



LINEAR INTEGRATED CIRCUIT

PROGRAMMABLE TELEPHONE SPEECH CIRCUIT

The LS288 is a monolithic integrated circuit in 16 lead dual in-line plastic package. Designed as a replacement for the hybrid circuit in telephone sets it performs all the functions previously carried out by this circuit.

With the LS288 it is possible to select the operating mode (fixed or variable gain). The device works with both piezoceramic and dynamic transducers and therefore its gain, both in sending and receiving paths, can be preset by means of two external resistors. This feature can also be obtained in AGC operating mode, when the device automatically adjusts the Rx/Tx gains to compensate for the line attenuation by sensing the line current.

The LS288 can supply the decoupling FET when working with an electret microphone. Output impedance can be matched to the line independently of transducer impedance.

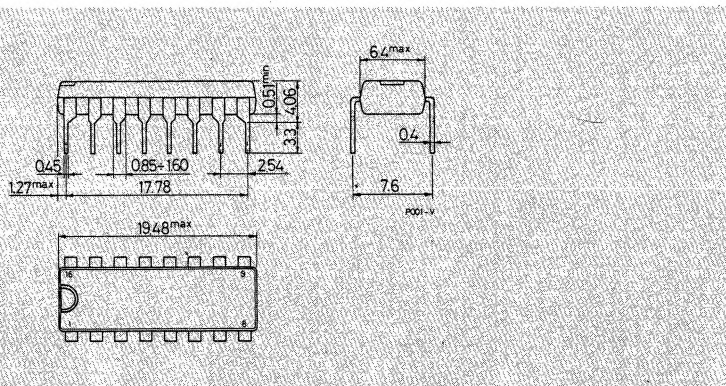
ABSOLUTE MAXIMUM RATINGS

V_L	Line voltage (3 ms pulse duration)	22	V
I_L	Forward line current	150	mA
I_L	Reverse line current	-150	mA
P_{tot}	Total power dissipation at $T_{amb} = 70^\circ\text{C}$	1	W
T_{op}	Operating temperature	-45 to 70	$^\circ\text{C}$
T_{stg}, T_j	Storage and junction temperature	-65 to 150	$^\circ\text{C}$

