

# PBL 388 12

## Voice-switch circuit for Handsfree speakerphone TAM

### Description

The PBL 388 12 contains all the necessary circuitry, amplifiers, detectors, comparators and control functions to implement a high performance, voice-switched, "hands-free " function in an answering machine. The gain dynamics (attenuation between channels) is settable (25dB or 50dB) via CTR pin that also control two mute levels. A background noise detector in the transmitting channel reduces the influence of continuous noise signals.

The PBL 388 12 is designed for answering machines that are either powered from the telephone line or from a mains powered dc. supply.

Filtering of both the audio and control signals in both transmitter and receiver channels possible.

An external loudspeaker amplifier has to be used, normally the same as used for the answering machine.

All figures in this paper refer to 16-pin SO package.

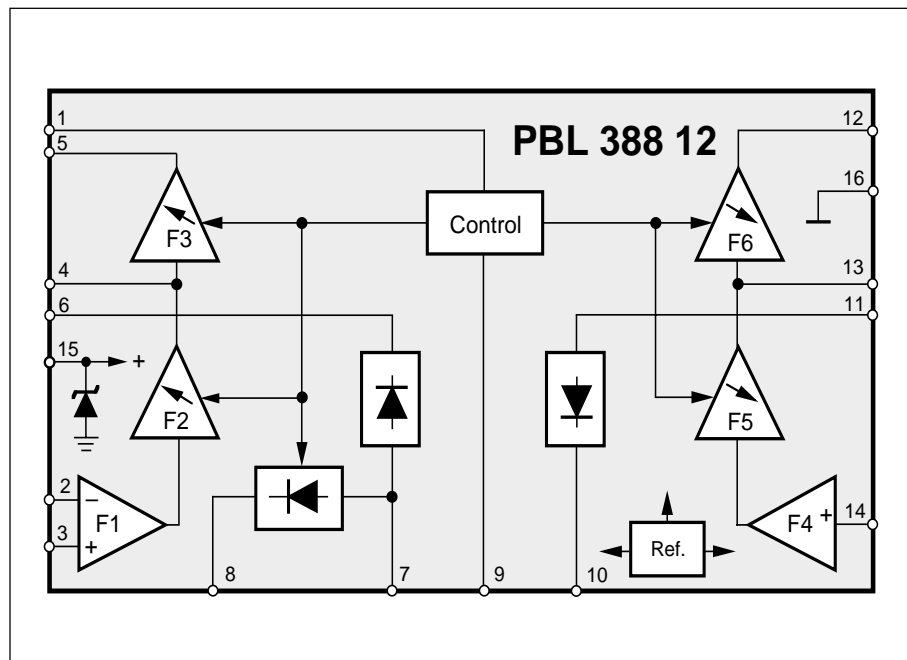
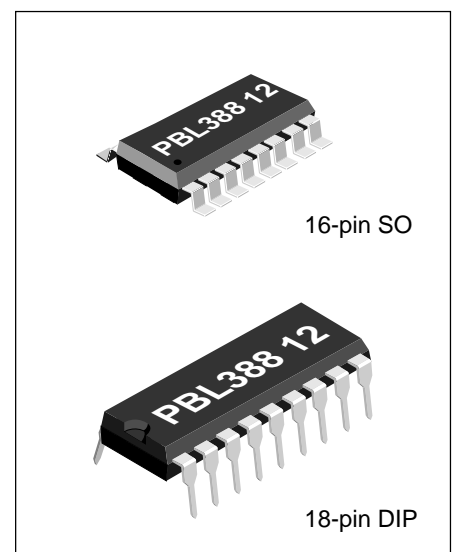


Figure 1. Block diagram. ( SO - package )

### Key Features

- Settable gain dynamics (25 or 50 dB).
- Low power consumption, totally 1.0mA at 3.3V typical.
- Background noise compensation in the transmitting channel with hold function.
- Excellent noise performance.
- Both channel input amplifiers have balanced inputs.
- Minimum of external components needed for function.
- 16-pin SO and 18-pin DIP encapsulation.



### Maximum Ratings

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

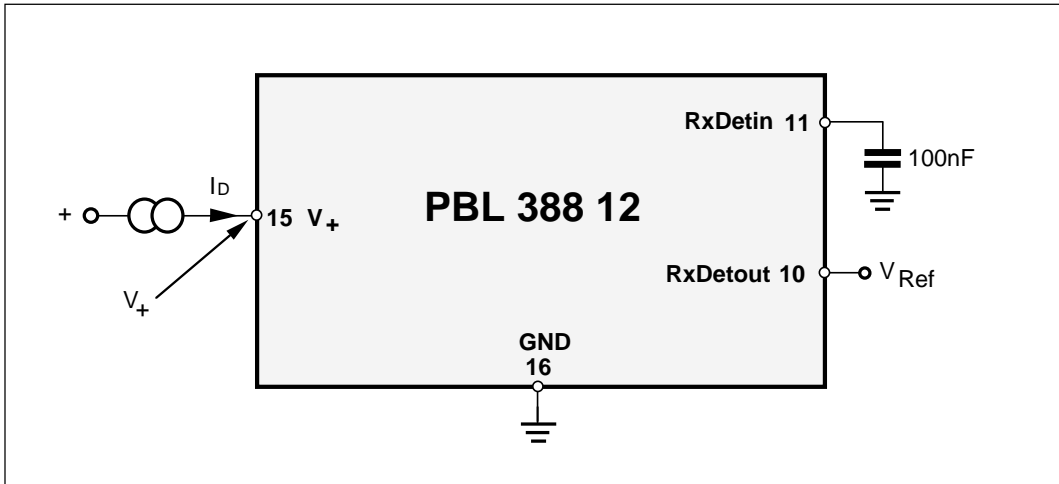


Figure 2. Isolation and measurement of  $V_{Ref}$  Reference figure No.2.

