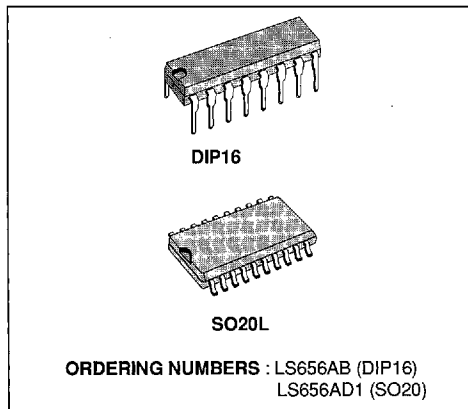


## TELEPHONE SPEECH CIRCUIT WITH MULTIFREQUENCY TONE GENERATOR INTERFACE

- PRESENTS THE PROPER DC PATH FOR THE LINE CURRENT, PARTICULAR CARE BEING PAID TO HAVE LOW VOLTAGE DROP
- HANDLES THE VOICE SIGNAL, PERFORMING THE 2/4 WIRES INTERFACE AND CHANGING THE GAIN ON BOTH SENDING AND RECEIVING AMPLIFIERS TO COMPENSATE FOR LINE ATTENUATION BY SENSING EITHER THE LINE CURRENT OR THE LINE VOLTAGE. IN ADDITION, THE LS656 CAN ALSO WORK IN FIXED GAIN MODE
- ACTS AS LINEAR INTERFACE FOR MF, SUPPLYING A STABILIZED VOLTAGE TO THE DIGITAL CHIP AND DELIVERING TO THE LINE THE MF TONES GENERATED BY THE M761

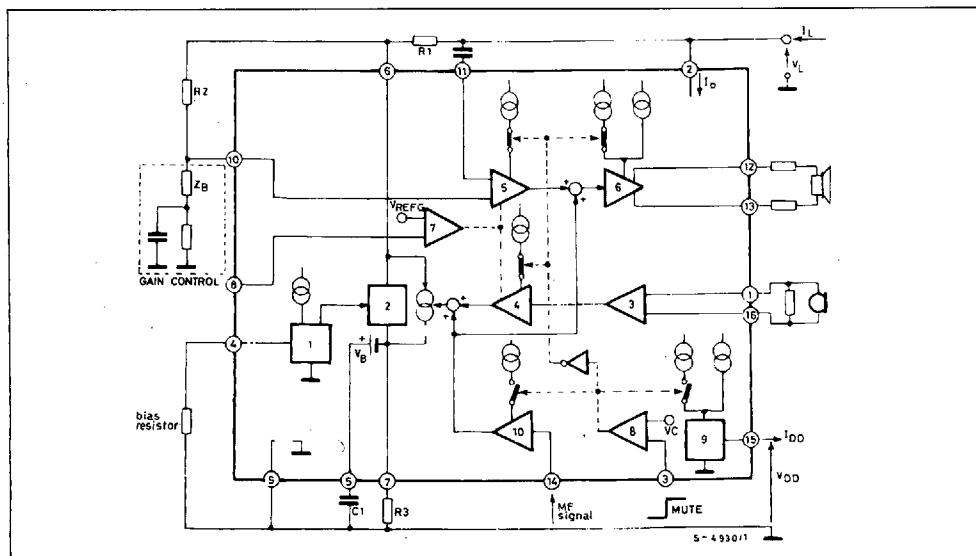


### DESCRIPTION

The LS656 is a monolithic integrated circuit in 16-lead plastic package to replace the hybrid circuit in telephone set. It works with the same type of transducers for both transmitter and receiver (typically dynamic capsules). Many of its electrical char-

acteristics can be controlled by means of external components to meet different specifications. In addition to the speech operation, the LS656 acts as an interface for the MF tone signal (particularly for M761 C/MOS frequency synthesizer).

### BLOCK DIAGRAM (DIP16)



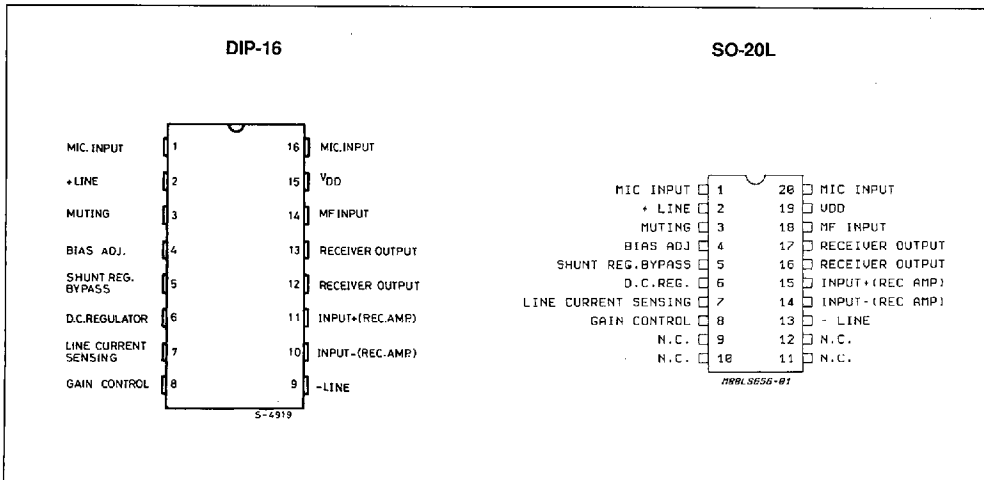
### ABSOLUTE MAXIMUM RATINGS

| Symbol         | Parameter                                                         | Value       | Unit               |
|----------------|-------------------------------------------------------------------|-------------|--------------------|
| $V_L$          | 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 $T_{amb} = 70\text{ }^{\circ}\text{C}$ | 1           | W                  |
| $T_{op}$       | Operating Temperature                                             | – 45 to 70  | $^{\circ}\text{C}$ |
| $T_{stg}, T_j$ | Storage and Junction Temperature                                  | – 65 to 150 | $^{\circ}\text{C}$ |

