LS288

PROGRAMMABLE TELEPHONE SPEECH CIRCUIT

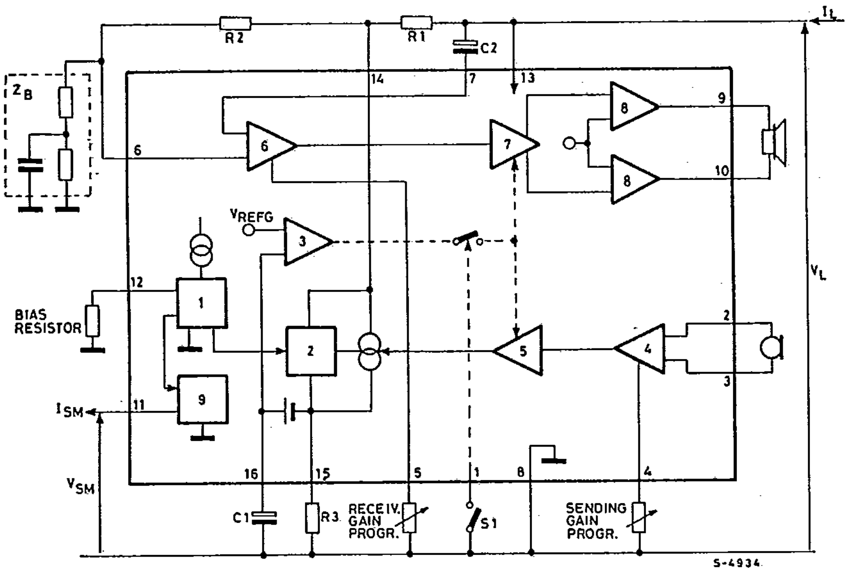
The LS288 is a monolithic integrated circuit in 16-lead dual in-line plastic package. Designed as a replacement for the hybrid circuit in telephone sets it performs all the functions previously carried out by this circuit.
With the LS288 it is possible to select the operating mode (fixed or variable 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.

DIP-16 Plastic (0.4)

ORDERING NUMBER: LS288B
LS288AB

BLOCK DIAGRAM

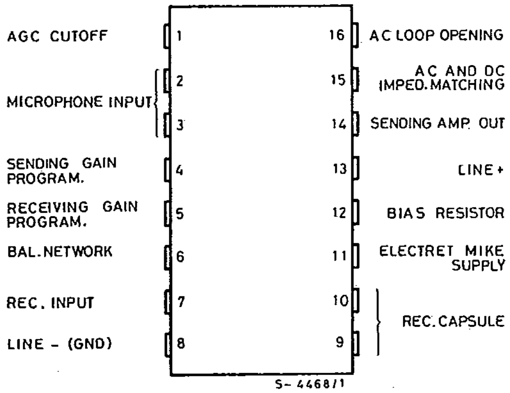


LS288

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 $T_{amb} = 70°C$	1	W
T_{op}	Operating temperature	-45 to 70	°C
T_{stg}, T_j	Storage and junction temperature	-65 to 150	°C

CONNECTION DIAGRAM
(top view)



THERMAL DATA

$R_{th\ j\text{-}amb}$	Thermal resistance junction-ambient	max	80	°C/W

TEST CIRCUITS

Fig. 1 – Test Circuit

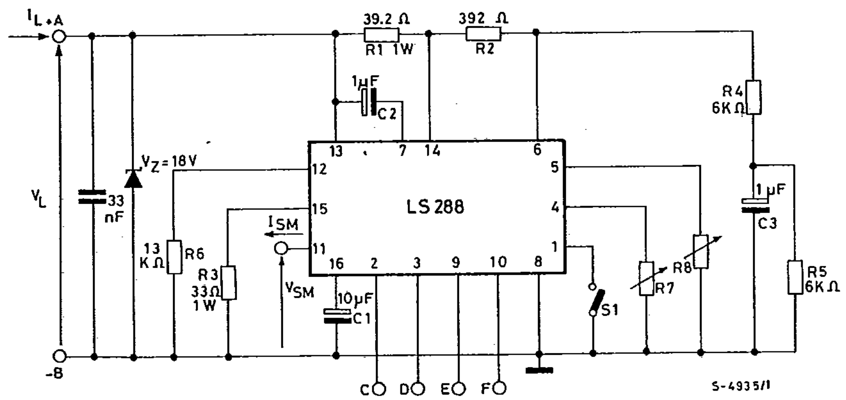
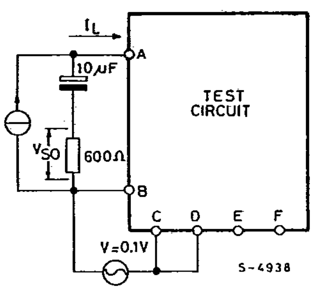
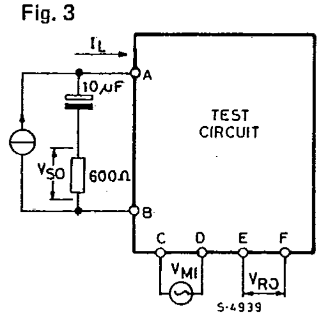


