# PBL 388 14 Voice-switched Speakerphone Circuit

## Description

The PBL 388 14 contains all the necessary circuitry, amplifiers, detectors, comparators and control functions to implement a high performance, voice-switched, loudspeaking, "hands-free " telephone. The gain dynamics (attenuation between channels) is settable (25dB or 50dB) via a separate pin. A background noise detector in the transmitting channel reduces the influence of continuous noise signals.

The PBL388 14 is designed for telephone systems that are powered from a mains Filtering of both the audio and control signals in both transmitter and receiver channels possible.

PBL 388 14 can be used for handsfree mobile telephone applications in cars together with external transistors for output higher than 2W.

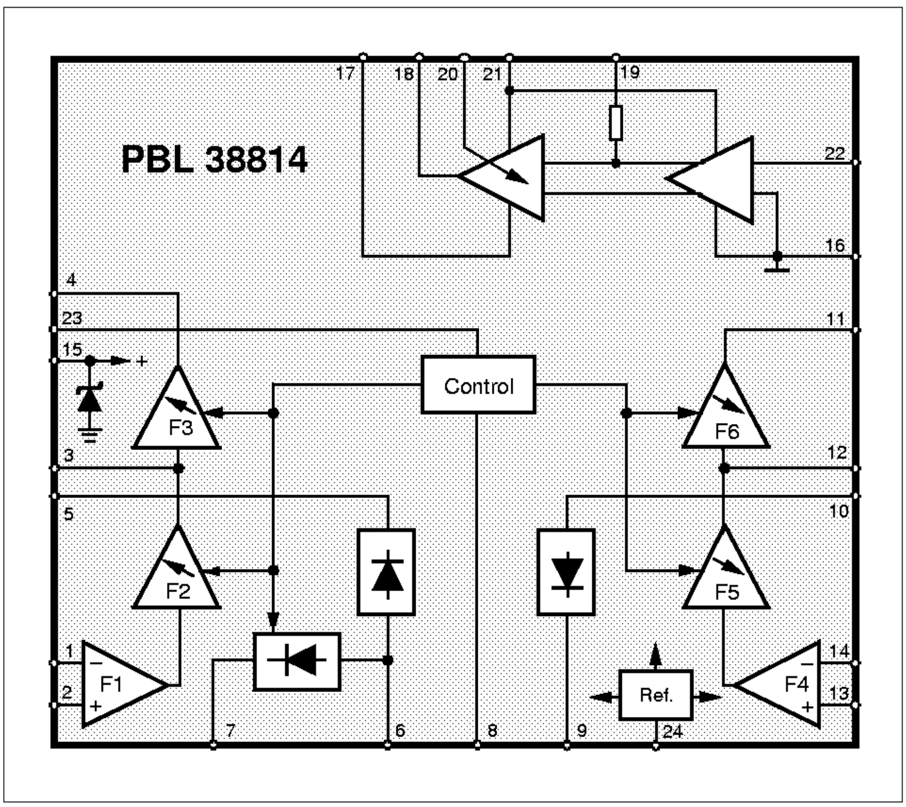
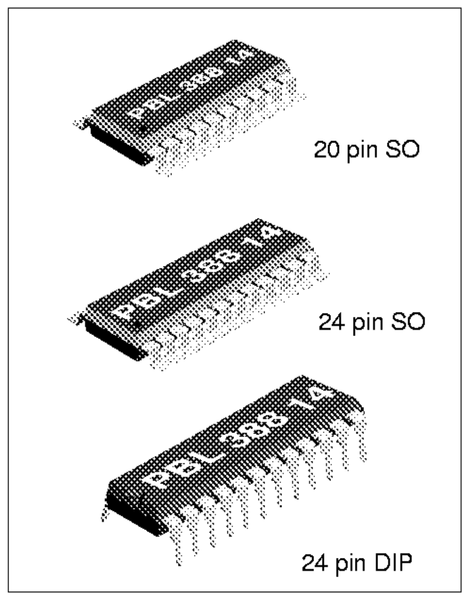



*Figure 1. Block diagram. Pin numbers refer to DIL package.*

## Key Features

- Settable gain dynamics (25 or 50 dB).
- Low power consumption, totally 1.0mA at 3.2V typical. (switching part)
- Direct drive of an 8 - 50 ohm loudspeaker.
- 24 pin plastic "skinny" DIP, 24 pin SO and 20 pin SO encapsulation.
- Background noise compensation in the transmitting channel with hold function.
- Exellent noise performance.
- Both channel input amplifiers have balanced inputs.
- Minimum of external components needed for function.
- Ref. voltage avaiable
- 0,5 W in 8 Ω speaker
  0,6 W in 16 Ω speaker
  2 W in 4 Ω speaker, with external transistors. (Not 20 pin SO)



## Maximum Ratings

| Parameter | Symbol | Min | Max | Unit |
|---|---|---|---|---|
| Speech switch supply current | $I_D$ | | 10 | mA |
| Speaker amplifier supply current | $I_{+L}$ | | 130 | mA |
| Voltage pin 1-14 | | -0,5 | $Vpin_{15}$+0.5 | V |
| Operating temperature | $T_{Amb}$ | -20 | +70 | °C |
| Storage temperature | $T_{Stg}$ | -55 | +125 | °C |