## THERMAL DATA

| Symbol          | Parameter                                  | Value | Unit |
|-----------------|--------------------------------------------|-------|------|
| $R_{th\ j-amb}$ | Thermal Resistance Junction-ambient<br>Max | 80    | °C/W |

### PIN CONNECTIONS (top view)



## TEST CIRCUITS

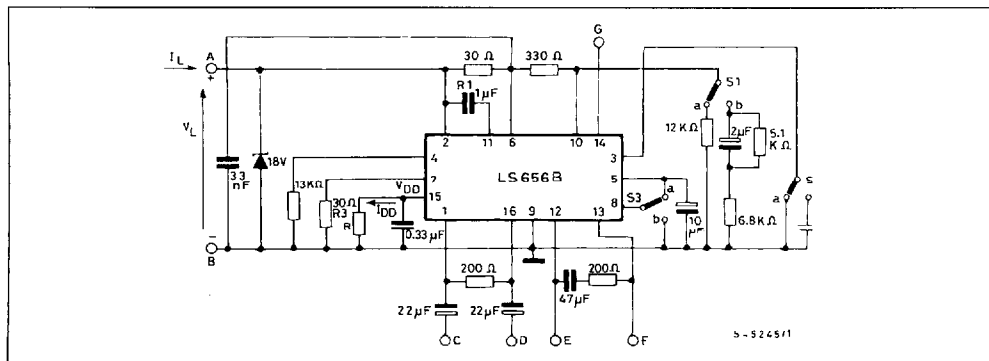


Figure 1.

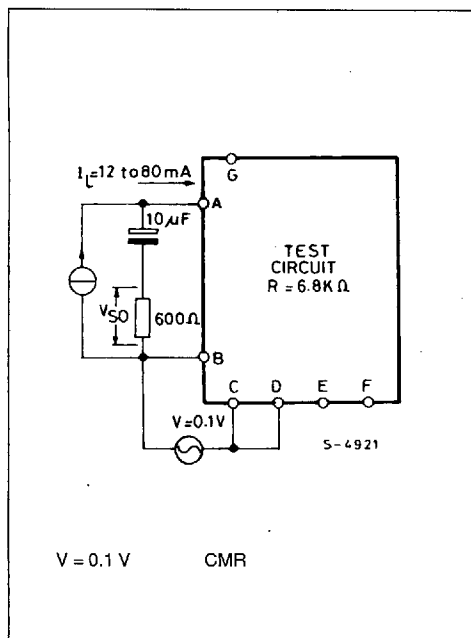


Figure 2.

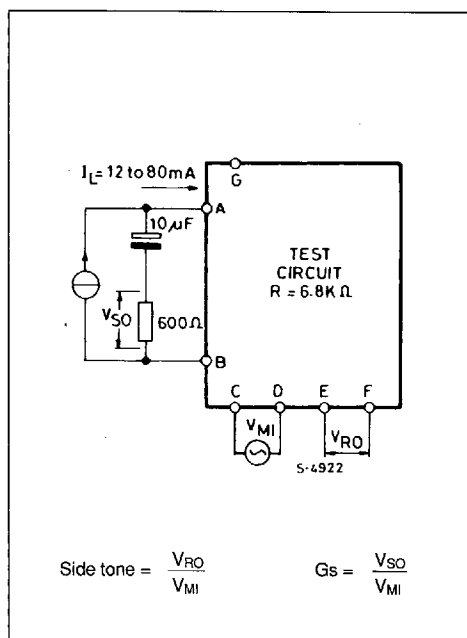


Figure 3.

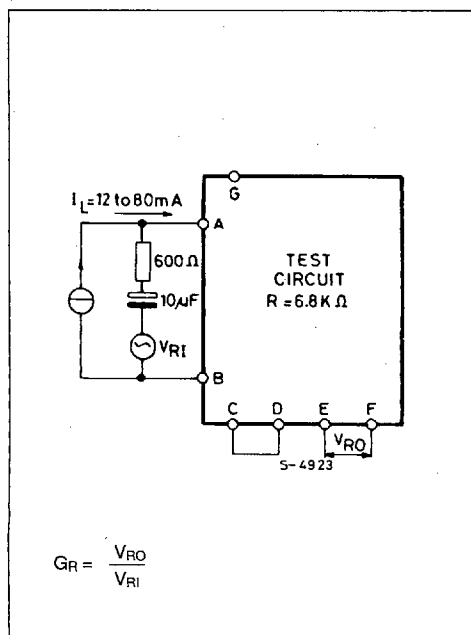
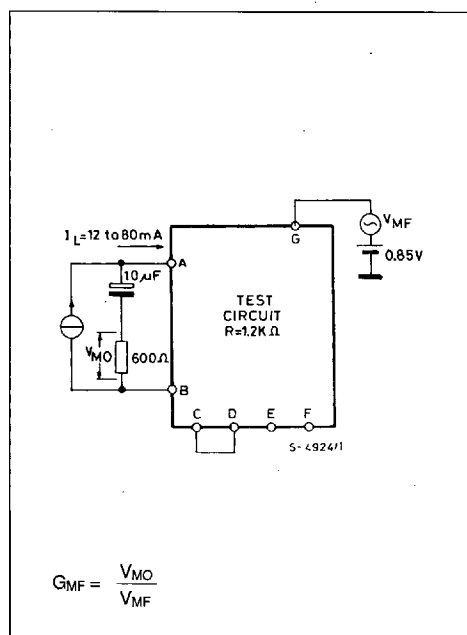


Figure 4.