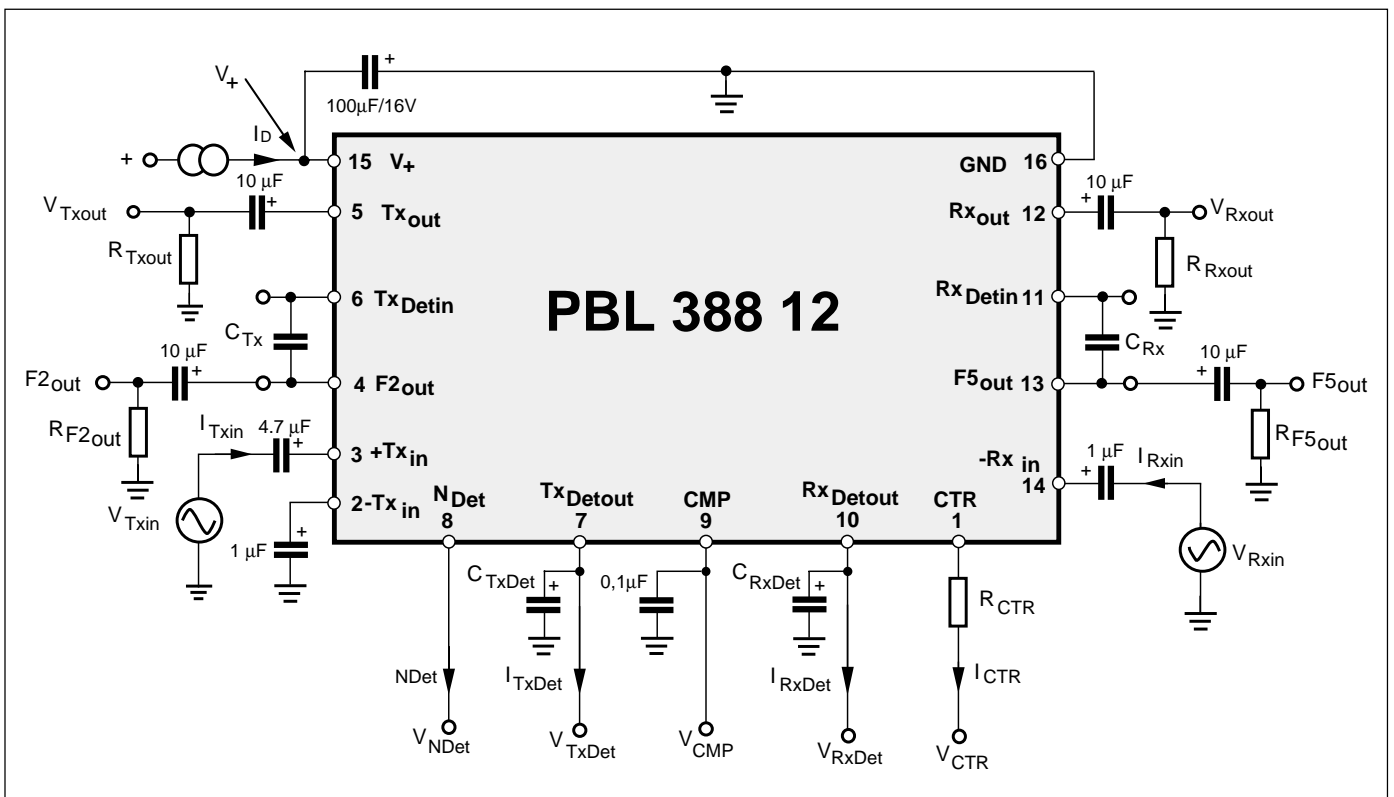


Figure 3. Test circuit. Reference figure No. 3.

## Electrical Characteristics

f = 1 kHz, T = 25°C, R<sub>CTR</sub>=0, C<sub>TxDet</sub> = 0, R<sub>Txout</sub> = ∞, R<sub>Rxout</sub> = ∞, R<sub>F2out</sub> = ∞, R<sub>F5out</sub> = ∞, R<sub>Tx</sub> = 0, R<sub>Rx</sub> = 0, C<sub>RxDet</sub> = 0 and I<sub>D</sub>=1.0mA unless otherwise noted.

