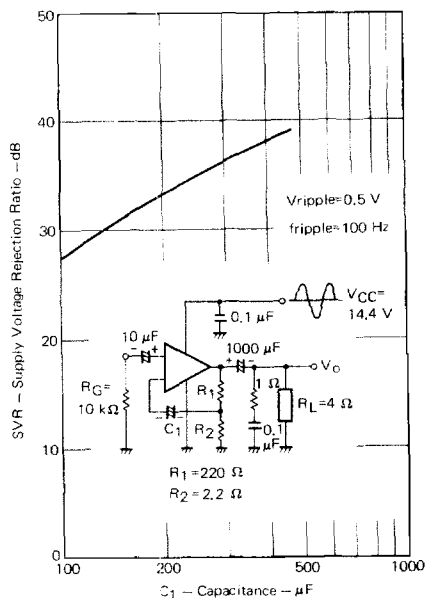


Fig. 9 Relation between SVR and C_1

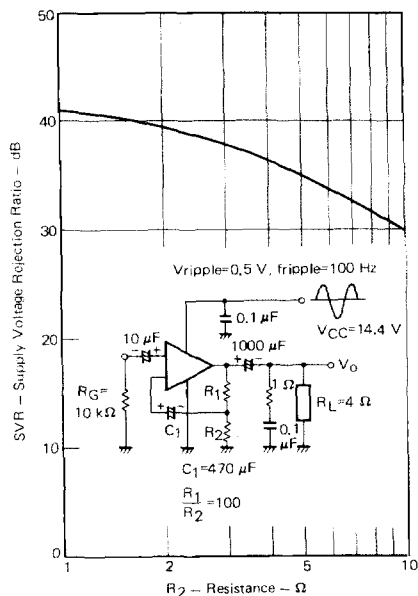


Fig. 10 Relation between SVR and R_2

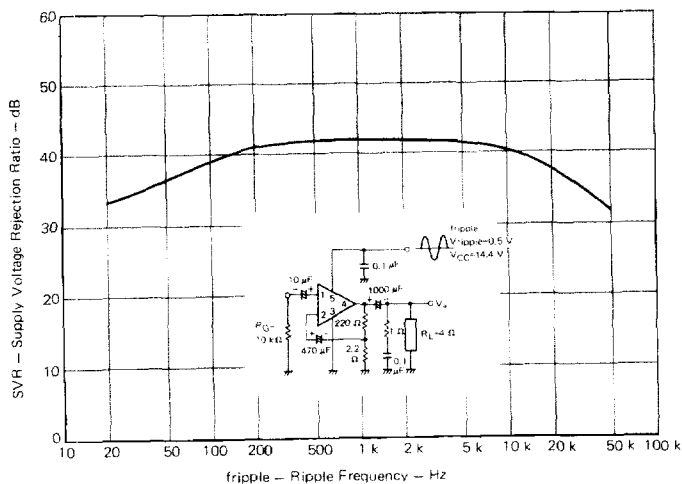


Fig. 11 SVRR Frequency Characteristic

POP VOLTAGE AND OUTPUT SIGNAL RISE TIME

μ PC2002 contains the circuit, as shown in Fig. 12, to suppress the pop voltage which occurs when power source is turned on. When power source is turned on, the capacitance connected to the #1 and #2 terminals are charged quickly so that the voltage of the #2 terminal is higher than that of the #1 terminal. This suppresses an abrupt rise of output terminal voltage, and thus suppresses a pop voltage.

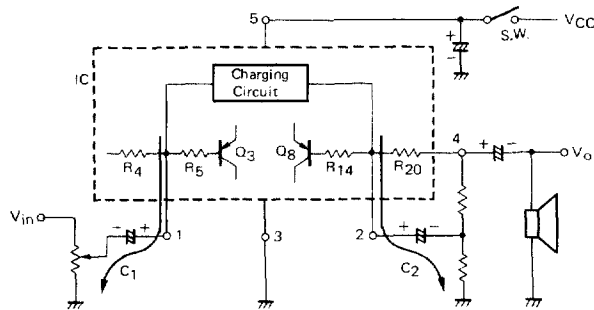


Fig. 12 Circuit to Suppress Pop Voltage

Fig. 13 shows the transient characteristic of each voltage at the #1, #2, and #4 terminals and the rising characteristic of output signal at the time when the power supply is turned on.