ORDERING NUMBER : LS288 B

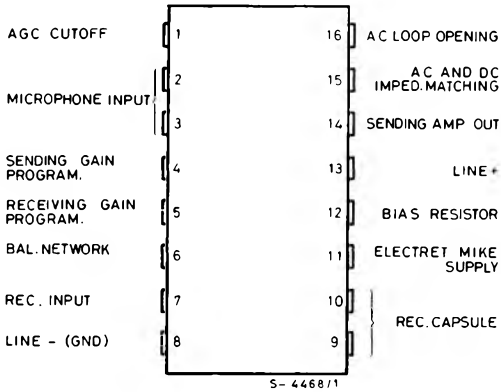
MECHANICAL DATA

Dimensions in mm

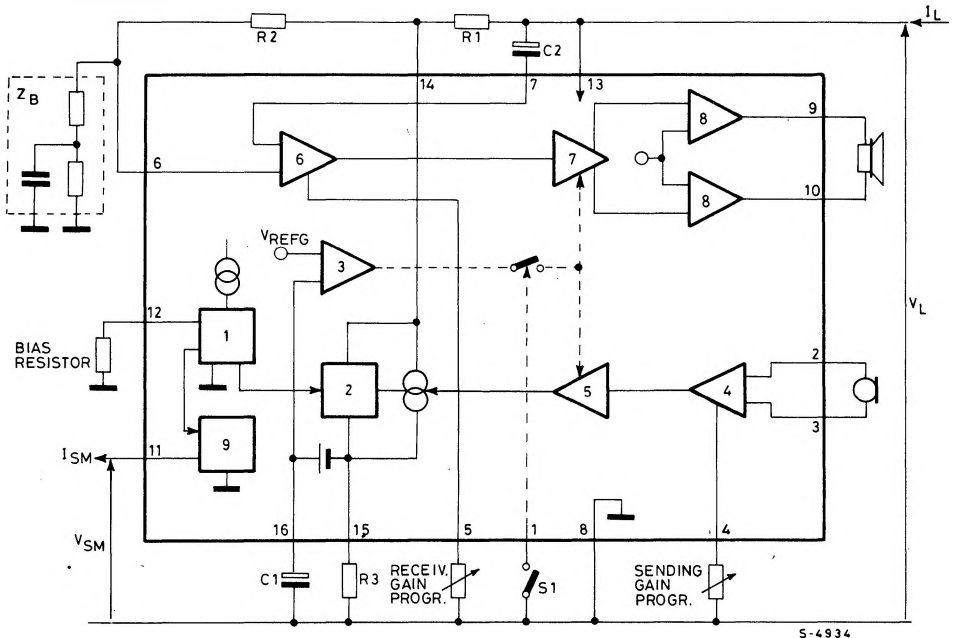


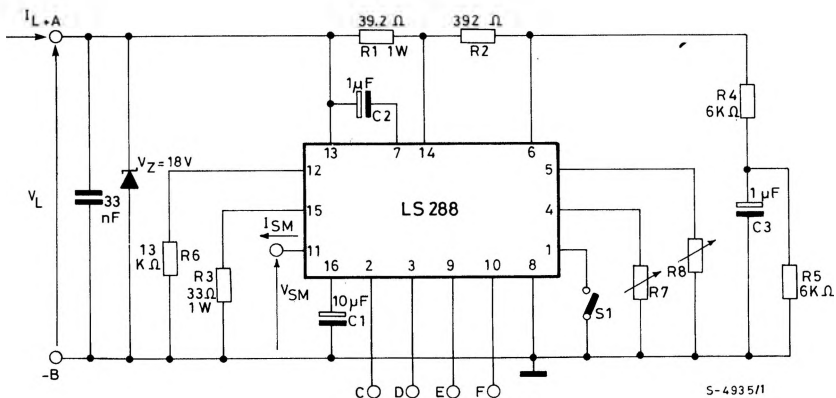
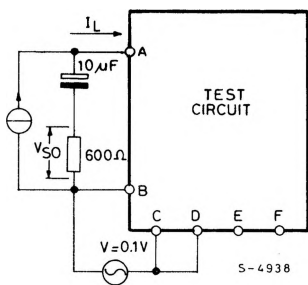
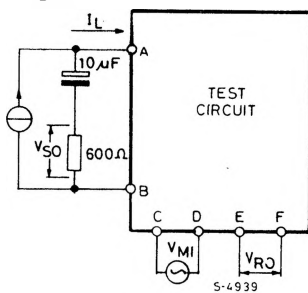
CONNECTION DIAGRAM

(top view)

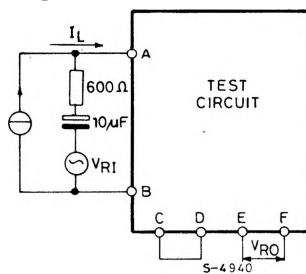


BLOCK DIAGRAM



TEST CIRCUITS
Fig. 1 - Test Circuit

Fig. 2

CMRR
Fig. 3


$$\text{Side tone} = \frac{V_{RO}}{V_{MI}} ; G_s = \frac{V_{SO}}{V_{MI}}$$

Fig. 4


$$G_R = \frac{V_{RO}}{V_{RI}}$$

THERMAL DATA
R_{th J-amb} Thermal resistance junction-ambient

max 80 °C/W

ELECTRICAL CHARACTERISTICS (Refer to the test circuits, $T_{amb} = -25$ to $+50^{\circ}\text{C}$, $f = 200$ to 3400 Hz, $I_L = 12$ to 120 mA, unless otherwise specified)