| Parameter   | Ref. fig. | Condition  | Min.     | Typ. | Max.  | Unit.             |
|---|-----------|--|----------|------|-------|-------------------|
| <b>Speech control section</b>   |           |  |          |      |       |                   |
| Terminal voltage, V <sub>+</sub>  | 3         | I <sub>D</sub> = 1.0mA   |          | 3.3  |       | V                 |
| Internal reference voltage, V <sub>Ref</sub>  | 2         |  |          | 1.96 |       | V                 |
| Frequency response for all amplifiers   | 3         | 200 - 3400 Hz, Relative 1 kHz  | -1       |      | 1     | dB                |
| Transmit gain, 20 • <sup>10</sup> log(V <sub>Txout</sub> / V <sub>Txin</sub> )              | 3         | V <sub>CMP</sub> = V <sub>Ref</sub> - 0.1 V  | 41.5     | 44   |       | dB                |
|   |           | V <sub>CMP</sub> = V <sub>Ref</sub> + 0.1 V  |          | -6   | -3.5  | dB                |
|   |           | V <sub>CMP</sub> = V <sub>Ref</sub> - 0.1 V R <sub>CTR</sub> =100k, V <sub>CTR</sub> =V+ | 41.5     | 44   |       | dB                |
|   |           | V <sub>CMP</sub> = V <sub>Ref</sub> + 0.1 V R <sub>CTR</sub> =100k, V <sub>CTR</sub> =V+ |          | 19   | 21.5  | dB                |
| Receive gain, 20 • <sup>10</sup> log(V <sub>Rxout</sub> / V <sub>Rxin</sub> )               | 3         | V <sub>CMP</sub> = V <sub>Ref</sub> + 0.1 V  | 26.5     | 29   |       | dB                |
|   |           | V <sub>CMP</sub> = V <sub>Ref</sub> - 0.1 V  |          | -21  | -18.5 | dB                |
|   |           | V <sub>CMP</sub> = V <sub>Ref</sub> + 0.1 V R <sub>CTR</sub> =100k, V <sub>CTR</sub> =V+ | 26.5     | 29   |       | dB                |
|   |           | V <sub>CMP</sub> = V <sub>Ref</sub> - 0.1 V R <sub>CTR</sub> =100k, V <sub>CTR</sub> =V+ |          | 4    | 6.5   | dB                |
| Max transmit detector gain, 20 • <sup>10</sup> log(V <sub>Txdet</sub> / V <sub>Txin</sub> ) | 3         | V <sub>TxDet</sub> < 200 mV <sub>p</sub> , C <sub>Tx</sub> = 100nF                       |          | 67.5 |       | dB                |
|   |           | V <sub>CMP</sub> = V <sub>Ref</sub> - 0.1 V  |          | 42.5 |       | dB                |
|   |           | V <sub>CMP</sub> = V <sub>Ref</sub> + 0.1 V  | 37       |      |       | dB                |
| Max receive detector gain, 20 • <sup>10</sup> log(V <sub>Rxdet</sub> / V <sub>Rxin</sub> )  | 3         | V <sub>RxDet</sub> < 200 mV <sub>p</sub> , C <sub>Tx</sub> = 100nF                       |          | 53   |       | dB                |
|   |           | V <sub>CMP</sub> = V <sub>Ref</sub> + 0.1 V  |          | 28   |       | dB                |
|   |           | V <sub>CMP</sub> = V <sub>Ref</sub> - 0.1 V  | 22.5     |      |       | dB                |
| Background noise rectifier gain, (note 1)   | 3         | V <sub>CMP</sub> = V <sub>Ref</sub> - 0.1 V, C <sub>Txdet</sub> =1μF                     |          | 6.0  |       | dB                |
|   |           | V <sub>CMP</sub> = V <sub>Ref</sub> + 0.1 V, C <sub>Txdet</sub> =1μF                     |          | Hold |       |                   |
| + Tx <sub>in</sub> input impedance  | 3         |  | 80       | 100  | 120   | kΩ                |
| - Tx <sub>in</sub> input impedance  | 3         |  | 2.4      | 3.0  | 3.6   | kΩ                |
| - Rx <sub>in</sub> input impedance  | 3         |  | 16       | 20   | 24    | kΩ                |
| Tx <sub>Out</sub> ac, load impedance  | 3         |  | 10       |      |       | kΩ                |
| Rx <sub>Out</sub> ac, load impedance  | 3         |  | 10       |      |       | kΩ                |
| F2 <sub>Out</sub> ac, load impedance  | 3         |  | 10       |      |       | kΩ                |
| F5 <sub>Out</sub> ac, load impedance  | 3         |  | 10       |      |       | kΩ                |
| Transmitter channel output swing, v <sub>TxOut</sub>  | 3         | 2% distortion, R <sub>Txout</sub> =R <sub>Rxout</sub> =25k Ω                             |          | 500  |       | mV <sub>p</sub>   |
| Receiver channel output swing, v <sub>RxOut</sub>   | 3         | 2% distortion, R <sub>Txout</sub> =R <sub>Rxout</sub> =25k Ω                             |          | 500  |       | mV <sub>p</sub>   |
| Transmitter output noise, v <sub>TxOut</sub>  | 3         | V <sub>CMP</sub> = V <sub>Ref</sub> - 0.1 V, V <sub>TxIn</sub> = 0 V                     |          | -75  |       | dB <sub>psf</sub> |
| Receiver output noise, v <sub>RxOut</sub>   | 3         | V <sub>CMP</sub> = V <sub>Ref</sub> + 0.1 V, V <sub>RxIn</sub> = 0 V                     |          | -75  |       | dB <sub>A</sub>   |
| Tx <sub>Det</sub> sink current, I <sub>TxDetOut</sub>                                       | 3         | V <sub>TxDetIn</sub> = V <sub>Ref</sub> + 0.1 V  |          | -6.0 | -2.5  | mA                |
| Rx <sub>Det</sub> source current, I <sub>RxDetOut</sub>                                     | 3         | V <sub>RxIn</sub> = V <sub>Ref</sub> - 0.1 V   | 2.5      | 6.0  |       | mA                |
| Tx <sub>Det</sub> source current, I <sub>TxDet</sub>  | 3         | V <sub>CMP</sub> = V <sub>Ref</sub> - 0.1 V  |          |      | 30    | μA                |
| Rx <sub>Det</sub> sink current, I <sub>RxDetOut</sub>                                       | 3         | V <sub>RxDetIn</sub> = V <sub>Ref</sub> + 0.1 V  | -30      |      |       | μA                |
| Tx <sub>Det</sub> swing relative to V <sub>Ref</sub> , V <sub>TxDetOut</sub>                | 3         | V <sub>TxDetIn</sub> = V <sub>Ref</sub> + 0.1 V  | (note 2) | -0.7 |       | V                 |
| Rx <sub>Det</sub> swing relative to V <sub>Ref</sub> , V <sub>RxDetOut</sub>                | 3         | V <sub>RxDetIn</sub> = V <sub>Ref</sub> - 0.1 V  | (note 2) | +0.7 |       | V                 |
| N <sub>Det</sub> sink current (fast charge), I <sub>NDet</sub>                              | 3         | V <sub>TxDetIn</sub> = V <sub>Ref</sub> - 0.1 V  |          | -4.5 | -1.5  | mA                |
|   |           | V <sub>CMP</sub> = V <sub>Ref</sub> - 0.1 V  |          |      |       |                   |
| N <sub>Det</sub> source current, I <sub>NDet</sub>  | 3         | V <sub>TxDetIn</sub> = V <sub>Ref</sub> + 0.1 V  | 3        | 5    | 7     | μA                |
|   |           | V <sub>CMP</sub> = V <sub>Ref</sub> + 0.1 V  |          |      |       |                   |