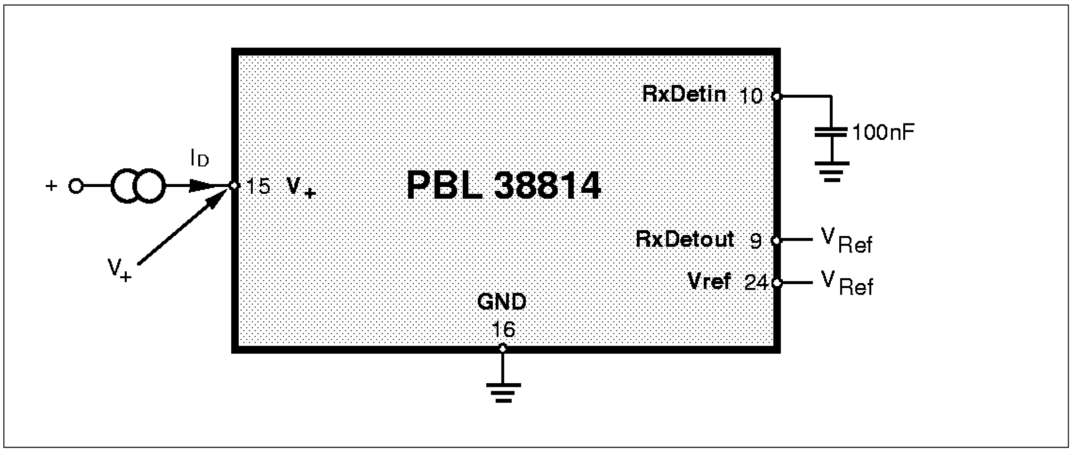



*Figure 2. Isolation and measurement of $V_{Ref}$. Ref fig No.2.*

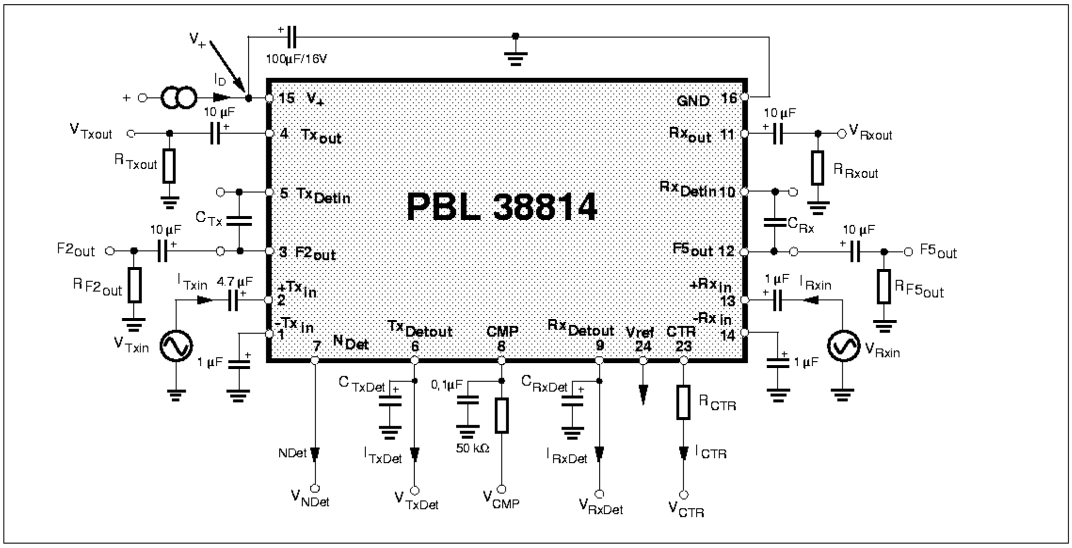



*Figure 3. Test circuit. Reference figure No. 3.*

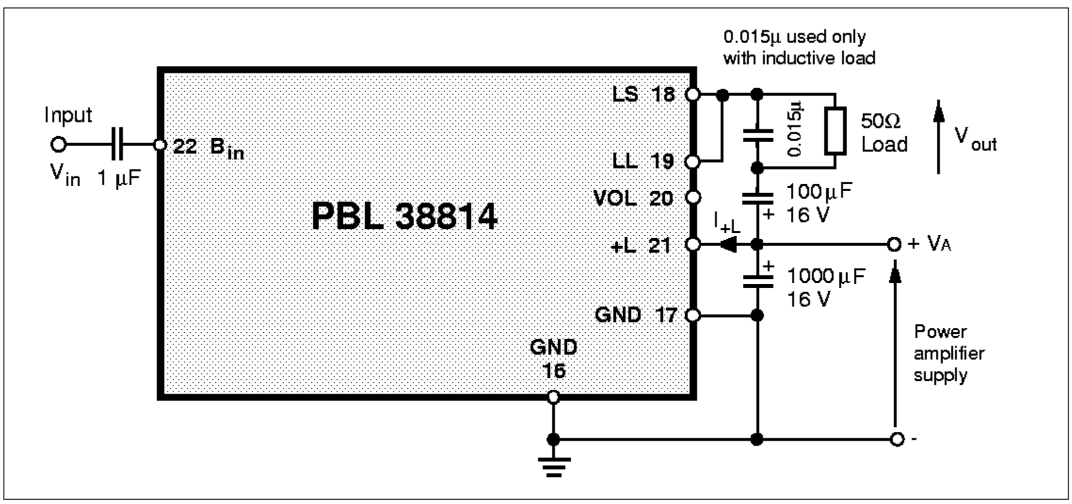



*Figure 4. Test circuit. Reference figure No. 4.*

## Electrical Characteristics

f = 1 kHz, T = 25°C, $R_{CTR}$=0, $C_{TxDet}$ = 0, $R_{Txout}$ = ∞, $R_{Rxout}$ = ∞, $R_{F2out}$ = ∞, $R_{F5out}$ = ∞, $R_{Tx}$ = 0, $R_{Rx}$ = 0, $C_{RxDet}$ = 0 and $I_D$=1.0mA unless otherwise noted.