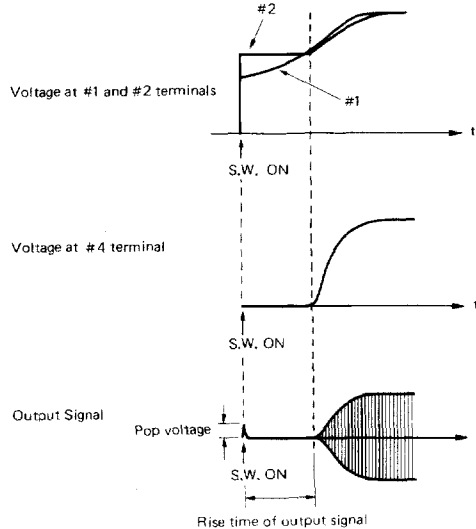


Fig. 13 Transient Characteristic of Each Voltage at The #1, #2, and #4 Terminals and Rising Characteristic of Output Signal

The pop voltage at the time when the power supply is turned on, is dependent on capacitance C_1 and C_2 connected to the #1 and #2 terminals. To keep the pop voltage lower than 1.0 V, C_1 should be 4.7 to 10 μF . Fig. 14 shows the relation between pop voltage and C_1 , C_2 .

As shown in Fig. 13, the voltage at the #4 terminal rises and the output signal rises when the voltages at the #1 and #2 terminals becomes equal after the power has been turned on. The rise time of the output signal is dependent on the capacitance C_1 connected to the #1 terminal and the time constant of input resistance of the IC. If C_1 of 10 μF is used for μPC2002, the typical rise time of output signal is about 0.6 second.

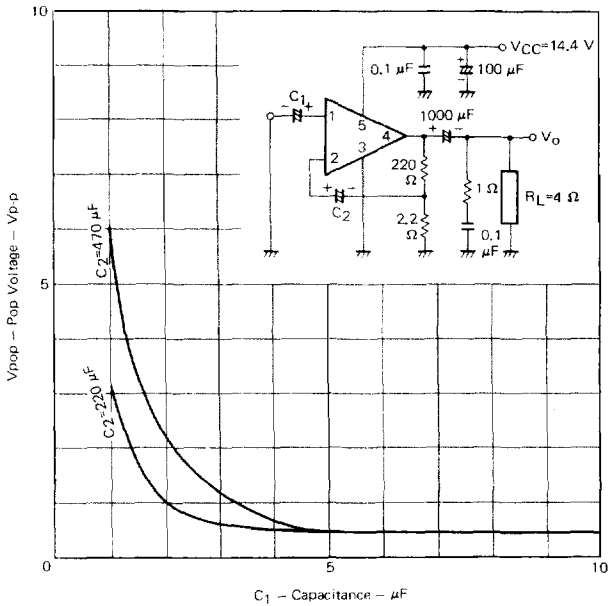


Fig. 14 Relation between Pop Voltage and Capacitance C_1 , C_2

PROTECTION CIRCUIT

μ PC2002 contains protection circuits which protect the device from anomaly such as impression of over-voltage and surge voltage of power supply and load short-circuit.

(1) Protection circuit against overvoltage and surge voltage of power supply

When an overvoltage or surge voltage higher than 21 V is applied across power supply and GND (#5 terminal and #3 terminal), the built-in protection circuit works to cut off the power transistor and bias circuit completely. When the supply voltage returns to a normal voltage lower than 18 V, the protective function is released and the normal operation is restored automatically.

The overvoltage and surge voltage of power supply that can be applied to the IC are limited due to the breakdown voltage of the power transistors in the IC. μ PC2002 is designed to withstand a surge voltage up to 40 V (pulse width 50 ms) and a DC overvoltage up to 28 V. It is anticipated that a supply surge voltage rises momentarily as high as 100 to 120 V on an automobile. Therefore, in actual use of μ PC2002, the circuit should be designed as shown in Fig. 15, in which an LC filter using a choke coil should be connected to power supply so that the voltage applied to the #5 terminal is lower than the surge voltage the IC withstands.