| Parameter   | Ref. fig. | Conditions   | Min. | Typ.  | Max. | Unit.         |
|---|-----------|--|------|-------|------|---------------|
| $N_{\text{Det}}$ leakage current (hold), $I_{\text{NDet}}$                          | 3         | $V_{\text{TxDetIn}} = V_{\text{Ref}} - 0.1 \text{ V}$ ,<br>$V_{\text{CMP}} = V_{\text{Ref}} + 0.1 \text{ V}$ , |      | -100  |      | nA            |
| $N_{\text{Det}}$ swing relative to $V_{\text{Ref}}$ , $V_{\text{NDet}}$             | 3         | $V_{\text{CMP}} = V_{\text{Ref}} - 0.1 \text{ V}$ ,<br>$V_{\text{TxDetIn}} = V_{\text{Ref}} + 0.1 \text{ V}$   |      | -0.45 |      | V             |
| CMP (comparator) sensitivity, transmit (Tx) mode to receive (Rx) mode or vice versa | 3<br>13   | Tx mode = max Tx gain,<br>Rx mode = max Rx gain  |      | 50    | 100  | mV            |
| CTR voltage for 25 dB dynamics, $V_{\text{CTR}}$                                    | 3         | $V_{\text{CMP}} = V_{\text{Ref}} \pm 0.35 \text{ V}$ , $R_{\text{CTR}}=100\text{k}\Omega$                      |      | $V_+$ |      | V             |
| CTR voltage for mute, $I_{\text{CTR}}$  | 3         | $V_{\text{CMP}} = V_{\text{Ref}} \pm 0.35 \text{ V}$   |      |       |      | $\mu\text{A}$ |
| CTR voltage for disable, $V_{\text{CTR}}$   | 3         |  |      |       | 0.55 | V             |

**Notes:**

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

$V_{\text{NDet}}$  = voltage at noise detector output

$V_{\text{Ref}}$  = reference voltage (about 1.9 V) see figure 2.

$V_{\text{TxDet}}$  = Voltage at transmit detector output.

$V_{\text{TxDetO}}$  = 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.

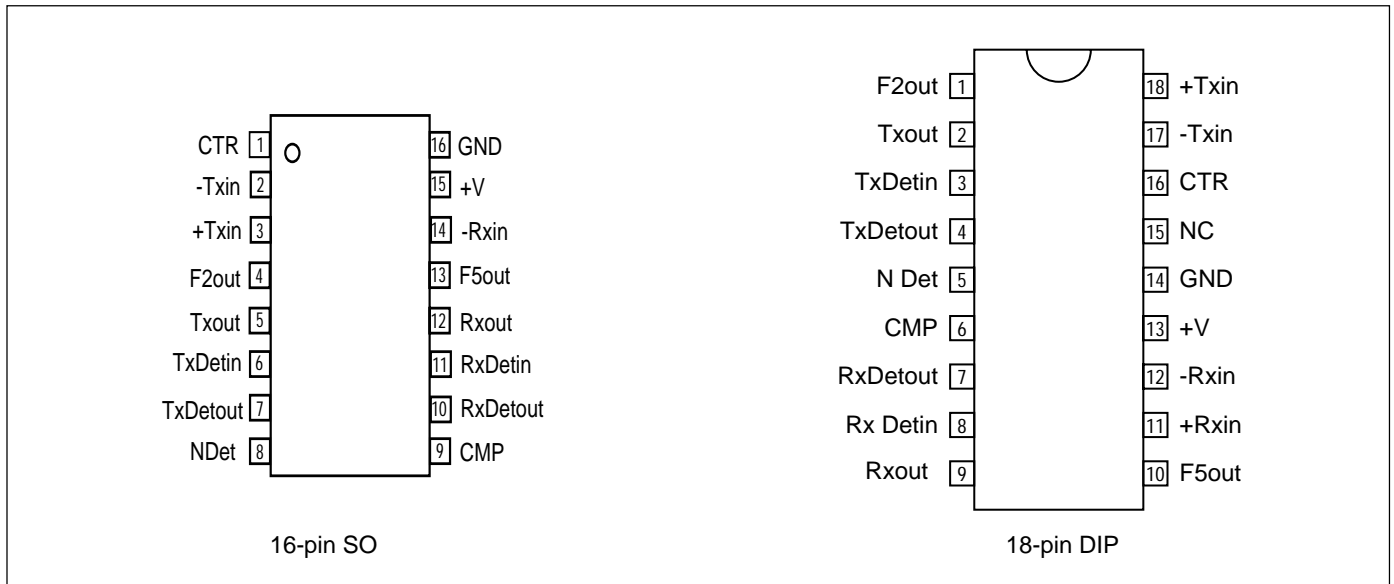


Figure 4. Pin configuration.