| Parameter | Ref. fig. | Condition | Min. | Typ. | Max. | Unit. |
|---|---|---|---|---|---|---|
| **Speech control section** | | | | | | |
| Terminal voltage, $V_+$ | 3 | $I_D$ = 1.0mA | | 3.4 | | V |
| Internal reference voltage, $V_{Ref}$ | 2 | | | 1.96 | | V |
| Frequency response for all amplifiers | 3 | 200 - 3400 Hz, Relative 1 kHz | -1 | | 1 | dB |
| Transmit gain, 20 • $^{10}$log($V_{Txout}$ /$V_{Txin}$) | 3 | $V_{CMP}$ = $V_{Ref}$ - 0.1 V | 41.5 | 44 | | dB |
| | | $V_{CMP}$ = $V_{Ref}$ + 0.1 V | | -6 | -3.5 | dB |
| | | $V_{CMP}$ = $V_{Ref}$ - 0.1 V $R_{CTR}$=100k, $V_{CTR}$=V+ | 41.5 | 44 | | dB |
| | | $V_{CMP}$ = $V_{Ref}$ + 0.1 V $R_{CTR}$=100k, $V_{CTR}$=V+ | | 19 | 21.5 | dB |
| Receive gain, 20 • $^{10}$log($V_{Rxout}$ /$V_{Rxin}$) | 3 | $V_{CMP}$ = $V_{Ref}$ + 0.1 V | 26.5 | 29 | | dB |
| | | $V_{CMP}$ = $V_{Ref}$ - 0.1 V | | -21 | -18.5 | dB |
| | | $V_{CMP}$ = $V_{Ref}$ + 0.1 V $R_{CTR}$=100k, $V_{CTR}$=V+ | 26.5 | 29 | | dB |
| | | $V_{CMP}$ = $V_{Ref}$ - 0.1 V $R_{CTR}$=100k, $V_{CTR}$=V+ | | 4 | 6.5 | dB |
| Max transmit detector gain, | 3 | $V_{TxDet}$ < 200 $mV_p$ , $C_{Tx}$ = 100nF | | | | |
| 20 • $^{10}$log($V_{Txdet}$ /$V_{Txin}$) | | $V_{CMP}$ = $V_{Ref}$ - 0.1 V | | 67.5 | | dB |
| | | $V_{CMP}$ = $V_{Ref}$ + 0.1 V | 37 | 42.5 | | dB |
| Max receive detector gain, | 3 | $V_{RxDet}$ < 200 $mV_p$ , $C_{Tx}$ = 100nF | | | | |
| 20 • $^{10}$log($V_{Rxdet}$ /$V_{Rxin}$) | | $V_{CMP}$ = $V_{Ref}$ +0.1 V | | 53 | | dB |
| | | $V_{CMP}$ = $V_{Ref}$ - 0.1 V | 22.5 | 28 | | dB |
| Background noise rectifier gain, (note 1) | 3 | $V_{CMP}$ = $V_{Ref}$ - 0.1 V, $C_{Txdet}$=1µF | | 6.0 | | dB |
| | | $V_{CMP}$ = $V_{Ref}$ + 0.1 V, $C_{Txdet}$=1µF | | Hold | | |
| + $Tx_{In}$ input impedance | 3 | | 80 | 100 | 120 | kΩ |
| - $Tx_{In}$ input impedance | 3 | | 2.4 | 3.0 | 3.6 | kΩ |
| + $Rx_{In}$ input impedance | 3 | | 120 | 140 | 160 | kΩ |
| - $Rx_{In}$ input impedance | 3 | | 16 | 20 | 24 | kΩ |
| $Tx_{Out}$ ac, load impedance | 3 | | 25 | | | kΩ |
| $Rx_{Out}$ ac, load impedance | 3 | | 25 | | | kΩ |
| $F2_{Out}$ ac, load impedance | 3 | | 25 | | | kΩ |
| $F5_{Out}$ ac, load impedance | 3 | | 25 | | | kΩ |
| **Dynamics** | | | | | | |
| Transmitter channel output, $v_{TxOut}$ | 3 | 2% distortion,$R_{Txout}$=$R_{Rxout}$=25k Ω | | 500 | | $mV_p$ |
| Receiver channel output, $v_{RxOut}$ | 3 | 2% distortion,$R_{Txout}$=$R_{Rxout}$=25k Ω | | 500 | | $mV_p$ |
| Transmitter output noise, $v_{TxOut}$ | 3 | $V_{CMP}$ = $V_{Ref}$ - 0.1 V, $v_{TxIn}$ = 0 V | | -75 | | $dB_{psof}$ |
| Receiver output noise, $v_{RxOut}$ | 3 | $V_{CMP}$ = $V_{Ref}$ + 0.1 V, $v_{RxIn}$ = 0 V | | -80 | | $dB_A$ |
| $Tx_{Det}$ sink current, $I_{TxDetOut}$ | 3 | $V_{TxDetIn}$ = $V_{Ref}$ + 0.1 V | | -6.0 | -2.5 | mA |
| $Rx_{Det}$ source current, $I_{RxDetOut}$ | 3 | $V_{RxIn}$ = $V_{Ref}$ - 0.1 V | 2.5 | 6.0 | | mA |
| $Tx_{Det}$ source current, $I_{TxDet}$ | 3 | $V_{CMP}$ = $V_{Ref}$ - 0.1 V | | | 30 | µA |
| $Rx_{Det}$ sink current, $I_{RxDetOut}$ | 3 | $V_{RxDetIn}$ = $V_{Ref}$ + 0.1 V | -30 | | | µA |
| $Tx_{Det}$ swing relative to $V_{Ref}$ , $V_{TxDetOut}$ | 3 | $V_{TxDetIn}$ = $V_{Ref}$ + 0.1 V | (note 2) | -0.7 | | V |
| $Rx_{Det}$ swing relative to $V_{Ref}$ , $V_{RxDetOut}$ | 3 | $V_{RxDetIn}$ = $V_{Ref}$ - 0.1 V | (note 2) | +0.7 | | V |
| $N_{Det}$ sink current (fast charge), $I_{NDet}$ | 3 | $V_{TxDetIn}$ = $V_{Ref}$ - 0.1 V | | -4.5 | -1.5 | mA |
| | | $V_{CMP}$ = $V_{Ref}$ - 0.1 V | | | | |
| $N_{Det}$ source current, $I_{NDet}$ | 3 | $V_{TxDetIn}$ = $V_{Ref}$ + 0.1 V | 3 | 5 | 7 | mA |
| | | $V_{CMP}$ = $V_{Ref}$ + 0.1 V | | | | |

| Parameter | Ref. fig. | Conditions | Min. | Typ. | Max. | Unit. |
|---|---|---|---|---|---|---|
| $N_{Det}$ leakage current (hold), $I_{NDet}$ | 3 | $V_{TxDetIn} = V_{Ref}$ - 0.1 V, $V_{CMP} = V_{Ref}$ + 0.1 V, | | -100 | | nA |
| $N_{Det}$ swing relative to $V_{Ref}$, $V_{NDet}$ | 3 | $V_{CMP} = V_{Ref}$ - 0.1 V, $V_{TxDetIn} = V_{Ref}$ + 0.1 V | | -0.45 | | V |
| CMP (comparator) sensitivity, transmit (Tx) mode to receive (Rx) mode or vice versa | 3 13 | Tx mode = max Tx gain, Rx mode = max Rx gain | | 50 | 100 | mV |
| CTR voltage for 25 dB dynamics, $V_{CTR}$ | 3 | $V_{CMP} = V_{Ref} \pm 0.35$ V, $R_{CTR}$=100kΩ | | $V_+$ | | V |
| CTR voltage for mute, $I_{CTR}$ | 3 | $V_{CMP} = V_{Ref} \pm 0.35$ V | | | | µA |
| CTR voltage for disable, $V_{CTR}$ | 3 | | | | 0.55 | V |
| **Loudspeaker amplifier** | | | | | | |
| Operating voltage, $V_A$ | 4 | | 2.5 | | 12 | V |
| Current consumption (no signal), $I_{+L}$ | 4 | $V_A$ = 3.0 V | | 1 | 2.3 | mA |
| | 4 | $V_A$ = 5.0 V | | 1.5 | | mA |
| | 4 | $V_A$ = 12.0 V | | 4 | 9 | mA |
| Current consumption (output swing at 5% dist.) | 4 | $V_A$ = 3.0 V | | 7 | | mA |
| | 4 | $V_A$ = 5.0 V | | 13 | | mA |
| | 4 | $V_A$ = 12.0 V | | 30 | | mA |
| Swing at 5% dist., $V_{Out}$ | 4 | $V_A$ = 3.0 V | 0.6 | 0.85 | | $V_p$ |
| | 4 | $V_A$ = 5.0 V | 1.5 | 1.7 | | $V_p$ |
| | 4 | $V_A$ =12.0 V | 3.6 | 4.0 | | $V_p$ |
| Gain | 4 | $V_A$ =5.0 V | 34.5 | 36.5 | 38.5 | dB |
| Frequency response | 4 | 200 to 3400 Hz, relative 1kHz, | -1 | | 1 | dB |
| Amplifier power efficiency (5% dist), n | 4 | $V_A$ = 3.0 to 12.0 V, n = 100 • $P_{Load}/P_{Supply}$ | | 40 | | % |
| Input impedance pin 23 | 4 | | 24 | 30 | 36 | kΩ |
| $Iout_{peak}$ | | $Vout_{p-p}=V_A$-1V, dist. ≤ 5% | ±100 | ±200 | | mA |

## Notes

1. $$20 \cdot {}^{10}\log \left(\frac{V_{NDet} - V_{Ref}}{V_{TxDet} - V_{TxDetO}}\right)$$

   $V_{NDet}$ = voltage at noise detector output
   $V_{Ref}$ = reference voltage (about 1.9 V) see figure 2.
   $V_{TxDet}$ = Voltage at transmit detector output.
   $V_{TxDetO}$= voltage at transmit detector output at the point when the voltage at the noise detector starts moving when a signal at transmit channel input is gradually increased (threshold, typical value 30 mV)