Fig. 2



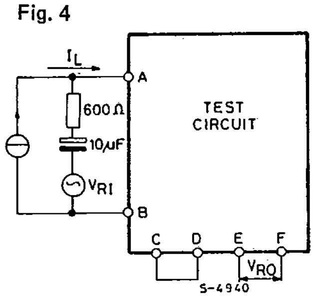
CMRR

Fig. 3



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

Fig. 4



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

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

Parameter		Test Conditions		Min	Typ	Max	Unit	Fig.
AGC off (pin 1 floating)								
V_L	Line voltage	T_{amb} = 25°C	I_L = 15mA I_L = 22mA I_L = 60mA I_L = 120mA	4.1	4.5	4.9 5.4 10 14	V	1
CMR	Common mode rejection	f = 1KHz		50			dB	2
G_S *	Sending gain (for B type)	I_L = 60mA T_{amb} = 25°C f = 1KHz R8 = 14.5KΩ V_{MI} = 2mV	R7 = 8.9KΩ R7 = 31.1KΩ	26 40.5		28 43.5	dB	3
G_S *	Sending gain (for AB type)	I_L = 60mA T_{amb} = 25°C f = 1KHz R8 = 14.5KΩ V_{MI} = 2mV	R7 = 8.9KΩ R7 = 31.1KΩ	25 40		29 44	dB	3
ΔG_S	Sending gain flatness (vs. freq.) for B type	V_{MI} = 2mV f_{ref} = 1KHz	$I_{L\ ref}$ = 60mA			± 0.5	dB	3
ΔG_S	Sending gain flatness (vs. freq.) for AB type	V_{MI} = 2mV I_{ref} = 1KHz	$I_{L\ ref}$ = 60mA			± 1	dB	3
ΔG_S	Sending gain flatness (vs. current) for B type	V_{MI} = 2mV f_{ref} = 1KHz	$I_{L\ ref}$ = 60mA			± 0.5	dB	3
ΔG_S	Sending gain flatness (vs. current) for AB type	V_{MI} = 2mV f_{ref} = 1KHz	$I_{L\ ref}$ = 60mA			± 1	dB	3
d_s	Sending distortion for B type	f = 1KHz R7 = 31.1KΩ R8 = 14.5KΩ	V_{so} = 450mV V_{so} = 775mV			2 5	%	3
d_s	Sending distortion for AB type	f = 1KHz R7 = 31.1KΩ R8 = 14.5KΩ	V_{so} = 450mV V_{so} = 775mV			4 5	%	3
	Sending noise for B type	R7 = 31.1KΩ R8 = 14.5KΩ	V_{MI} = 0 I_L = 12mA		-70		dBmp	3
R_{2-3}	Microphone input impedance pin 2-3	V_{MI} = 2mV f = 1KHz		11	16		KΩ	3
G_R *	Receiving gain for B type	I_L = 60mA T_{amb} = 25°C f = 1KHz R7 = 31.1KΩ V_{RI} = 0.3V	R8 = 14.5KΩ R8 = 17.1KΩ	0 3		2 5	dB	4
G_R *	Receiving gain for AB type	I_L 60mA T_{amb} = 25°C f = 1KHz R7 = 31.1KΩ V_{RI} = 0.3V	R8 = 14.5KΩ R8 = 17.1KΩ	-1 2		3 6	dB	4

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

ELECTRICAL CHARACTERISTICS (continued)