**ELECTRICAL CHARACTERISTICS** (refer to the test circuits,  $V_G = 1$  to 2V,  $I_L = 12$  to 80mA, S1, S2 and S3 in (a),  $T_{amb} = -25$  to  $+50^\circ\text{C}$ ,  $f = 200$  to 3400Hz, unless otherwise specified)

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit | Fig. |
|--------|-----------|-----------------|------|------|------|------|------|
|--------|-----------|-----------------|------|------|------|------|------|

## SPEECH OPERATION

|          |                                          |                                                                                                                            |           |     |                   |               |   |
|----------|------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|-----------|-----|-------------------|---------------|---|
| $V_L$    | Line Voltage                             | $T_{amb} = 25^\circ\text{C}$<br>$I_L = 12\text{mA}$<br>$I_L = 30\text{mA}$<br>$I_L = 60\text{mA}$                          | 3.4       |     | 4.0<br>5.1<br>7.0 | V             | — |
| CMR      | Common Mode Rejection                    | $f = 1\text{kHz}$                                                                                                          | 50        |     |                   | dB            | 1 |
| $G_S$    | Sending Gain                             | $T_{amb} = 25^\circ\text{C}$ , $f = 1\text{kHz}$ ,<br>$V_{MI} = 2\text{mV}$<br>$I_L = 25\text{mA}$<br>$I_L = 50\text{mA}$  | 48<br>44  |     | 51<br>47          | dB            | 2 |
|          | Sending Gain Flatness (versus frequency) | $V_{MI} = 2\text{mV}$ , $f_{ref} = 1\text{kHz}$                                                                            | -1        |     | +1                | dB            | 2 |
|          | Sending Gain Flatness (versus current)   | $V_{MI} = 3\text{mV}$ , $I_{ref} = 50\text{mA}$ ,<br>S3 in (b)                                                             | -1        |     | +1                | dB            | 2 |
|          | Sending Distortion                       | $f = 1\text{kHz}$ , $I_L = 16\text{mA}$<br>$V_{SO} = 775\text{mV}$<br>$V_{SO} = 900\text{mV}$                              |           |     | 3<br>10           | %<br>%        | 2 |
|          | Sending Noise                            | $V_{MI} = 0\text{V}$ ; $V_G = 1\text{V}$ ; S1 in (b)                                                                       |           | -71 |                   | dBmp          | 2 |
|          | Microphone Input Impedance (pin 1-16)    | $V_{MI} = 2\text{mV}$                                                                                                      | 40        |     |                   | k $\Omega$    | — |
|          | Sending Gain in MF Operation             | $V_{MI} = 2\text{mV}$ , S2 in (b)                                                                                          | -30       |     |                   | dB            | 2 |
| $G_R$    | Receiving gain                           | $V_{RI} = 0.3\text{V}$ , $f = 1\text{kHz}$ ,<br>$T_{amb} = 25^\circ\text{C}$<br>$I_L = 25\text{mA}$<br>$I_L = 50\text{mA}$ | -6<br>-11 |     | -3<br>-8          | dB            | 3 |
|          | Receiving Gain Flatness (vs. freq.)      | $V_{RI} = 0.3\text{V}$ , $f_{ref} = 1\text{kHz}$                                                                           | -1        |     | +1                | dB            | 3 |
|          | Receiving Gain Flatness (vs. current)    | $V_{RI} = 0.3\text{V}$ , $I_{ref} = 50\text{mA}$ ,<br>S3 in (b)                                                            | -1        |     | +1                | dB            | 3 |
|          | Receiving Distortion                     | $f = 1\text{kHz}$ , $I_L = 15\text{mA}$<br>$V_{RO} = 400\text{mV}$<br>$V_{RO} = 450\text{mV}$                              |           |     | 3<br>10           | %             | 3 |
|          | Receiving Noise                          | $V_{RI} = 0\text{V}$ ; $V_G = 1\text{V}$ ; S1 in (b)                                                                       |           | 150 |                   | $\mu\text{V}$ | 3 |
|          | Receiving Output Impedance (pins 12-13)  | $V_{RO} = 50\text{mV}$                                                                                                     |           | 30  |                   | $\Omega$      | — |
|          | Sidetone                                 | $f = 1\text{kHz}$ , $T_{amb} = 25^\circ\text{C}$ ,<br>S1 in (b)                                                            |           |     | 36                | dB            | 2 |
| $Z_{ML}$ | Line Matching Impedance                  | $V_{RI} = 0.3\text{V}$ , $f = 1\text{kHz}$                                                                                 | 500       | 600 | 700               | $\Omega$      | 3 |
| $I_S$    | Input Current for Gain Control (pin 8)   |                                                                                                                            |           |     | -10               | $\mu\text{A}$ | — |