2. Depends on $V_+$. Channels are tracking.

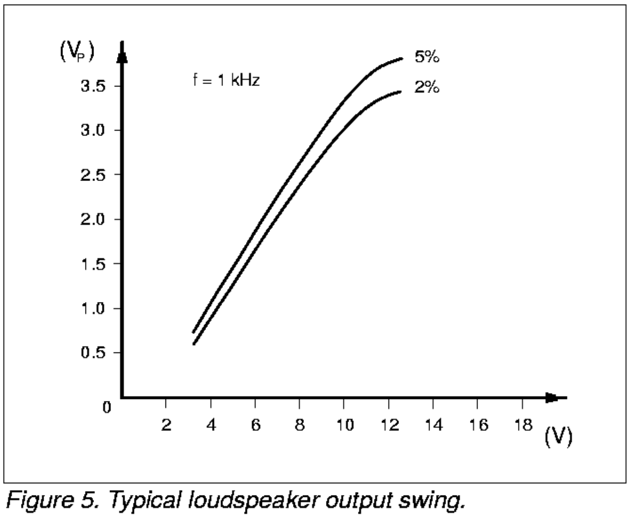



*Figure 5. Typical loudspeaker output swing.*

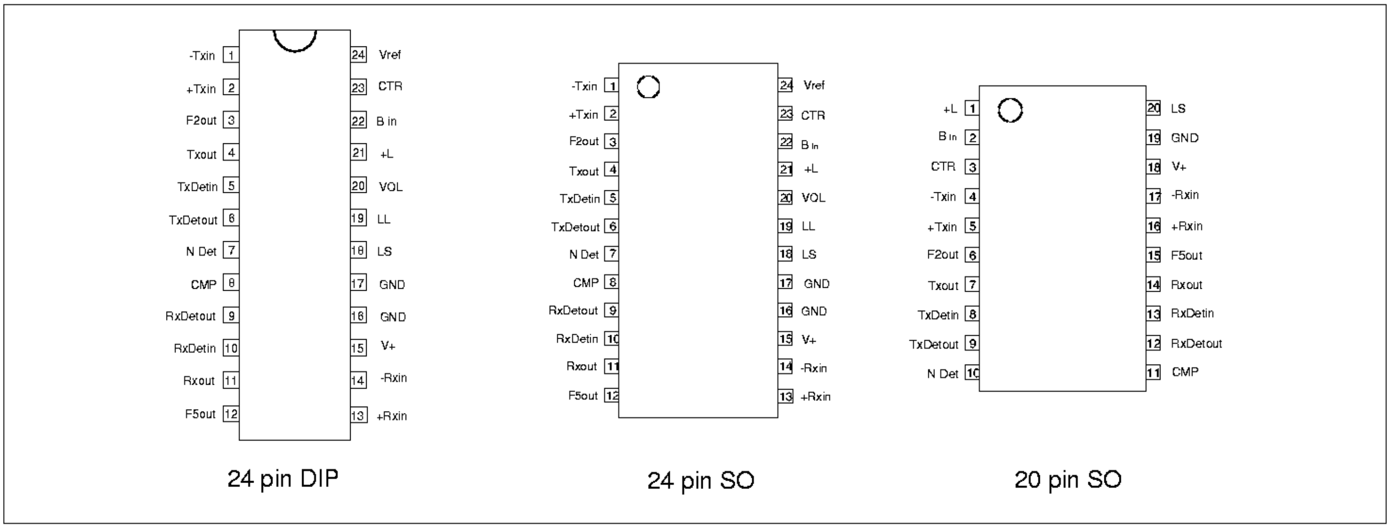



*Figure 6. Pin configuration.*

## Pin Descriptions

Refer to figure 6. (24 pin DIP, 24 pin SO and 20 pin SO package)

| 24 pin | 20 pin | Symbol | Description |
|---|---|---|---|
| 1 | 4 | -Txin | Transmitter channel negative input. Input impedance 3.16 kohm. |
| 2 | 5 | +Txin | Transmitter channel positive input. Input impedance 100 kohm. |
| 3 | 6 | F2out | Output of the second amplifier in the transmitter channel. |
| 4 | 7 | Txout | Transmitter channel output. Min. ac load impedance 25 kohm. |
| 5 | 8 | TxDetin | Input of the transmitter channel signal detector. Input impedance 13 kohm. |
| 6 | 9 | TxDetout | Output of the transmitter channel signal detector. Goes nagative referred to the internal ref. voltage of 1.9V when a transmitter signal is present. |
| 7 | | REF | Reference voltage out. |
| 8 | 10 | NDet | Background noise detector output. Goes positive referred to the internal ref. voltage of app. 2V when a background noise signal is present |
| 9 | 11 | CMP | Comparator input. External resistance to this point should not be less than 50 kohm. Summing point to the different detector outputs. |
| 10 | 12 | RxDetout | Output of the receiver channel signal detector. Goes positive referred to the internal ref. voltage of 1.9V when a receiver signal is presen |
| 11 | 13 | RxDetin | Input of the receiver channel signal detector. Input impedance 13 kohm. |
| 12 | 14 | Rxout | Receiver channel output. Min. ac load impedance 25 kohm. |
| 13 | 15 | F5out | Output of the second amplifier in the receiver channel. |
| 14 | 16 | +Rxin | Receiver channel positive input. Input impedance 100 kohm. |
| 15 | 17 | -Rxin | Receiver channel negative input. Input impedance 10 kohm. |
| 16 | 18 | V+ | Supply of the speech switching circuitry. A shunt regulator, voltage apprx. 3.2V at 1.0mA. |
| 17 | 19 | GND | System ground (- line ). |
| 18 | | GND | System ground (- line ). |
| 19 | 20 | LS | Loudspeaker power amplifier output. |
| 20 | | LL | Makes it possible to break the feedback loop to use external power transistors for higher power. |
| 21 | | VOL | DC volume control. |
| 22 | 1 | +L | Positive supply for the loudspeaker amplifier. |
| 23 | 2 | Bin | Loudspeaker amplifier signal input. Input impedance 30 kohm. |
| 24 | 3 | CTR | Control input for gain dynamics (25 or 50dB), mute and disable. |