**Pin Descriptions:**

Refer to figure 4. (16-pin SO and 18-pin DIP package)

| Pin SO | Pin DIP | Symbol   | Description   | Pin SO | Pin DIP | Symbol   | Description  |
|--------|---------|----------|---|--------|---------|----------|--|
| 1      | 16      | CTR      | Control input for gain dynamics (25 or 50dB), mute and disable.   | 9      | 6       | CMP      | Comparator input.. Summing point to the different detector outputs.  |
| 2      | 17      | -Txin    | Transmitter channel negative input. Input impedance 3 kohm.   | 10     | 7       | RxDetout | Output of the receiver channel signal detector. Goes positive referred to the internal ref. voltage of app. 2V when a receiver signal is present |
| 3      | 18      | +Txin    | Transmitter channel positive input. Input impedance 100 kohm.   | 11     | 8       | RxDetin  | Input of the receiver channel signal detector. Input impedance 13 kohm.  |
| 4      | 1       | F2out    | Output of the second amplifier in the transmitter channel.  | 12     | 9       | Rxout    | Receiver channel output. Min. ac load impedance 10 kohm.   |
| 5      | 2       | Txout    | Transmitter channel output. Min. ac load impedance 10 kohm.   | 13     | 10      | F5out    | Output of the second amplifier in the receiver channel.  |
| 6      | 3       | TxDetin  | Input of the transmitter channel signal detector. Input impedance 13 kohm.  |        | 11      | +Rxin    | Receiver channel positive input. Input impedance 140 kohm.   |
| 7      | 4       | TxDetout | Output of the transmitter channel signal detector. Goes negative referred to the internal ref. voltage of app. 2V when a transmitter signal is present. | 14     | 12      | -Rxin    | Receiver channel negative input. Input impedance 20 kohm.  |
| 8      | 5       | NDet     | Background noise detector output. Goes positive referred to the internal ref. voltage of app. 2V when a background noise signal is present              | 15     | 13      | +V       | Supply of the speech switching circuitry. A shunt regulator, voltage approx. 3.3V at 1.0mA.  |
|        |         |          |   | 16     | 14      | GND      | System ground.   |
|        |         |          |   |        | 15      | NC       | Not connected.   |

## 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 of the amplifiers must be ac. coupled because they are dc. wise at the internal reference voltage ( $\approx 2V$ ) level. F1 and F4 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 comparator receives its 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 F5 and F6 will have minimum gain and vice versa. See figure 5 and figure 11.

The positive input on transmitter and the negative input on receiver channel has a rather high input impedance. It renders a good gain precision and noise performance when used with low signal source impedance. The differential input of the transmitter channel can be used to suppress unwanted signals in the microphone supply, see figure 7. Also see application 1.

### Signal Detectors and Comparator

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.

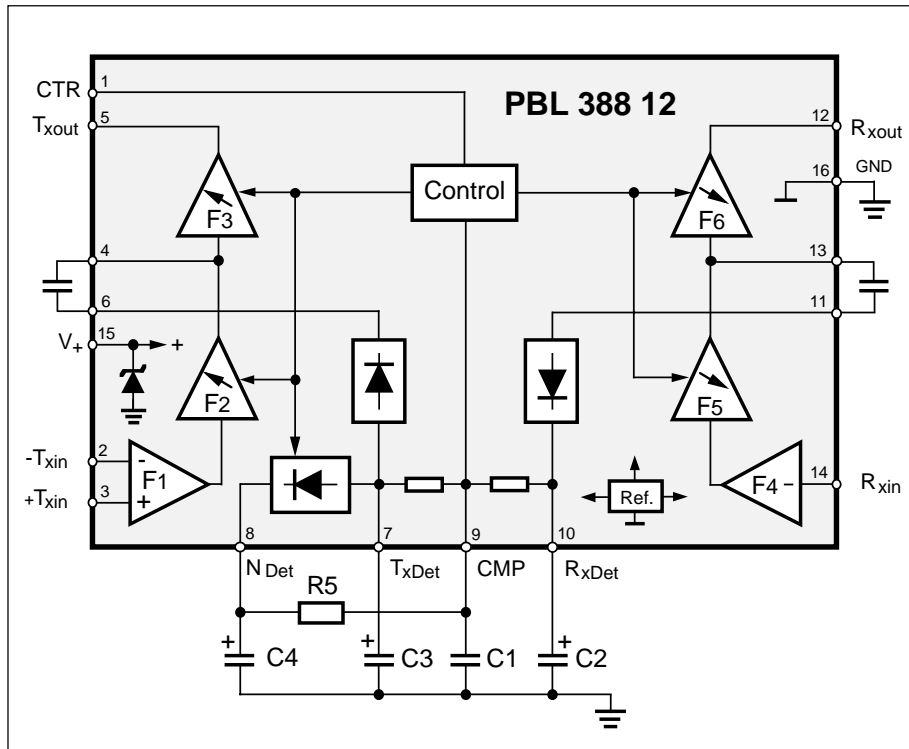


Figure 5. Passive networks setting the speech control function.