## ELECTRICAL CHARACTERISTICS (continued)

| Symbol   | Parameter                                | Test Conditions                                                       | Min.     | Typ.                | Max. | Unit          | Fig.   |
|----------|------------------------------------------|-----------------------------------------------------------------------|----------|---------------------|------|---------------|--------|
| $V_{DD}$ | MF Supply Voltage Stand by and Operation | S2 in (b)                                                             | 2.4      | 2.5                 | 2.7  | V             | —      |
| $I_{DD}$ | MF Supply Current Stand by Operation     | S2 in (b)                                                             | 0.5<br>2 |                     |      | mA<br>mA      | —<br>— |
|          | MF Amplifier Gain                        | $f_{MF\text{ in}} = 1\text{ kHz}$ , $V_{MF\text{ in}} = 80\text{ mV}$ | 15       |                     | 17   | dB            | 4      |
| $V_I$    | DC Input Voltage Level (pin 14)          | $V_{MF\text{ in}} = 80\text{ mV}$                                     |          | $V_{DD} \times 0.3$ |      | V             | —      |
| $R_I$    | Input Impedance (pin 14)                 | $V_{MF\text{ in}} = 80\text{ mV}$                                     | 60       |                     |      | k $\Omega$    | —      |
| d        | Distortion                               | $V_{MF\text{ in}} = 150\text{ mVp}$ , $I_L > 17\text{ mA}$            |          |                     | 4    | %             | 4      |
|          | Starting Delay Time                      |                                                                       |          |                     | 5    | ms            | —      |
|          | Muting Threshold Voltage (pin3)          | Speech Operation<br>MF Operation                                      | 1.6      |                     | 1    | V<br>V        | —<br>— |
|          | Muting Stand by Current (pin 3)          |                                                                       |          |                     | - 10 | $\mu\text{A}$ | —      |
|          | Muting Operating Current (pin 3)         | S2 in (b)                                                             |          |                     | + 10 | $\mu\text{A}$ | —      |

## CIRCUIT DESCRIPTION

## 1. DC Characteristic

The fig. 5 shows the DC equivalent circuit of the LS656.

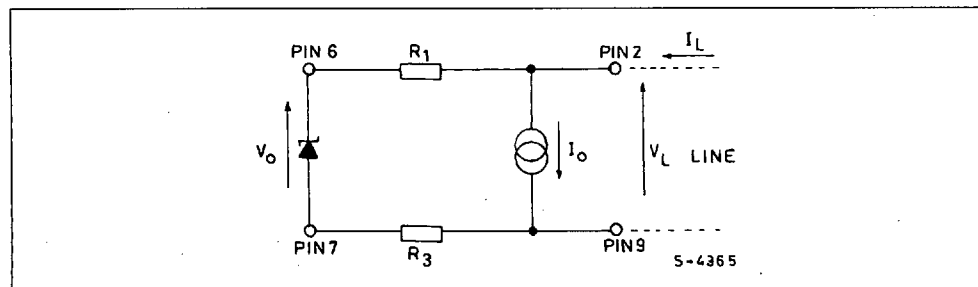
A fixed amount  $I_o$  of the total available current  $I_L$  is drained for the proper operation of the circuit. The value of  $I_o$  can be programmed externally by changing the value of the bias resistor connected to pin 4 (see block diagram).

The minimum value of  $I_o$  is 7.5 mA.

The voltage  $V_o = 37\text{ V}$  of the shunt regulator is independent of the line current.

The shunt regulator (2) is controlled by a temperature compensated voltage reference (1) (see the

Figure 5 : Equivalent DC Load to the Line.



block diagram).

Fig. 6 shows a more detailed circuit configuration of the shunt regulator.

The difference  $I_L - I_o$  flows through the shunt regulator being  $I_o$  negligible.  $I_a$  is an internal constant current generator; hence  $V_o = V_B + I_a \cdot R_a = 3.7\text{ V}$ .

The  $V_L$ ,  $I_L$  characteristic of the device is therefore similar to a pure resistance in series to a battery.

It is important to note that the DC voltage at pin 5 is proportional to the line current ( $V_5 = V_7 + V_B = (I_L - I_o) R_3 + V_B$ ).

The DC characteristic of the LS656 is shown in fig. 7.

Figure 6 : Circuit Configuration of the Shunt Regulator.

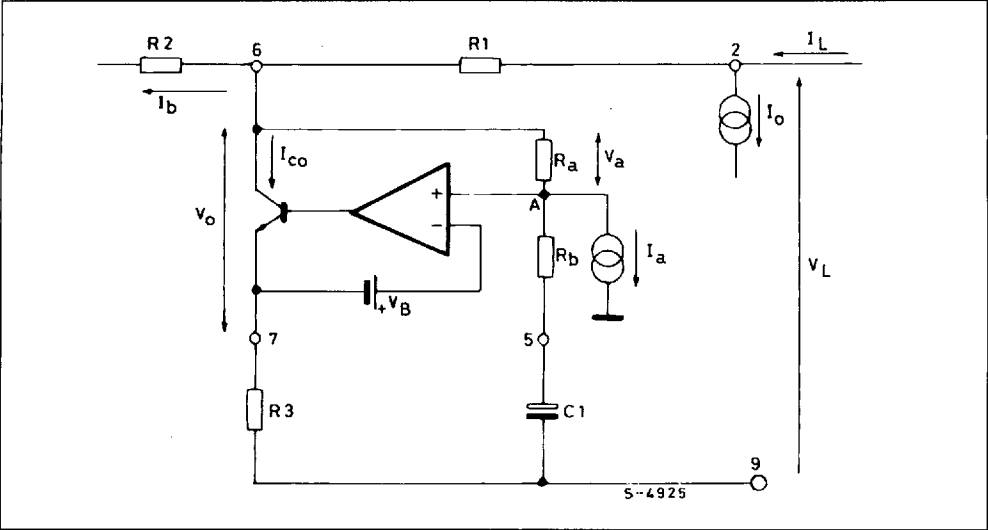
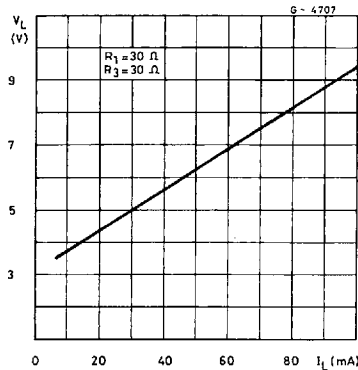


Figure 7 : DC Characteristic.



2. Two to Four Wires Conversion

The LS656 performs the two wires (line) to four wires (microphone, earphone) conversion by means of a Wheatstone bridge configuration so obtaining the proper decoupling between sending and receiving signals (see fig. 8).