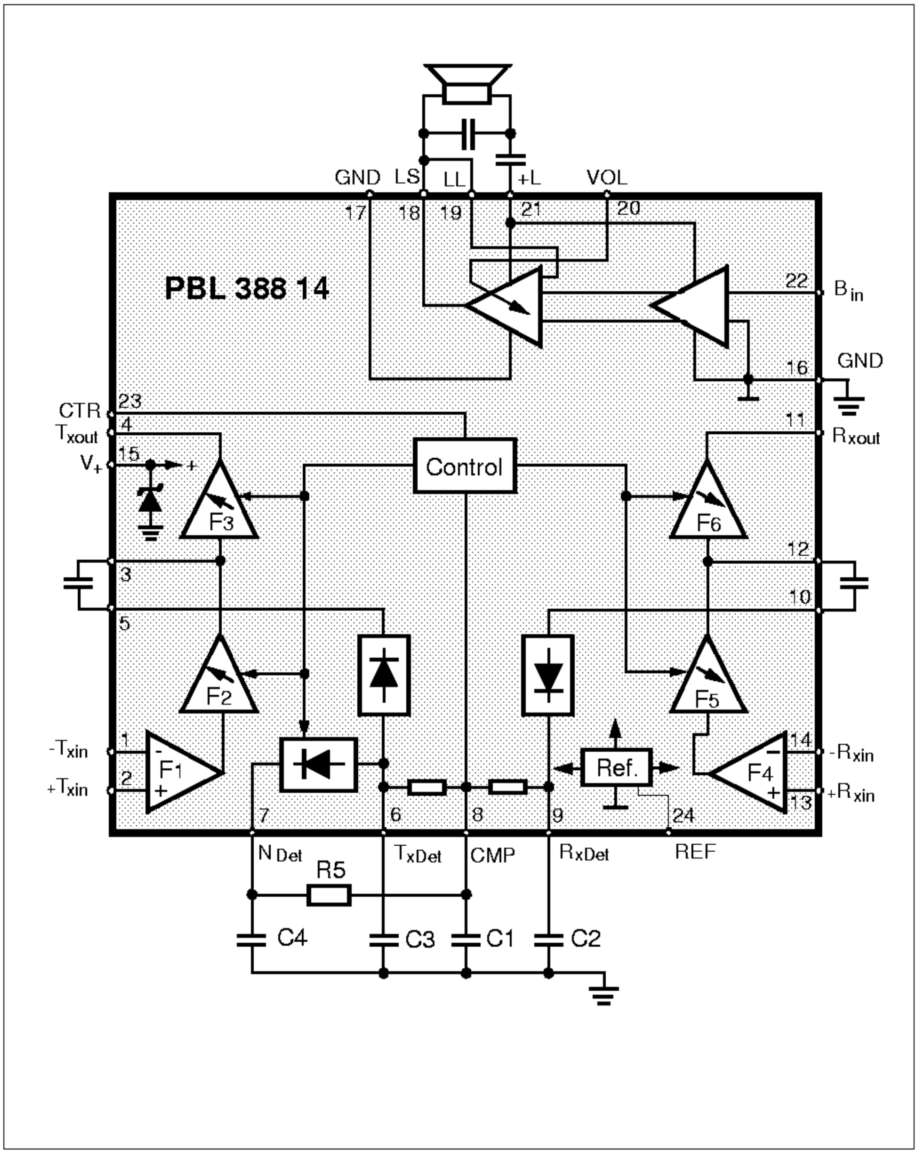



*Figure 7. Passive networks setting the speech control function.*

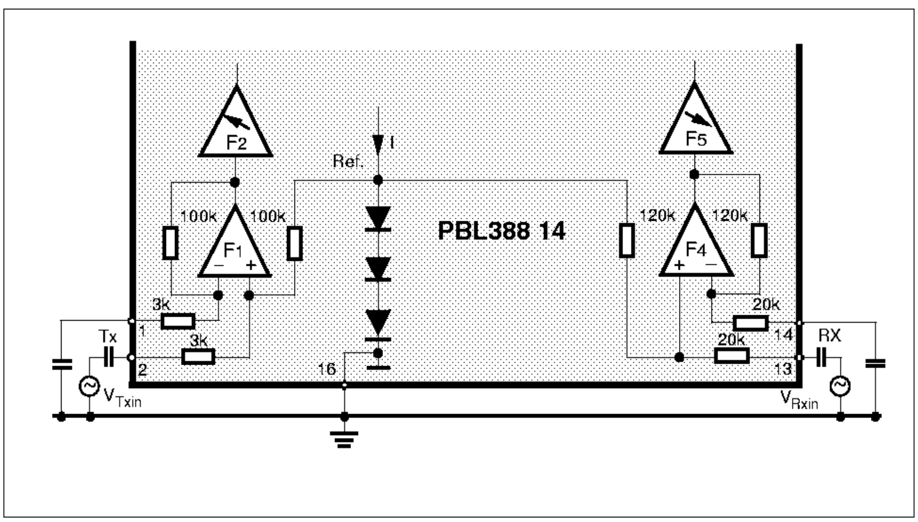



*Figure 8. Receive and transmit channel input arrangement.*

# Functional Description Speech control section

## Transmitter and Receiver Channels

The transmitter and receiver channels consist of three amplifying stages each, F1, F2, F3 and F4, F5, F6. The inputs and outputs of the amplifiers must be ac. coupled because they are dc. vise at the internal reference voltage (≈2V) level. F1 and F2 are fixed gain amplifiers of 30,5 dB and 15.5 dB respectively, while the rest of them are of controlled gain type.The gain of F2, F3 as well as F5 and F6 is controlled by comparators. The comparators receive their information partly from the summing point of the transmitter, receiver and background noise detectors at CMP input and partly through the control input, CTR, which controls the gain dynamics (25 or 50 dB). Amplifiers F2 and F3 have the maximum gain when the transmitter channel is fully open, consequently the amplifiers F5 and F6 will have minimum gain and vice versa. See figure 7 and figure 13.

The positive input on each channel has a high input impedance. It renders a good gain precision and noise performance when used with low signal source impedance. The negative input of the receiver channel should be returned to ground with a capacitor. The differential input of the transmitter channel can be used to suppress unwanted signals in the microphone supply, see figure 9. Also see application 1.

## Signal Detectors and Comparators

The signal detectors sense and rectify the receiver and microphone signals to opposite polarities referenced to the internal reference voltage of approx. 2V. The voltage at RxDet will go positive and at TxDet negative in the presence of a signal at the respective channel input. In the idle (no signal) state, the voltages at RxDet ,TxDet and CMP are equal to the internal reference voltage. Signal at Txin will result in an decreasing level at TxDetout and hence also at CMP input. The comparators will increase the gain in

*Figure 9. Transmitter channel input amplifier used to suppress ripple in the mic. supply. (CMRR). R1 is used to establish a balansed input.*
*R1 = R2 ≈ 3k2*
*R3 = R4 ≈ 100k*
*R5 = R6*
*C1 = C2*