Parameter	Test conditions	Min.	Typ.	Max.	Unit	Fig.
V_L Line voltage	$T_{amb} = 25^{\circ}\text{C}$ $I_L = 15$ mA $I_L = 22$ mA $I_L = 60$ mA $I_L = 120$ mA	4.1	4.5	4.9 5.4 10 14	V	1
CMRR Common mode rejection	$f = 1$ KHz		50		dB	2
G_S Sending gain (*)	$I_L = 15$ mA $T_{amb} = 25^{\circ}\text{C}$ $f = 1$ KHz $R_8 = 17$ K Ω $V_{MI} = 3$ mV $R_7 = 8$ K Ω $R_7 = 29$ K Ω $R_7 = 47$ K Ω	40	26 41 51	42	dB	3
ΔG_S Sending gain flatness (vs. freq.)	$V_{MI} = 3$ mV $f_{ref} = 1$ KHz			± 0.5	dB	3
ΔG_S Sending gain flatness (vs. current)	$I_{Lref} = 60$ mA			± 0.5	dB	
d_S Sending distortion	$f = 1$ KHz $G_S = 42$ dB $V_{SO} = 450$ mV $V_{SO} = 775$ mV			2 5	%	3
Sending noise	$G_S = 42$ dB $V_{MI} = 0$			-72	dBmp	3
R_{2-3} Microphone input impedance pin 2-3	$V_{MI} = 3$ mV	11	15		K Ω	3
G_R Receiving gain (*)	$I_L = 15$ mA $T_{amb} = 25^{\circ}\text{C}$ $f = 1$ KHz $R_8 = 8$ K Ω $R_8 = 17$ K Ω $R_8 = 23$ K Ω $V_{RI} = 0.3$ V $R_7 = 29$ K Ω	4	-6 5 14	6	dB	4
ΔG_R Receiving gain flatness (vs. freq.)	$V_{RI} = 0.3$ V $f_{ref} = 1$ KHz			± 0.5	dB	4
ΔG_R Receiving gain flatness (vs. current)	$I_{Lref} = 60$ mA			± 0.5	dB	
d_R Receiving distortion	$f = 1$ KHz $G_R = -3$ dB $V_{RI} = 570$ mV $V_{RI} = 1.2$ V			2 5	%	4
Receiving noise	$G_R = 0$ dB $V_{RI} = 0$		250		μ V	4
R_{9-10} Receiver output impedance (pin 9 and 10)	$V_{RO} = 50$ mV		20		Ω	4
Sidetone	$f = 1$ KHz $G_S = 42$ dB $G_R = -3$ dB		15		dB	3
Z_{ML} Line matching impedance	$V_{RI} = 0.3$ V $f = 1$ KHz	650	750	850	Ω	4
Max receiving output (click suppressor)	$V_{RI} = 2$ V $G_R = 0$ dB		2.3		V _p	4
V_{SM} Microphone supply voltage (pin 11)	$I_{SM} = 0.8$ mA	1.9		2.1	V	1

(*) The sending and receiving gains are not completely independent but the variation in sending gain over the whole range of receiving gain (and vice-versa) is less than 0.5 dB.



LS200

ELECTRICAL CHARACTERISTICS (continued)

Parameter	Test condition	Min.	Typ.	Max.	Unit	Fig.
-----------	----------------	------	------	------	------	------

AGC on (pin 1 grounded)

ΔG_S and ΔG_R	Sending and receiving gain variation (**)	$T_{amb} = 25^\circ C$ $f = 1 KHz$	$I_L = 25 mA$ $I_L = 50 mA$ $I_L = 110 mA$	-1 -6 -7	+1 -4 -5	dB	3-4
-------------------------------	---	---------------------------------------	--	----------------	----------------	----	-----

(**) Referred to any value fixed by means of R_7 and R_8 .

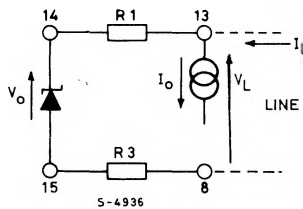
CIRCUIT DESCRIPTION

1. DC Characteristic

In accordance with CCITT recommendations, any device connected to a telephone line must exhibit a proper DC characteristic V_L, I_L .

The DC characteristics of the LS288 is determined by the shunt regulator (block 2) together with two series resistors R_1 and R_3 (see the block diagram). The equivalent circuit is shown in fig. 5.

Fig. 5 - Equivalent DC load to the line



A fixed amount, I_o , of the total available current, I_L , is drained to allow the circuit to operate correctly. The value of I_o can be programmed externally by changing the value of the bias resistor connected to pin 12.

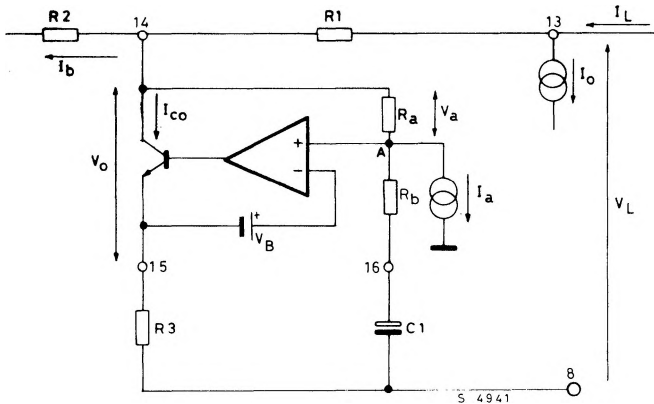
CIRCUIT DESCRIPTION (continued)

The recommended minimum value of I_o is 7.5 mA with R pin 12 = 13 K Ω .