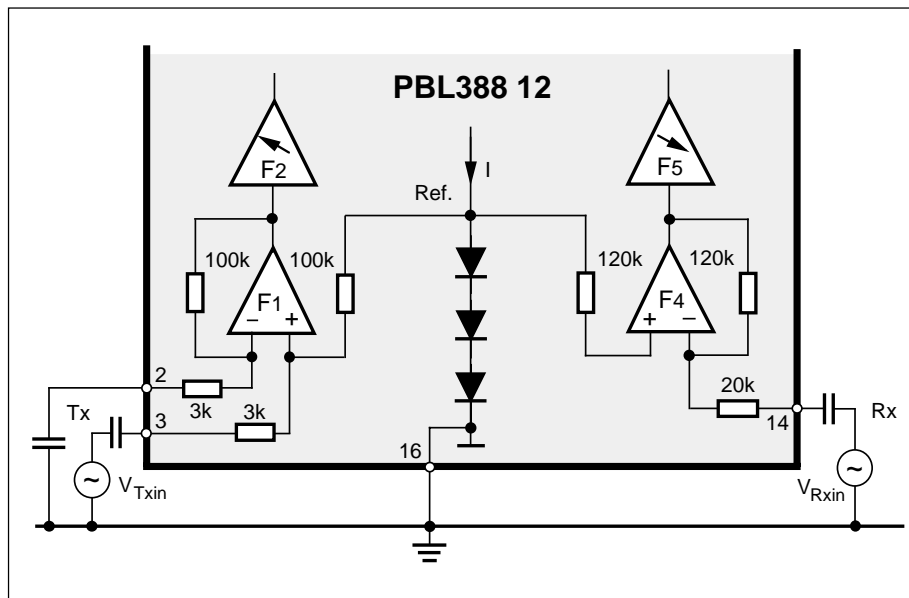


Figure 6. Receiver and transmitter channel input arrangement.

Figure 7. Transmitter channel input amplifier used to suppress ripple in the mic. supply. (CMRR).

$R1 = R2 \approx 3k$   
 $R3 = R4 \approx 100k$   
 $R5 = R6$   
 $C1 = C2$

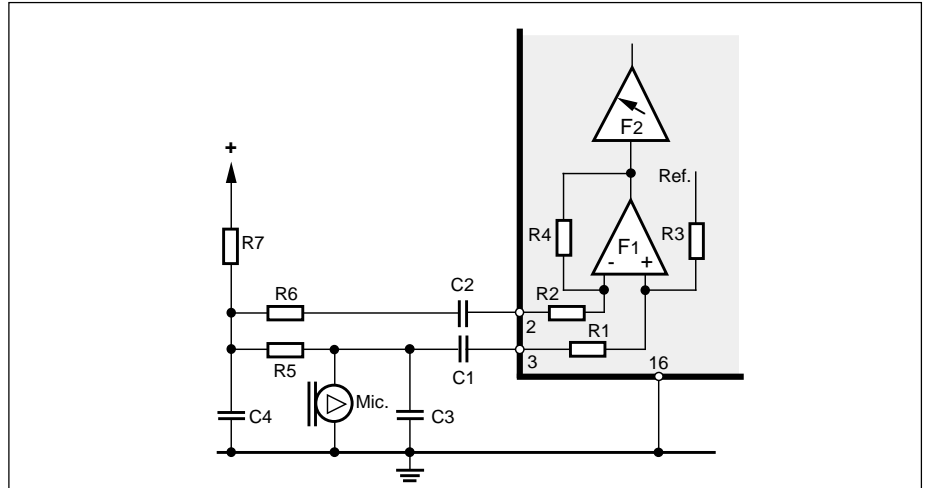


Figure 8. Transmitter and receiver channel rectifier characteristics.

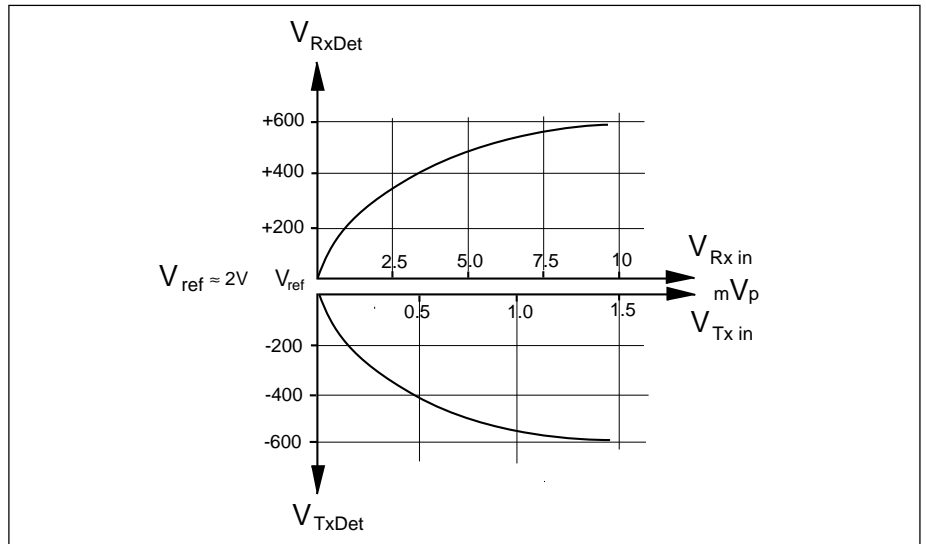


Figure 9. Relationship in timing between the voltage levels at  $Tx_{in}$ ,  $Tx_{Det}$  and  $N_{Det}$