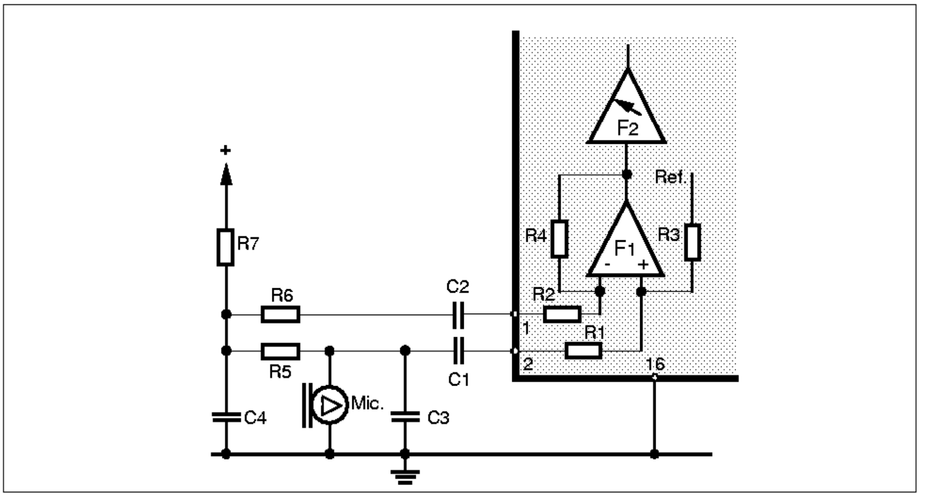



*Figure 10. Transmitter and receiver channel rectifier characteristics.*

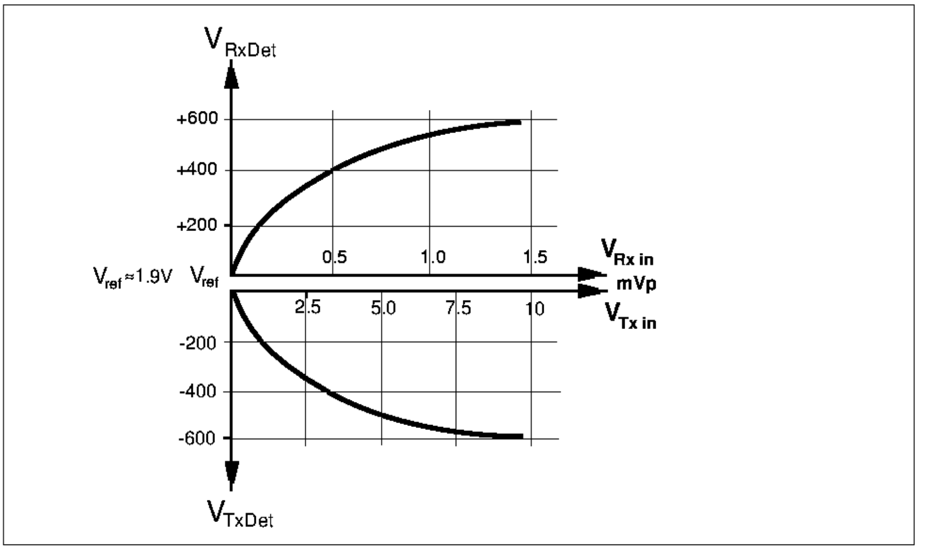



*Figure 11. Relationship in timing between the voltage levels at $Tx_{In}$, $Tx_{Det}$ and $N_{Det}$*

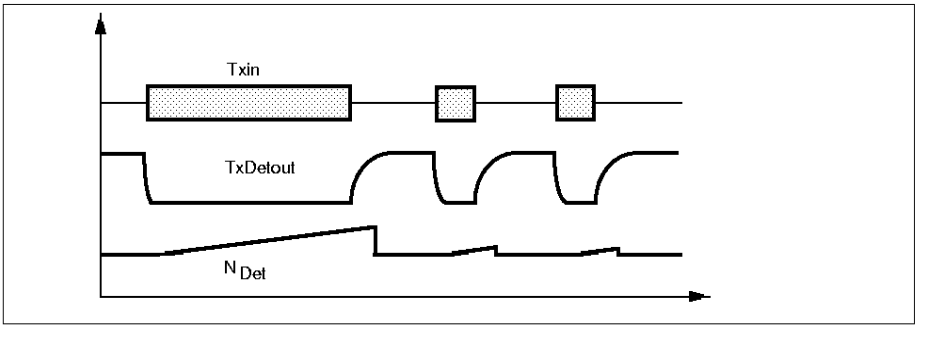
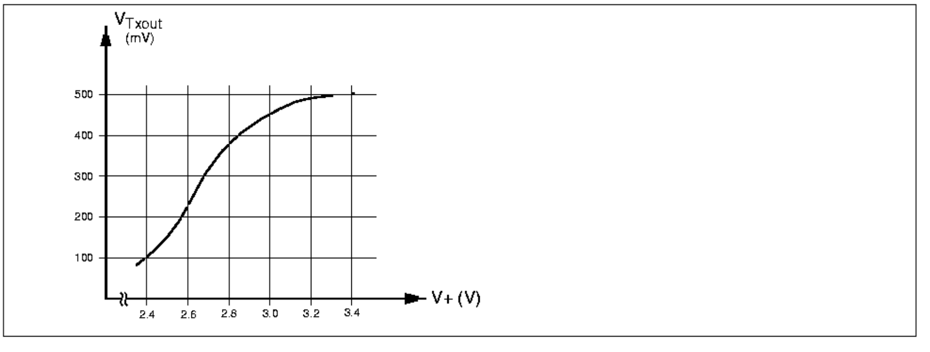