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 6 and 9). A small percentage of the signal power is lost on  $Z_B$  (being  $Z_B \gg Z_L$ ); 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 11 and 10). After amplification it is applied to the receiving capsule.

The impedance  $Z_M$  is simulated by the shunt regulator that is also intended to work as a transconductance amplifier for the transmission signal.

The impedance  $Z_M$  is defined as  $\frac{\Delta V_6 - 9}{\Delta I_6 - 9}$

From fig. 6 considering  $C_1$  as a short circuit for AC signal, any variation  $\Delta V_6$  generates a variation :

$$\Delta V_7 = \Delta V_A = \Delta V_6 \cdot \frac{R_b}{R_a + R_b}$$

The corresponding current is

$$\Delta I = \frac{\Delta V_7}{R_3}$$

Therefore

$$Z_M = \frac{\Delta V_6}{\Delta I} = R_3 \left( 1 + \frac{R_a}{R_b} \right)$$

The total impedance across the line connections (pin 11 and 9) is given by

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

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

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

The received signal amplitude across pin 11 and 10 can be changed using different value of  $R_1$  (of course the relationship  $Z_L/Z_B = R_1/R_2$  must be always valid).

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

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

Note that by changing the value of  $R_1$ , the transmission signal current is not changed, being the microphone amplifier a transconductance amplifier.

### 3. Automatic Gain Control

The LS656 automatically adjusts the gain of the sending and receiving amplifiers to compensate for line attenuation.

This function is performed by the circuit of fig. 9.

The differential stage is progressively unbalanced by changing  $V_G$  in the range 1 to 2 V ( $V_{REFG}$  is an internal reference voltage, temperature compensated).

It changes the current  $I_G$ , and this current is used as a control quantity for the variable gain stages (amplifier (4) and (5) in the block diagram). The voltage  $V_G$  can be taken :

- from the LS656 itself (both in variable and in fixed mode) and.
- from a resistive divider, directly at the end of the line.

a) In the first case, connecting  $V_G$  (pin 8) to the regulator bypass (pin 5) it is possible to obtain a gain characteristic depending on the current.

In fact (see fig. 6)

$$V_5 = V_B + V_7 \approx V_B = (I_L - I_0) R_3$$

The starting point of the automatic level control is obtained at  $I_L = 25$  mA when the drain current  $I_0 = 7.5$  mA.

Minimum gain is reached for a line current of about 50 mA for the same drain current  $I_0 = 7.5$  mA. When

$I_0$  is increased by means of the external resistor connected to pin 4, the two above mentioned values of the line current for the starting point and for the minimum gain increase accordingly.

It is also possible to change the starting point without changing  $I_0$  by connecting pin 8 to the centre of a resistive divider placed between pin 5 and ground (the total resistance seen by pin 5 must be at least 100 K $\Omega$ ). In this case, the AGC range increases too; for example using a division 1 : 1 (50 K/50 K) the AGC starting point shifts to about  $I_L = 40$  mA, and the minimum gain is obtained at  $I_L = 95$  mA. In addition to this operation mode, the  $V_G$  voltage can be maintained constant thus fixing the gain value ( $R_x$ ,  $T_x$ ) independently of the line conditions.

For this purpose the  $V_{DD}$  voltage, available for supplying the MF generator, can be used.

b) When gains have to be related to the voltage at the line terminals of the telephone set, it is necessary to obtain  $V_G$  from a resistive divider directly connected to the end of the line.

This type of operation meets the requirements of the French standard. (See the application circuit of fig. 13).

### 4. Transducer Interfacing

The microphone amplifier (3) has a differential input stage with high impedance ( $\approx 40$  k $\Omega$ ) so allowing a good matching to the microphone by means of external resistor without affecting the sending gain. The receiving output stage (6) is particularly intended to drive dynamic capsules. (Low output impedance (100  $\Omega$  max) ; high current capability 3 mA).

When a piezoceramic capsule is used, it is useful to increase the receiving gain by increasing  $R_1$  value (see the relationship for  $V_R$ ).

With very low impedance transducer, 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.

### 5. Multifrequency Interfacing

The LS656 acts as a linear interface for the Multifrequency synthesizer M761 according to a logical signal (mute function) present on pin 3.

When no key of the keyboard is pressed the mute state is low and the LS656 feeds the M761 through pin 15 with low voltage and low current (standby operation of the M761). The oscillator of the M761 is not operating.

When one key is pressed, the M761 sends a "high state" mute condition to the LS656. A voltage com-

parator (8) of LS656 drives internal electronic switches ; the voltage and the current delivered by the voltage supply (9) are increased to allow the operation of the oscillator.

This extra current is diverted by the receiving and sending section of the LS656 and during this operation the receiving output stage is partially inhibited and the input stages of sending and receiving amplifiers are switched OFF.

A controlled amount of the signalling is allowed to reach the earphone to give a feedback to the subscriber ; the MF amplifier (10) delivers the dial tones to the sending paths.

The mute function can be used also when a temporary inhibition of the output signal is requested. The application circuit shown in fig. 10 fulfils the EUROPE II standard (-6, -8 dBm). If the EUROPE I levels are required (-9, -11 dBm) an external divider

Figure 8 : Two to Four Wires Conversion.