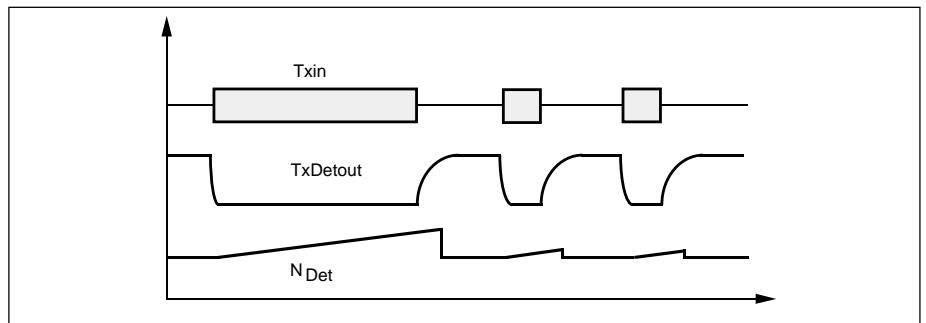
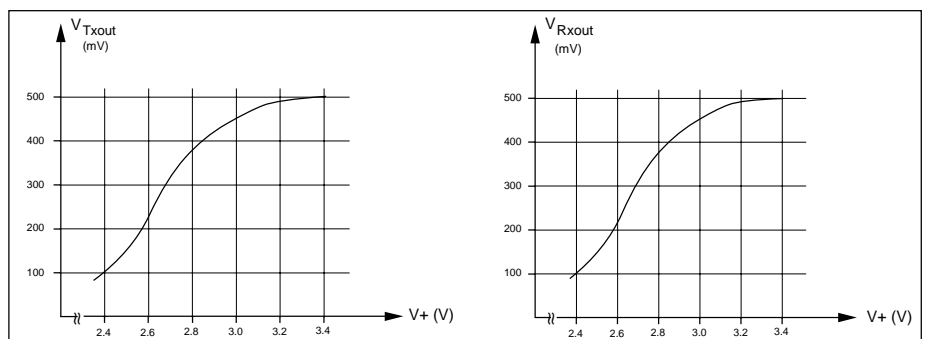


Figure 10. Transmitter and receiver channel output dynamics.



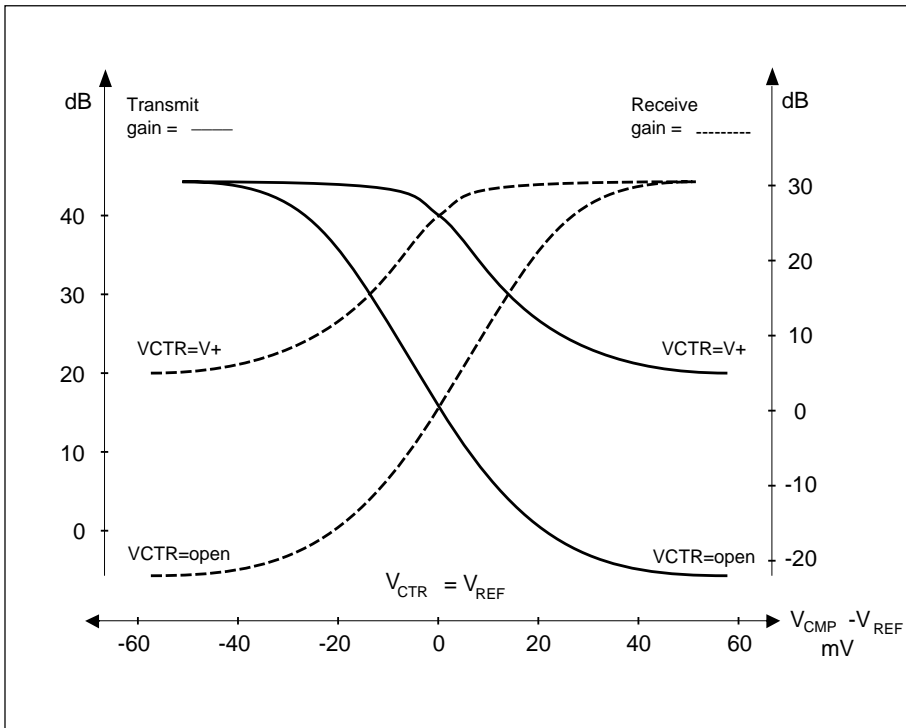


Figure 11. Transmit and receive gain as a function of  $V_{CMP}$  and  $V_{CTR}$ .

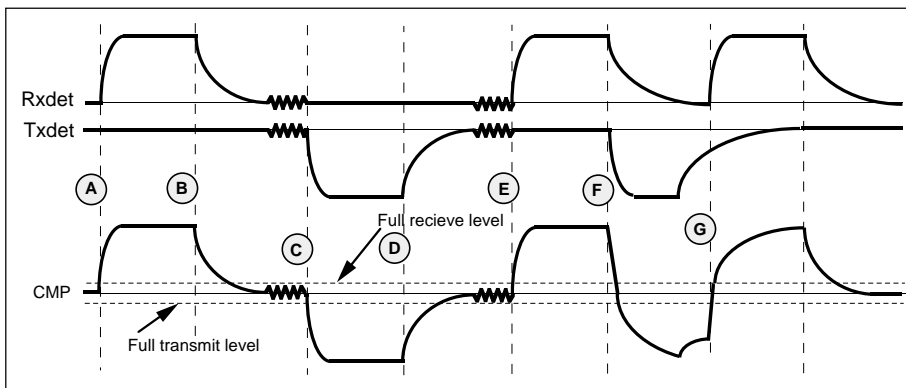


Figure 12. Timing of the transmitter and receiver channels at the CMP-input.