The voltage $V_o \cong 3.8V$ of the shunt regulator is independent of the line current.

The shunt regulator (block 2) is controlled by a temperature compensated voltage reference (block 1). Fig. 6 shows a more detailed circuit configuration of the shunt regulator.

Fig. 6 - Circuit configuration of the shunt regulator



The difference $I_L - I_o$ flows through the shunt regulator since I_b is negligible.

I_a is an internal constant current generator; hence $V_o = V_B + I_a \cdot R_a = 3.8V$.

The V_L, I_L characteristic of the device is therefore similar to a pure resistance in series with a battery. It is important to note that the DC voltage at pin 16 is proportional to the line current $V_{16} = V_{15} + V_B = (I_L - I_o) R_3 + V_B$.

2. Two to four wires conversion

The LS288 performs the two wire (line) to four wire (microphone, earphone) conversion by means of a Wheatstone bridge configuration thus obtaining the proper decoupling between sending and receiving signals (see fig. 7).

For a perfect balancing of the bridge $\frac{Z_L}{Z_B} = \frac{R_1}{R_2}$

The AC signal from the microphone is sent to one diagonal of the bridge (pin 8 and 14). A small percentage of the signal power is lost on Z_B (since $Z_B \gg Z_L$); the main part is sent to the line via R_1 .

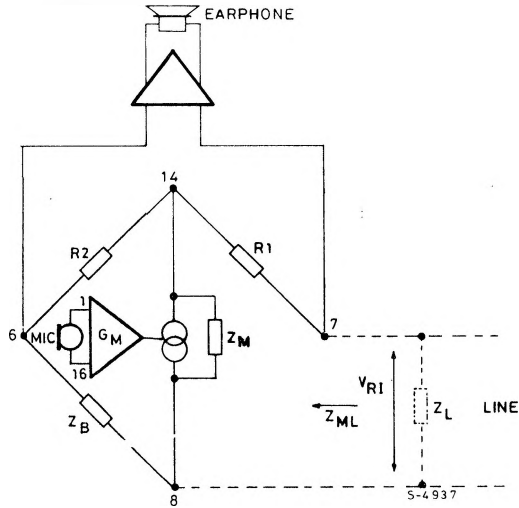
In receiving mode, the AC signal coming from the line is sensed across the second diagonal of the bridge (pin 6 and 7). After amplification it is applied to the receiving capsule.

The impedance Z_M is simulated by the shunt regulator which also acts as a transconductance amplifier for the transmission signal.

The impedance Z_M is defined as $\frac{\Delta V_{(14-8)}}{\Delta I_{(14-8)}}$.

CIRCUIT DESCRIPTION (continued)

Fig. 7 - Two to four wires conversion



From fig. 6, considering C_1 as a short circuit to the AC signal, any variation in ΔV_{14} generates a variation as follows:

$$\Delta V_{15} = \Delta V_A = \Delta V_{14} \frac{R_b}{R_a + R_b}$$

The corresponding current change is:

$$\Delta I = \frac{\Delta V_{15}}{R_3}$$

therefore

$$Z_M = \frac{\Delta V_{14}}{\Delta I} = R_3 \left(1 + \frac{R_a}{R_b} \right)$$

The total impedance across the line connections (pin 13 and 8) is given by

$$Z_{ML} = R_1 + Z_M // (R_2 + Z_B)$$

By choosing $Z_M \gg R_1$ and $Z_B \gg Z_M$

$$Z_{ML} \cong Z_M = R_3 \left(1 + \frac{R_a}{R_b} \right)$$

The amplitude of the signal received across pins 6 and 7 can be changed using different values of R_1 .

(Of course the relationship $\frac{Z_L}{Z_B} = \frac{R_1}{R_2}$ must always be valid).

The received signal is related to the value of R_1 according to the approximated relationship:

$$V_R = V_{R1} \cdot 2 \frac{R_1}{R_1 + Z_M}$$

Note that if the value of R_1 is changed the transmission signal current is not changed, since the microphone amplifier is a transconductance amplifier.

3. Input and output amplifiers

The microphone amplifier (4) has a differential input stage with high impedance (min $11 \text{ K}\Omega$) so allowing a good matching to the microphone by means of an external resistor without affecting the sending gain.

The receiving output stage (8) is intended to drive both piezoceramic and dynamic capsules. It has low output impedance, a maximum voltage swing greater than 2 V_p and a peak current of 2 mA .

With very low impedance transducers, DC decoupling by an external capacitor must be provided to prevent a large DC current flow across the transducer itself due to the receiving output stage offset.