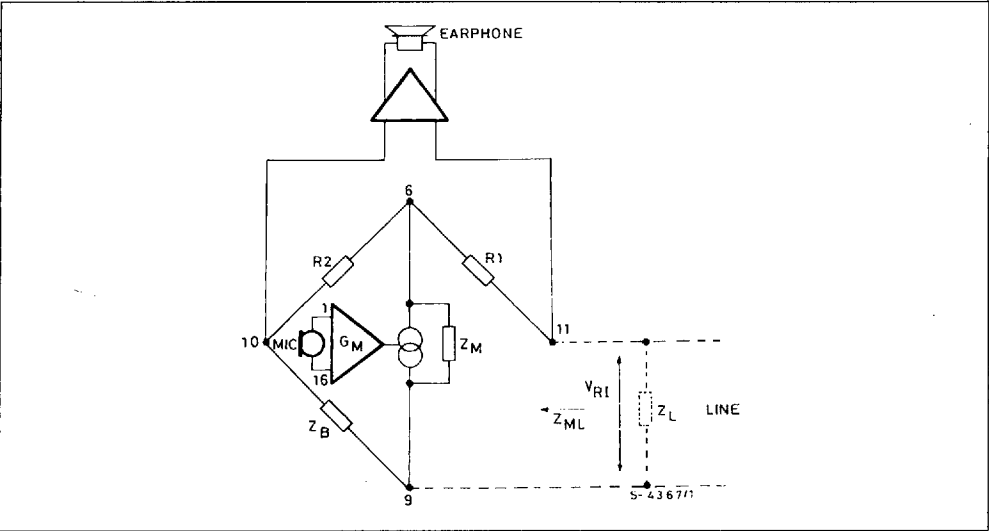
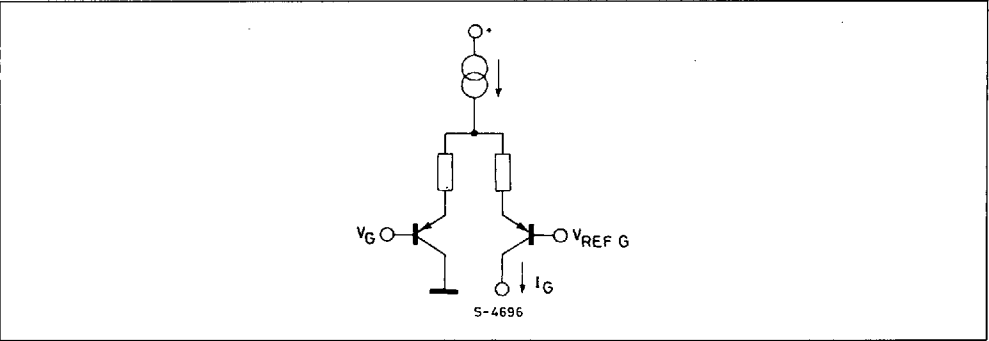


Figure 9.



## APPLICATION INFORMATION

Figure 10 : Application Circuit with Multifrequency (Europe II STD).

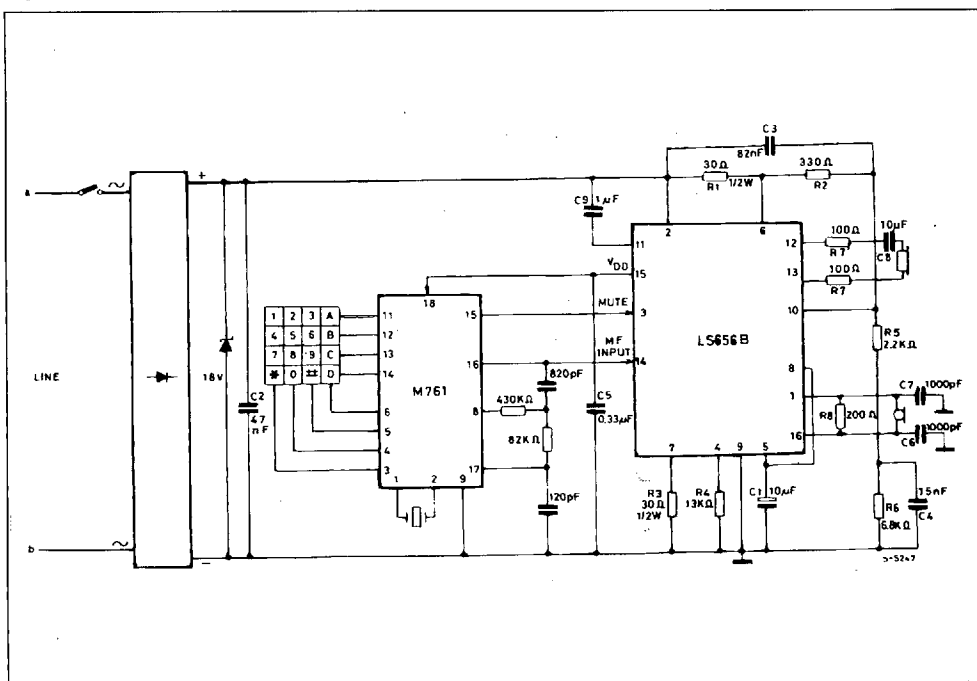
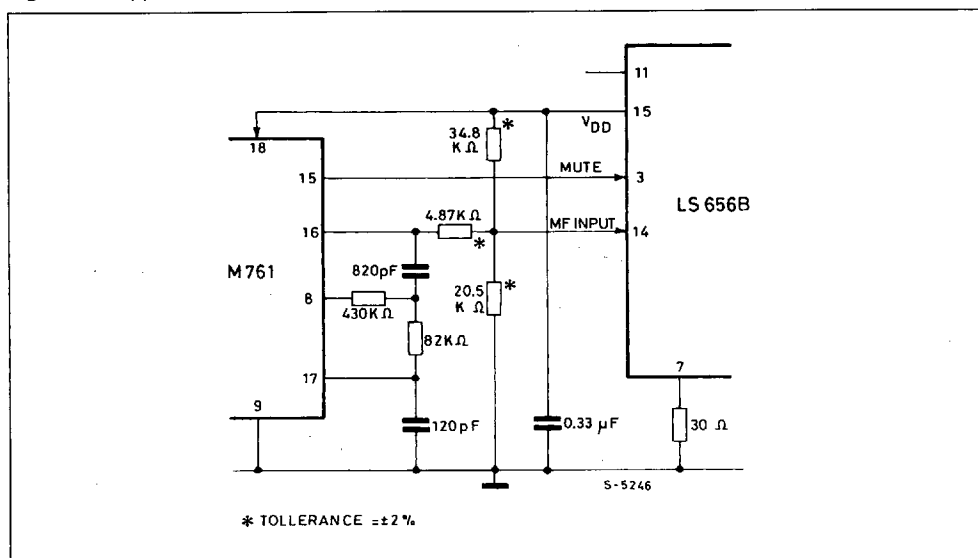
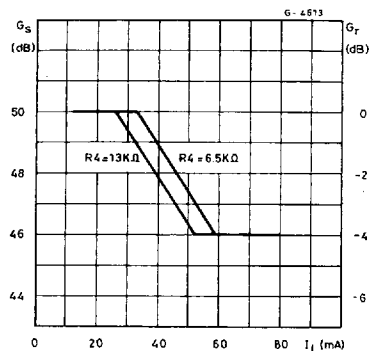