*Figure 12. Transmitter and receiver channel output dynamics.*



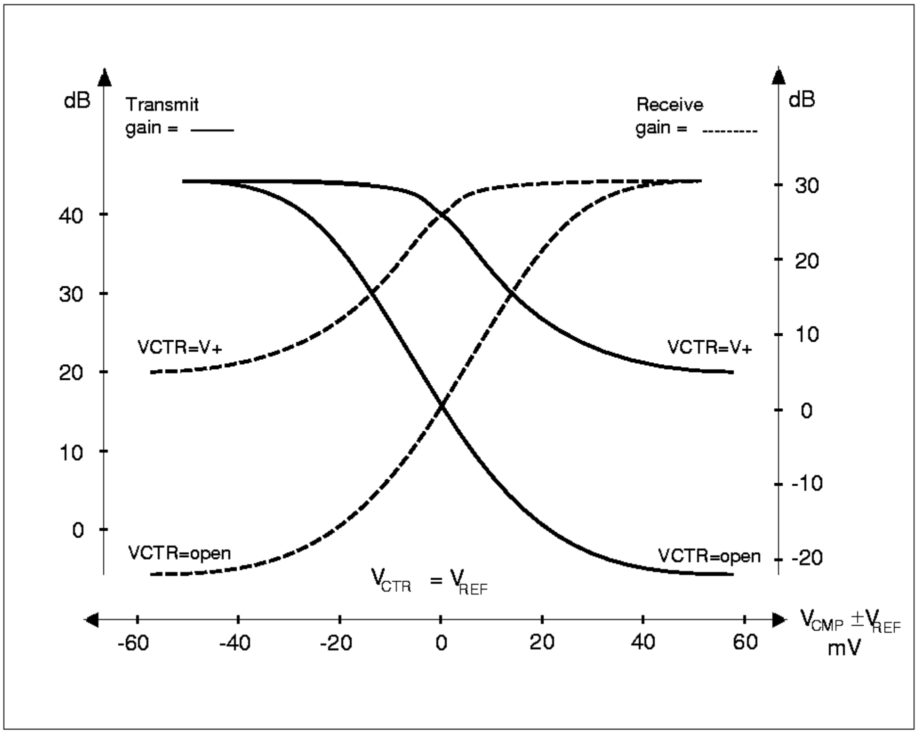



*Figure 13. Transmit and receive gain as a function of $V_{CMP}$ and $V_{Ref}$.*

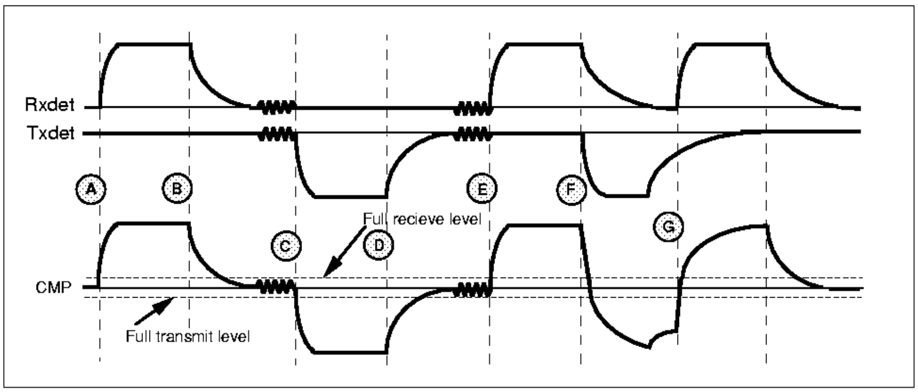



*Figure 14. Timing of the transmitter and receiver channels at the CMP-input.*

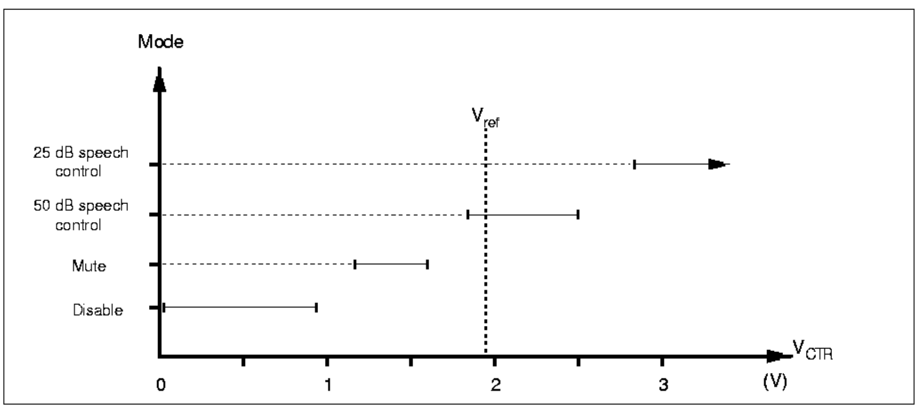



*Figure 15. Control modes as function of voltage applied to gain dynamics control input CTR $I_D$=1mA, $V_+$=3.4V.*

the transmitter channel and decrease it in the receiver channel. Signal at Rxin will do vice versa. The voltages RxDetout and TxDetout control thus the gain setting in respective channel through the comparators using the CMP input as a summing point with an input current of less than 1μA. The attack and decay times for the signals RxDetout and TxDetout are controlled by individual external RC-networks. The attack time in the receiver channel is set by C2 together with C1 and either by the maximum current capability of the detector output or it with R2 added. The transmitter channel works likewise. See fig. 7.

The decay time in the receiver and transmitter channels is set by C2 and C3 respectively. The resistor in the time constant is formed by an internal 200kΩ resistor in parallel with the external resistors R3 and R4 respectively. The influence of eventual R1 and R2 can be omitted.

The text above describes the case when only one channel is open at a time and there is a distinctive pause between signals at receiver and transmitter channel inputs so the circuit will have time to reach its idle state. See fig.14 A) to E). If one of the channels gets an input signal immediately after the signal has disappeared from the other channel input the effective decay time, as the CMP input sees it, will be shorter than in the first case. See fig.14 F) to G). The capacitor C4 at CMP - input sets the speed of the gain change in the transmitter and receiver channels. The capacitors C2 and C3 should be dimensioned for a charging time of 0.5 - 10mS and for a discharge time of 150 - 300 mS. The question of switching times being a highly subjective proposition, is in large dependent of the language being spoken in the system, caused by the varying sound pressure picture of the different languagues. The total external resistance being presented for the CMP - input should be approx. 50k (internal balance requirement). A hysteresis effect is achieved in the switching since the level detectors sense the signals after F2 and F5 respectively (F2 and F5 are affected by the gain setting). For example: If the transmitter channel is open (maximum gain), a smaller signal at Txin is enough to keep the channel open than would be