4. Gain Control

It is possible to set the LS288 gain characteristics by means of one pin (pin 1).

When the pin 1 is floating, the gains of the sending and receiving amplifiers do not depend on the line current (AGC off). When the pin 1 is grounded the LS288 automatically changes the gain to compensate for line attenuation (AGC on).

4.1. AGC OFF

In this conditions, as already mentioned, both the sending and the receiving gain are fixed. Their values are determined, independently for the two paths, by the two external resistors R_7 (for T_x , between pin 4 and ground) and R_8 (for R_x , between pin 5 and ground). R_7 values ranging from $8 \text{ K}\Omega$ up to $50 \text{ K}\Omega$ giving sending gains from 26 dB to 51 dB . R_8 values range from $8 \text{ K}\Omega$ to $23 \text{ K}\Omega$ giving receiving gains from -6 dB to $+14 \text{ dB}$ (see fig. 9 and 10).

This allows the LS288 to be used with a variety of different transducers.

Fig. 9 - Sending gain vs. R_7 value (AGC off)

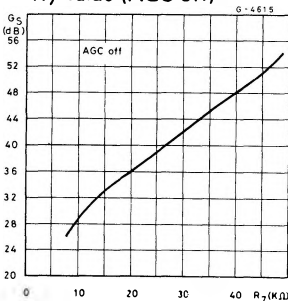
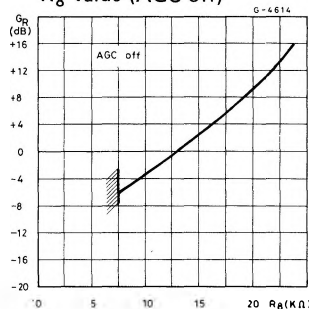


Fig. 10 - Receiving gain vs. R_8 value (AGC off)



DESCRIPTION CIRCUIT (continued)

4.2. AGC ON

Starting from any couple of gain values, fixed by the appropriate values of R_7 and R_8 , the LS288 can automatically change the sending and receiving gains depending on the line current. The line current is sensed across R_3 (see fig. 7) and transferred to pin 16 by the regulator.

$$V_{16} = V_B + V_{15} = V_B + (I_L - I_o) \cdot R_3$$

Following comparison with an internal reference V_{REFG} (see the block diagram) the voltage at pin 16 is used to modify the gain of the amplifiers (5) and (7) on both the sending and receiving paths. The starting point of the automatic level control is obtained at $I_L = 25$ mA when the drain current $I_o = 7.5$ mA.

The external resistors R_7 and R_8 fix the maximum value for the gains.

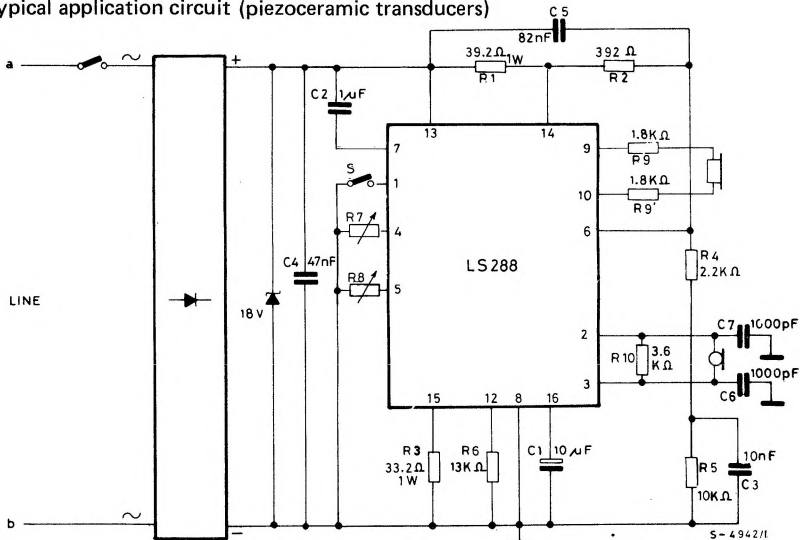
Minimum gain is reached for a line current of about 110 mA when the same drain current I_o of 7.5 mA is used.

When I_o is increased by means of the external resistor connected to pin 12 the two above mentioned line current values for the starting point and for the minimum gain increase accordingly.