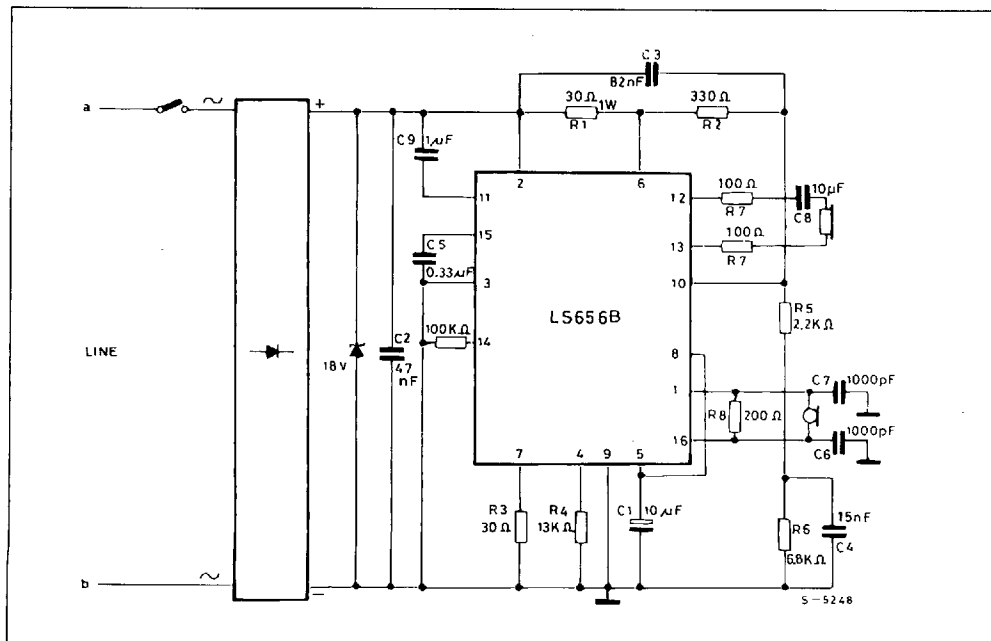
Figure 11 : Application Circuit with Multifrequency (Europe I STD).



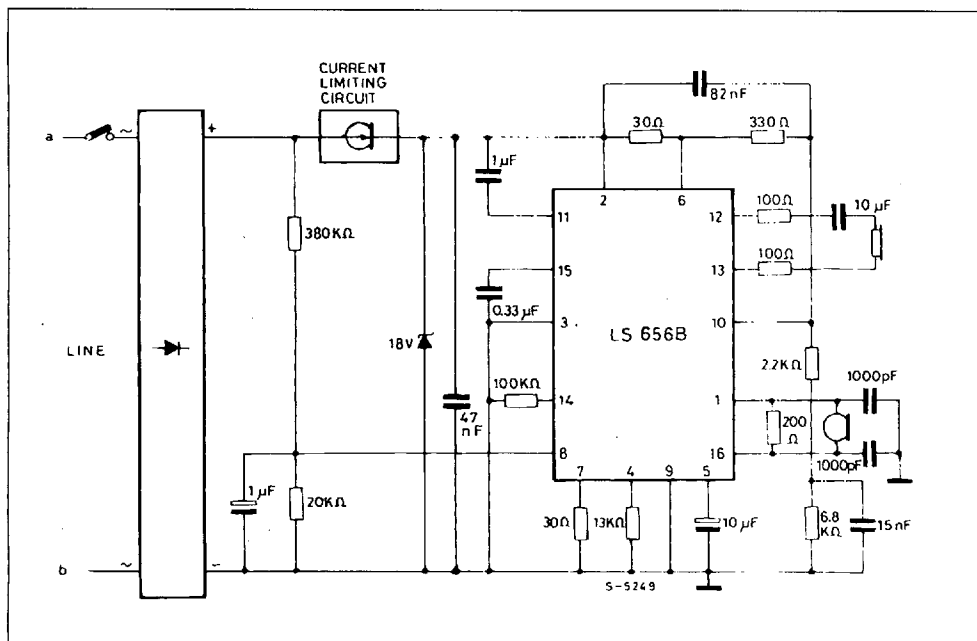
**Figure 12 :** Sending and Receiving Gain vs. Line Current (application circuit of fig. 10).