	Parameter	Test Conditions		Min	Typ	Max	Unit	Fig.
ΔG_R	Receiving gain flatness (vs. freq.) for B type	V_{RI} = 0.3V f_{ref} = 1KHz	$I_{L\,ref}$ = 60mA			± 0.5	dB	4
ΔG_R	Receiving gain flatness (vs freq.) for AB type	V_{RI} = 0.3V f_{ref} = 1KHz	$I_{L\,ref}$ = 60mA			± 1	dB	4
ΔG_R	Receiving gain flatness (vs. current) for B type	V_{RI} = 0.3V f_{ref} = 1KHz	$I_{L\,ref}$ = 60mA			± 0.5	dB	4
ΔG_R	Receiving gain flatness (vs. current) for AB type	V_{RI} = 0.3V f_{ref} = 1KHz	$I_{L\,ref}$ = 60mA			± 1	dB	4
d_R	Receiving distortion for B type	f = 1KHz R8 = 14.5KΩ R7 = 31.1KΩ	V_{RI} = 570mV V_{RI} = 1.1V			2 5	%	4
d_R	Receiving distortion for AB type	f = 1KHz R8 = 14.5KΩ R7 = 31.1KΩ	V_{RI} = 570mV V_{RI} = 1.1V			4 5	%	4
	Receiving noise for B type	R8 = 14.5KΩ V_{RI} = 0	I_L = 12mA R7 = 31.1KΩ		250		µV	4
R_{9-10}	Receiver output impedance (Pin 9 and 10)	V_{RO} = 50mV			30		Ω	
	Sidetone	f = 1KHz R7 = 31.1KΩ R8 = 14.5KΩ	V_{MI} = 2mV I_L = 12mA		22		dB	3
Z_{ML}	Line matching impedance	V_{RI} = 0.3V	f = 1KHz	650	750	850	Ω	4
	Max receiving output (click suppressor)	V_{RI} = 2V R8 = 14.5KΩ	I_L = 30mA R7 = 31.1KΩ		2.3		V_p	4
V_{SM}	Microphone supply voltage (Pin 11)	I_{SM} = 0.8mA		1.9		2.2	V	1

AGC on (pin 1 ground)

ΔG_S and ΔG_R **	Sending and receiving gain variation	T_{amb} = 25°C $I_{L\,ref}$ = 12mA f = 1KHz	I_L = 25mA I_L = 50mA I_L = 100mA	-1 -6 -7		1 -4 -5	dB	3-4

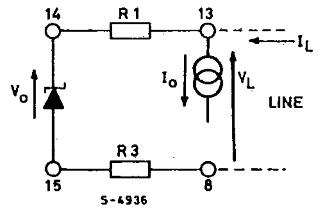
(**) Referred to any value fixed by means of R7 and R8.

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.

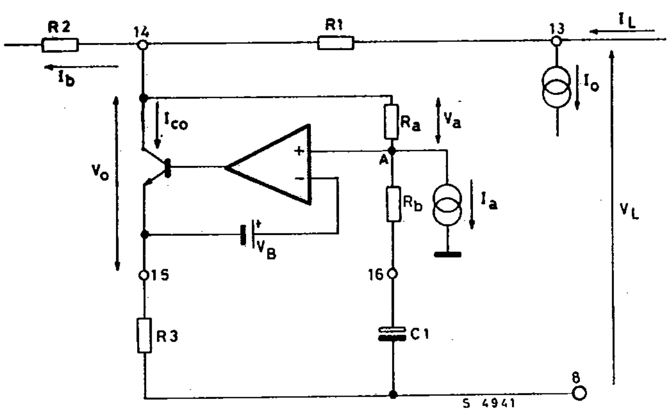
Fig. 5 – Equivalent DC load to the line



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.

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



CIRCUIT DESCRIPTION (continued)

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

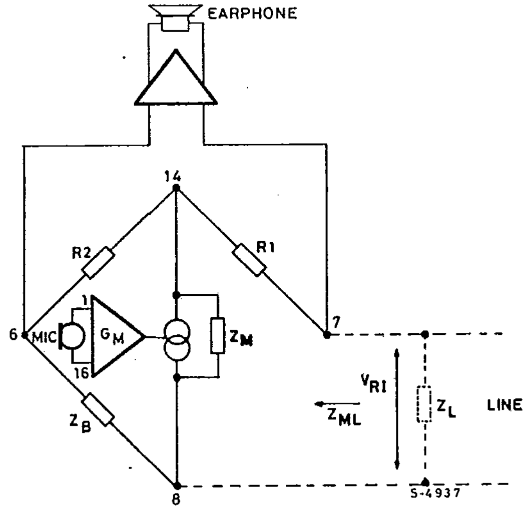
The LS288 performs the two wire (line) to four wire (microphone, earphone) conversion by means of a Wheatstone bridge configuration thus obtaining the proper decoupling between sending and receiving signals (see fig. 7).

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 $\frac{\Delta V_{(14-8)}}{\Delta I_{(14-8)}}$.

Fig. 7 - Two to four wires conversion



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CIRCUIT DESCRIPTION (continued)

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:

$$V_R = V_{RI} \, 2 \frac{R_1}{R_1 + Z_M}$$

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 KΩ) 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).