5. DC Shunt Regulator

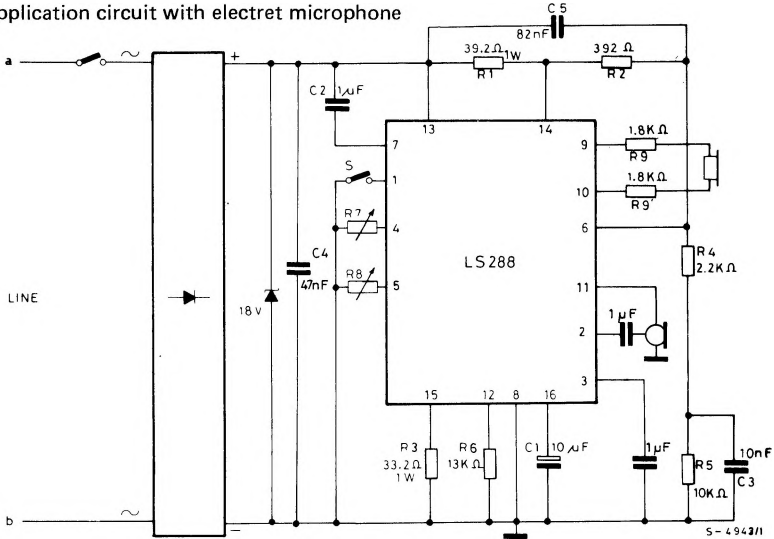
The LS288 has built into the chip a DC shunt regulator intended to supply the coupling FET when an electret microphone is used. It delivers 1 mA current with a voltage of 2 Volts (typ) regardless of the line current.

Fig. 11 - Typical application circuit (piezoceramic transducers)



CIRCUIT DESCRIPTION (continued)

Fig. 12 - Application circuit with electret microphone



The following table can be helpful to the designer when choosing different values for the external components; it refers to the typical application circuit of fig. 11.

Component	Value	Function	Note
R ₁	39.2 Ω	Bridge	R ₁ controls the receiving gain. The ratio R ₂ /R ₁ fixes the amount of signal delivered to the line. R ₁ helps in fixing the DC characteristic (see R ₃ note)
R ₂	392 Ω	Resistors	
R ₃	33.2 Ω	Line current sensing Fixing DC characteristic	The relationships involving R ₃ are: - $Z_{ML} = (25 R_3 // Z_B) + R_1$ - $G_s = K \cdot \frac{Z_L // Z_{ML}}{R_3}$ - $V_L = (I_L - I_o) (R_3 + R_1) + V_o$ [$V_o = 3.8V$] Values of Z _{ML} ranging from 650 up to 850Ω are easily obtainable.
R ₄	2.2 KΩ	Balance Network	In order to optimize the sidetone it is possible to change R ₄ and R ₅ values; in any case the following relationship applies: $\frac{Z_B}{Z_L} = \frac{R_2}{R_1}$ where $Z_B = R_4 + R_5 // X_{C3}$
R ₅	10 KΩ		

**LS 200****APPLICATION INFORMATION** (continued)

Component	Value	Function	Note
R ₆	13 K Ω	Bias Resistor	The suggested value assures the minimum operating current. It is possible to increase the supply current by decreasing R ₆ (they are inversely proportional), in order to achieve the shifting of the AGC starting point
R ₇	8 to 50 K Ω	Sending gain programming Resistor	
R ₈	8 to 23 K Ω	Receiving gain programming Resistor	
R ₉ , R _{9'}	1.8 K Ω	Receiver impedance matching	R ₉ and R _{9'} must be equal; the suggested value is good for matching to piezoceramic capsule; there is no problem in increasing and decreasing (down to 0 Ω) this value, but when low resistance levels are used DC decoupling must be inserted to stop the current due to the receiver output offset voltage (max 400 mV).
R ₁₀	4 K Ω	Microphone impedance matching	The suggested value is typical for a piezoceramic microphone, but it is possible to choose R ₁₀ from a wide range of values: $R_{\text{Mike}} = R_{10} // R_{\text{pin } 2-3}$.
C ₁	10 μ F	Regulator AC bypass	A value greater than 10 μ F gives a system start time too high for low line current. A lower value gives an alteration of the AC line impedance at low frequency.
C ₂	1 μ F	DC decoupling for receiving input	
C ₃	10 nF	Balance network	See note for R ₄ and R ₅ .
C ₄	47 nF	Matching to a capacitive line	C ₄ must be chosen according to the characteristics of the transmission line.
C ₅	82 nF	Receiving gain flatness	C ₅ depends on balancing and line impedance versus frequency.
C ₆ , C ₇	1000 pF	RF bypass	