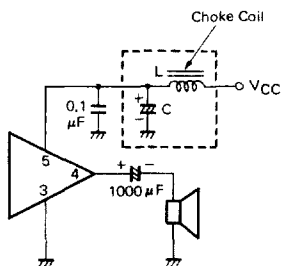


Fig. 15 LC Filter to Prevent Power Supply Surge

If a power supply surge as high as 100 to 120 V is taken into consideration, it is desirable to use an LC filter of $L = 2$ mH and $C = 1000 \mu F$.

(2) Heat detecting protection circuit (= thermal shut-down circuit)

μ PC2002 contains a thermal shut-down circuit which protects the IC from breakdown by reducing the current of the power transistor when the IC gets hot rapidly due to load short-circuit etc.

This circuit has its thermal detector near the power transistor. When the power transistor gets hotter than 175 °C, the protection circuit works to reduce the current of the power transistor and suppress the temperature rise. Although μ PC2002 is capable of operating up to the junction temperature of 150 °C, it should be operated at as low temperatures as possible to ensure high reliability.

APPLICATIONS

Fig. 16 shows an example of application circuit, and Table 2 shows the purpose and recommended values of the external parts for the application circuit.

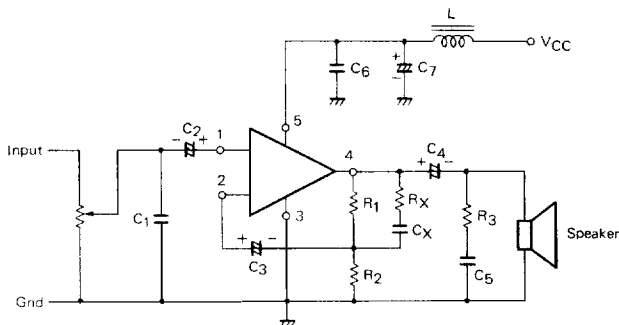


Fig. 16 Example of Application Circuit

EPILOGUE

Although μ PC2002 has been developed for use in a car radio and a car stereo, it will find use as an audio frequency amplifier in other application areas, because the operating supply voltage widely ranges from 8 to 18 V, the design of gain is easy, and the device is packaged in a small package with five leads.

Table 2 Purposes and Recommended Values of External Parts

External parts	Purpose of use	Recommended value	When smaller than recommended value	When greater than recommended value
R ₁	○ To set up voltage gain (A_v).	$\pm A_v \cdot R_2$	○ A_v goes down. ○ To be used at 100 Ω and up.	○ A_v goes up.
R ₂	○ To set up A_v. ○ To affect supply voltage rejection ratio (SVR)	2.2 Ω	○ A_v goes up.	○ A_v goes down. ○ SVR goes down.
R ₃	○ To prevent oscillation.	1 Ω	○ Apprehension to oscillate.	
R _X	○ To prevent oscillation due to excess phase rotation.	$\pm 20 \cdot R_2$	○ Apprehension to oscillate.	
C ₁	○ To prevent oscillation due to high signal source impedance.	1000 pF	○ Apprehension to oscillate in the case of high signal source impedance.	
C ₂	○ Input DC decoupling. ○ To affect output signal rise time.	10 μF	○ Output signal rise time becomes short. ○ Apprehension for making pop voltage to becomes high.	○ Output signal rise time becomes long.
C ₃	○ To reject power supply ripple.	470 μF	○ SVR goes down.	
C ₄	○ Output DC decoupling. ○ To affect lower cut-off frequency (f_L). ○ To affect the output power of low frequency.	1000 μF	○ f_L becomes high. ○ Output power at low frequency goes down.	○ f_L becomes low.
C ₅	○ To prevent oscillation.	0.1 μF (Mylar capacitor)	○ Apprehension to oscillate.	
C ₆	○ Power supply high frequency bypass. ○ To prevent oscillation.	0.1 μF	○ Apprehension to oscillate.	
C ₇	○ Power supply bypass. ○ To affect output power at low frequency.	1000 μF	○ Output power at low frequency goes down.	
C _X	○ To set up high cut-off frequency (f'_H).	$C_X = \frac{1}{2\pi \cdot R_1 \cdot f'_H}$	○ f'_H goes up.	○ f'_H goes down.
L	○ Power supply surge killer. ○ To affect output power.	2 mH	○ Effect of power supply surge killer goes down.	○ Output power goes down.