**Figure 13 :** Application Circuit without Multifrequency.



**Figure 14** : Application Circuit with Gain Controlled by Line Voltage (french standard).



**Figure 15** : Application Circuit with Fixed Gain Operation.

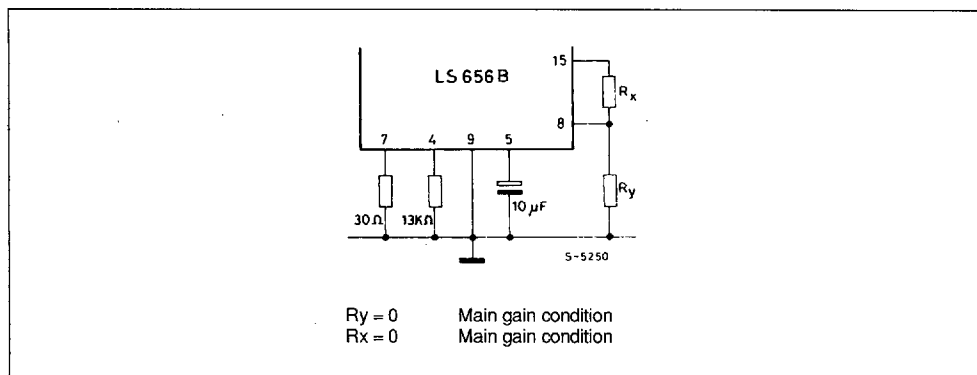
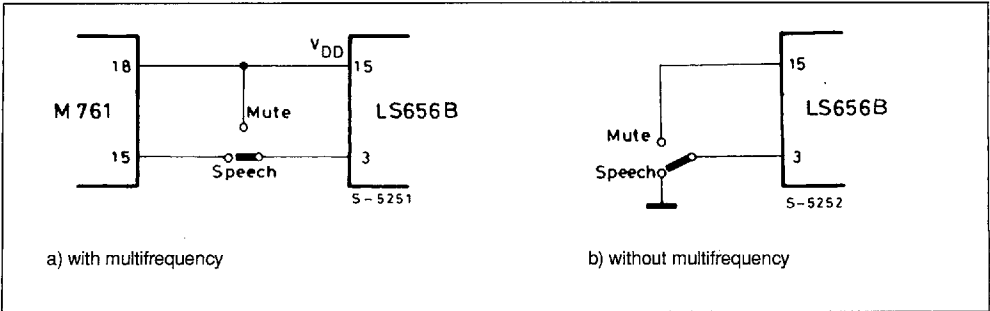


Figure 16 : External Mute Function.



In addition to the above mentioned applications, different values for the external components can be used in order to satisfy different requirements.  
The following table (refer to the application circuit of fig. 10) can help the designers.

| Component | Value  | Purpose                                       | Note                                                                                                                                                                                                                                                                                                                                |
|-----------|--------|-----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R1        | 30Ω    | Bridge Resistors                              | R1 controls the receiving gain. When high current values are allowed, R1 must be able to dissipate up to 1 W. The Ratio R2/R1 fixes the amount of signal delivered to the line. R1 helps in fixing the DC characteristics (see R3 note).                                                                                            |
| R2        | 330Ω   |                                               |                                                                                                                                                                                                                                                                                                                                     |
| R3        | 30Ω    | Line Current Sensing Fixing DC Characteristic | The relationships involving R3 are :<br>$Z_{ML} = (20 \cdot R3 // Z_B) + R1$ , $G_S = K \cdot \frac{Z_L // Z_{ML}}{R_3}$ and<br>$V_L = (I_L - I_0) (R3 + R1) + V_0$ ; $V_0 = 3.7V$<br>Without any problem it is possible to have a $Z_{ML}$ ranging from 600 up to 900Ω. As far as the power dissipation is concerned, see R1 note. |
| R4        | 13kΩ   | Bias Resistor                                 | The suggested value assures the minimum operating current. It is possible to increase the supply current by decreasing R4 (they are inversely proportional), in order to achieve the shifting of the AGC starting point. (see fig. 16). After R4 changement, so                                                                     |
| R5        | 2.2kΩ  | Balance Network                               | It's possible to change R5 and R6 values in order to improve the matching to different lines ; in any case : $\frac{Z_L}{Z_B} = \frac{R_1}{R_2}$ , $Z_B = R5 + R6 // X_{C4}$                                                                                                                                                        |
| R6        | 6.8kΩ  |                                               |                                                                                                                                                                                                                                                                                                                                     |
| R7-R7'    | 100Ω   | Receiver Impedance Matching                   | R7 and R7', must be equal ; the suggested value is good for matching to dynamic capsule ; there is no problem in increasing and decreasing (down to 0Ω) this value. A DC decoupling must be inserted when low resistance levels are used to stop                                                                                    |
| R8        | 200Ω   | Microphone Impedance Matchin                  |                                                                                                                                                                                                                                                                                                                                     |
| C1        | 10μF   | Regulator AC byPass                           | A value greater than 10 μF gives a system start time too high for low current line during MF operation ; a lower value gives an alteration of the AC line impedance at low frequency.                                                                                                                                               |
| C2        | 47nF   | Matching to a Capacitive Line                 | C2 changes with the characteristics of the transmission line.                                                                                                                                                                                                                                                                       |
| C3        | 82nF   | Receiving Gain Flatness                       | C3 depends on balancing and line impedance versus frequency.                                                                                                                                                                                                                                                                        |
| C4        | 15nF   | Balance Network                               | See note for R5, R6.                                                                                                                                                                                                                                                                                                                |
| C5        | 0.33μF | DC Filtering                                  | The C5 range is from 0.1 μF to 0.47 μF. The lowest value is ripple limited, the higher value is starting up time limited.                                                                                                                                                                                                           |
| C6-C7     | 1000pF | RF byPass                                     |                                                                                                                                                                                                                                                                                                                                     |
| C8        | 100μF  | Receiving Output DC Decoupling                | See note for R7, R7.                                                                                                                                                                                                                                                                                                                |
| C9        | 1 μF   | Receiving Input DC Decoupling                 |                                                                                                                                                                                                                                                                                                                                     |