DESCRIPTION CIRCUIT (continued)

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 KΩ up to 50 KΩ giving sending gains from 26 dB to 51 dB. R_8 values range from 8 KΩ to 23 KΩ giving receiving gains from -6 dB to +14 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)

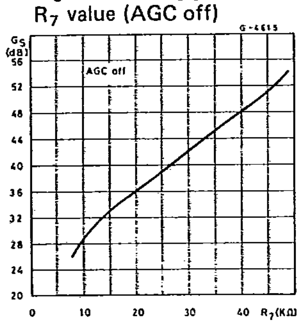
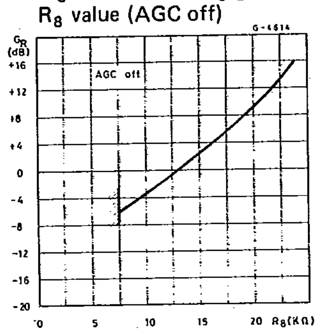


Fig. 10 – Receiving gain vs. R_8 value (AGC off)



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 mAp current with a voltage of 2 Volts (typ) regardless of the line current.

CIRCUIT DESCRIPTION (continued)

Fig. 11 - Typical application circuit (piezoceramic transducers)

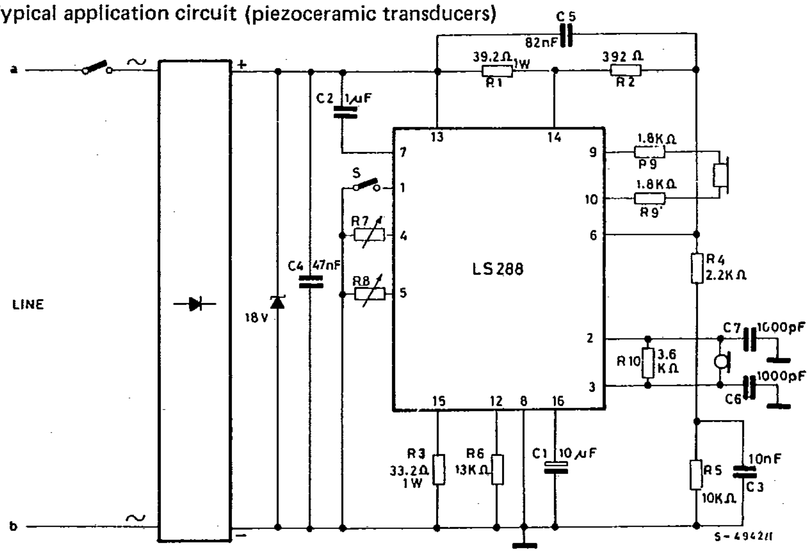
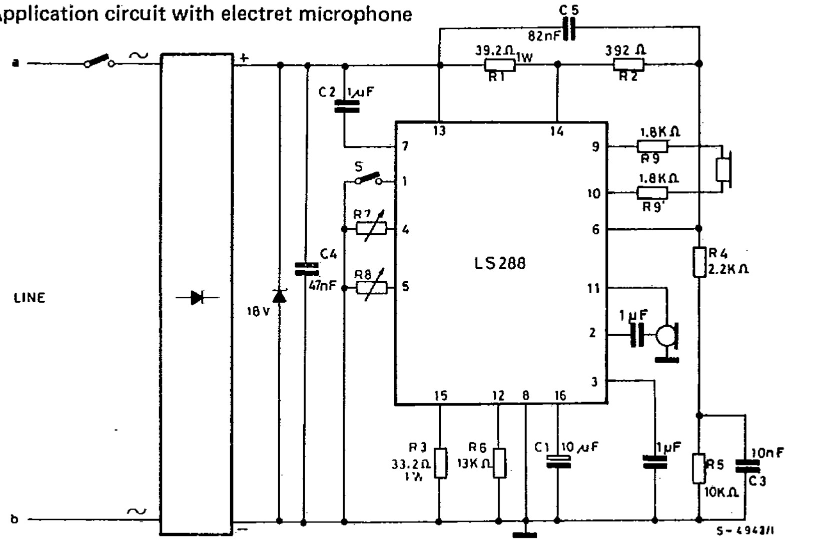


Fig. 12 - Application circuit with electret microphone



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		
R_6	13 KΩ	Bias Resistor	The suggested value assures the minimum operating current.
R_7	8 to 50 KΩ	Sending gain programming Resistor	
R_8	8 to 23 KΩ	Receiving gain programming Resistor	
R_9, R_9	1.8 KΩ	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 0Ω) 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 KΩ	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: $R_{Mike} = R_{10} // R_{pin\ 2-3}$.

APPLICATION INFORMATION (continued)

Component	Value	Function	Note
C_1	10 µF	Regulator AC bypass	A value greater than 10 µF 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 µF	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 flattness	C_5 depends on balancing and line impedance versus frequency.
C_6, C_7	1000 pF	RF bypass	