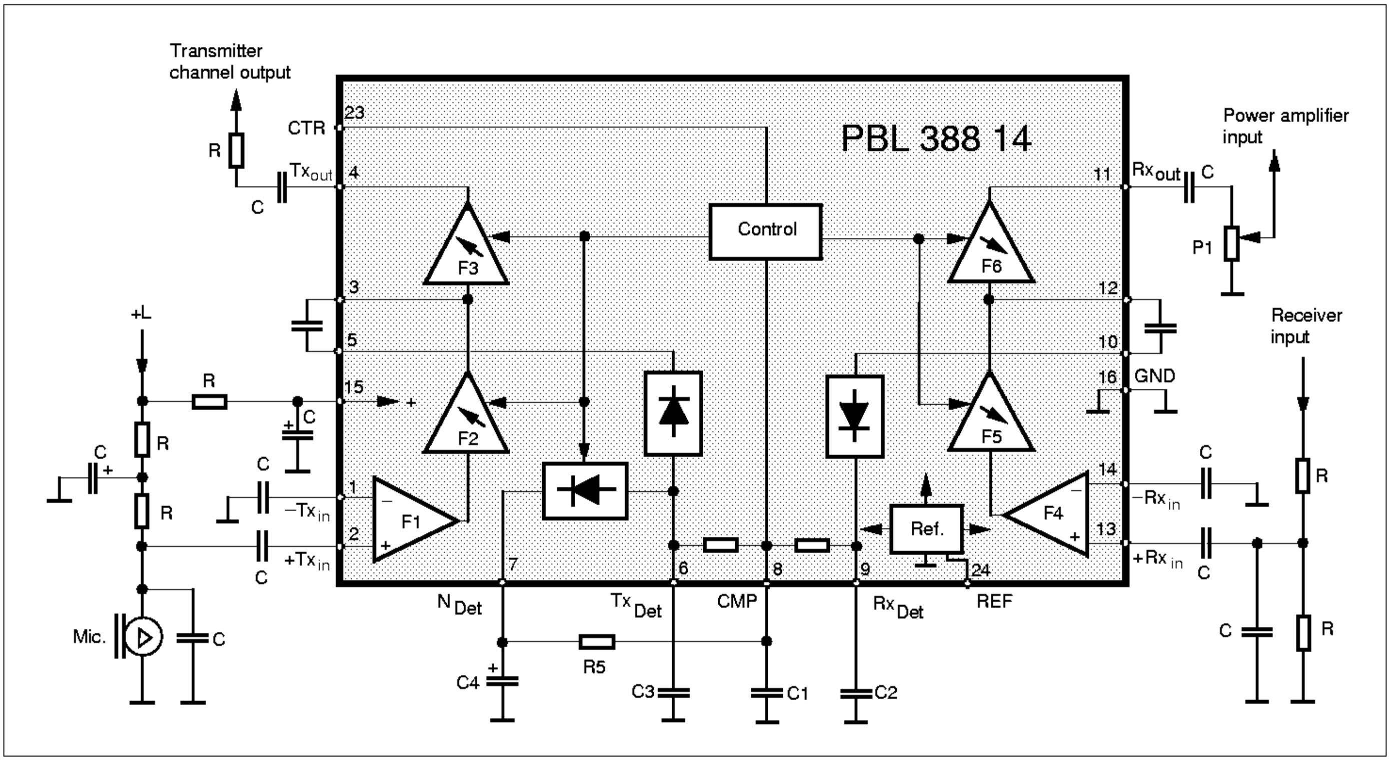



*Figure 16. Speech switching arrangement.*

necessary to open it when the receiver channel is open. The output swing of the level detectors is matched for variations in the supply voltage. The detectors have a logarithmic rectifier characteristic whereby gain and sensitivity is high at small signals. There is a break point in the curve at a level of ± 200mV from the internal reference voltage app. 2V, where the sensitivity for increasing input signals decreases with factor of 10, increasing the detectors dynamic range. See fig.10.

## Background Noise Detector

The general function of the backgro-und noise detector in the transmittng channel is to create a positive signal ( in respect to the referrence) so that, when coupled to the summing point at the CMP input, will counteract the signal from the transmitter level detector representing the actual sound pressure level at the microphone. This counteracts the noise from influencing the switching characteristics. The input signal to the backround noise level detector is taken from the output of the transmitter detector , a voltage representing the envelope of the amplified microphone signal. The detector inverts and amplifies this signal 2 x (transmitting mode) and has on it´s output a RC network consis-ting of an internal resistor of 100k and an external capacitor C4. The voltage across C4 is connected to the CMP input (summing point) via a resistor R5. The resistor R6 is important in order to keep the charging current of C4 within safe limits in regard of high charge peaks that could be audible in the system.. The extent to which the NDet output will influence the potential at CMP input is set by the gain of the detector, the maximum swing and R5. If a continuous input signal is received from the microphone ( > 10sec.) the voltage across C4 is pulled negative (relative to the reference) with a time constant set by C4 to e.g. 5 sec.. A continuous input signal is thus treated as noise. Since the output of the noise detector is going negative it thereby counteracts the signal from the transmitter detector and thus helping the receiver detector signal to maintain a set relation to the transmitter detector signal. If the transmitter input signal contains breaks like breath pauses the voltage at TxDetout decreases. If the voltage across C3 gets less than the inverted voltage across C4 divided by the detector gain a rapid charge of C4 towards reference will follow (all levels referred to the reference). If the breaks are frequent as in speech the backgro-und detector will not influence the switching characteristic of the system. See fig. 11. There is a threshold of approx. 50mV at TxDetout to prevent the activation of background noise detection in noiseless environment. In the receiver mode some of the loudspeaker output signal will be sensed by the microphone. In order not to treat this input signal as noise, the noise detector goes into a hold state and ”remembers” the level from the previous transmitting mode periode.

## CTR Input

For full speech control (50dB attenuation between the channels) this input can be left unconnected. To set the function to 25dB attenuation the input has to be higher than 600mV below V+. See figure 15. To set the circuit into a mute state (results in, redeced gain in receiver channel for the DTMF confidence tone in the loudspeaker and closed transmitter channel) a voltage below Vref has to be connected to the input. By lowering the voltage at the input below 0.9V a condition will emerge where both receiver and transmitter channels are closed. See fig. 17

## Loudspeaker amplifier

The loudspeaker amplifier drives a 8 - 50Ω impedance loudspeaker directly. The amplifier is designed to work under a number of different power supply conditions. Fig. 17. The supply could be either mains powered or power from the telephone line through an inductor. Current consumption is directly proportional to the voltage between pin +L and pin 17.

A function has been provided in the loudspeaker power amplifier circuit where the feedback loop can be broken thus making it possible to insert external power transistors in to the loop. This enables with external power supply output powers of several watts fed into 4-16 ohm loudspeaker. See. fig. 18.



1522-PBL 388 14 Uen Rev.A



ERICSSON

**Ericsson Components AB**
S-164 81 Kista-Stockholm, Sweden
Telephone: (08) 757 50 00

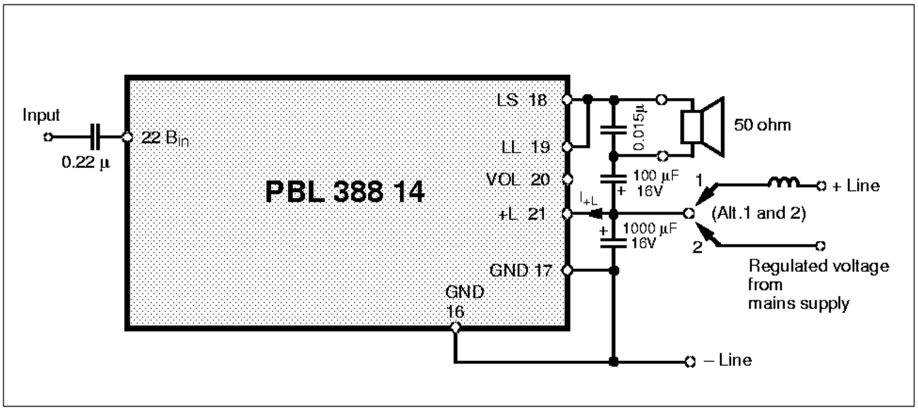



*Figure 17. External power supply.*

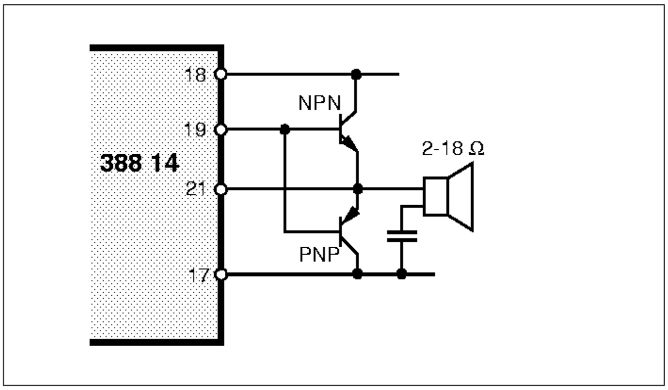



*Figure 18. Connection of external transistors.*

## Ordering Information

| Package | Temp. Range | Part No. |
|---|---|---|
| Plastic DIP | -20 to 70°C | PBL 388 14/1N |
| Plastic SO24 | -20 to 70°C | PBL 388 14/1SO |
| Plastic SO24 | -20 to 70°C | PBL 388 14/1SO:T (Tape and Reel) |
| Plastic SO20 | -20 to 70°C | PBL 388 14/2SO |
| Plastic SO20 | -20 to 70°C | PBL 388 14/2SO:T (Tape and Reel) |