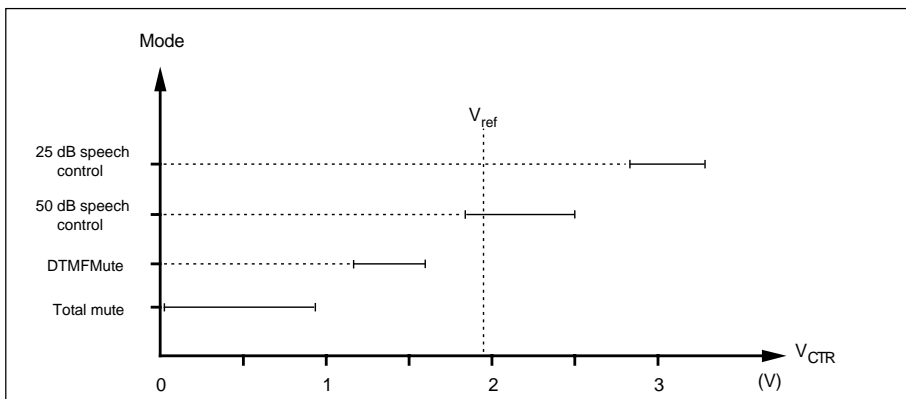


Figure 13. Control modes as function of voltage applied to gain dynamics control input CTR;  $I_D=1mA$ .

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  $1\mu A$ . 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  $200k\Omega$  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 languages. 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 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



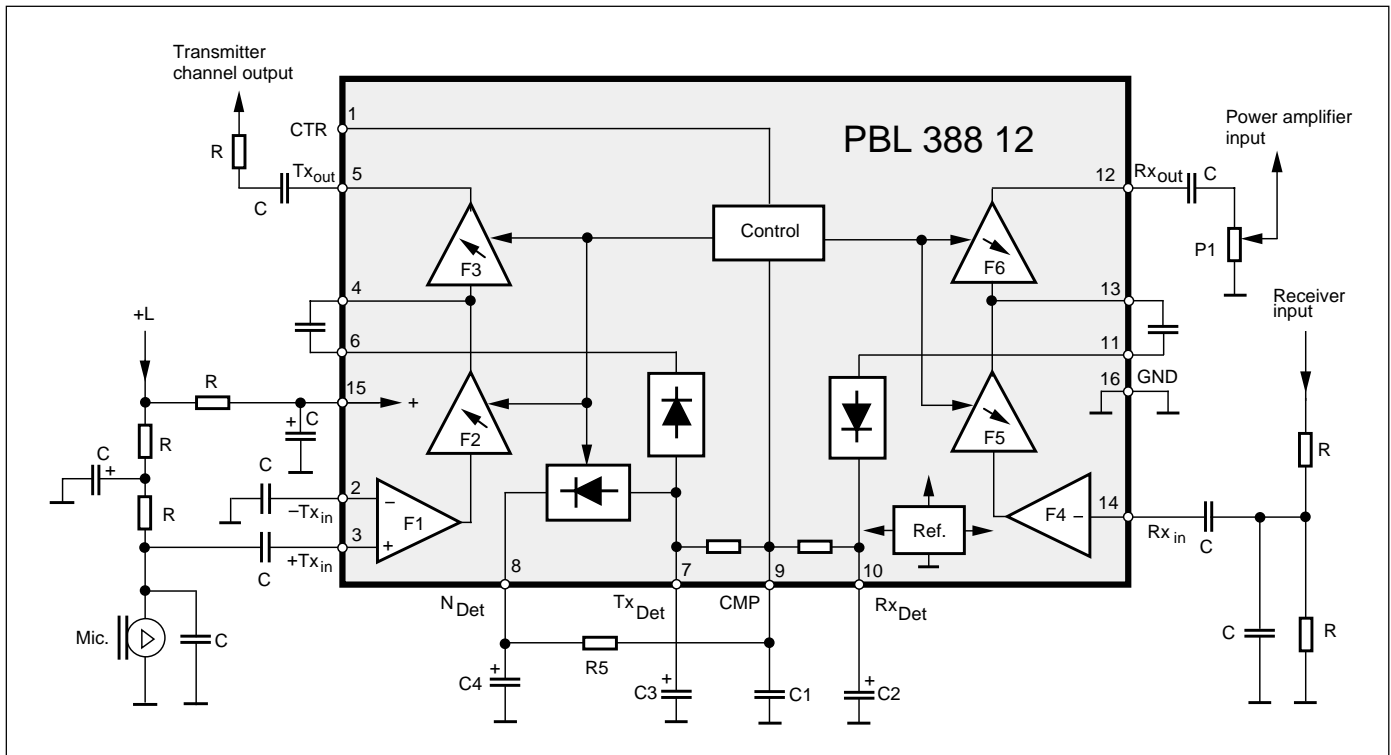


Figure 14. Speech switching arrangement.

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  $\pm 200\text{mV}$  from the internal reference voltage app.  $2\text{V}$ , where the sensitivity for increasing input signals decreases with factor of 10, increasing the detectors dynamic range. See fig.10.

### Background Noise Detector

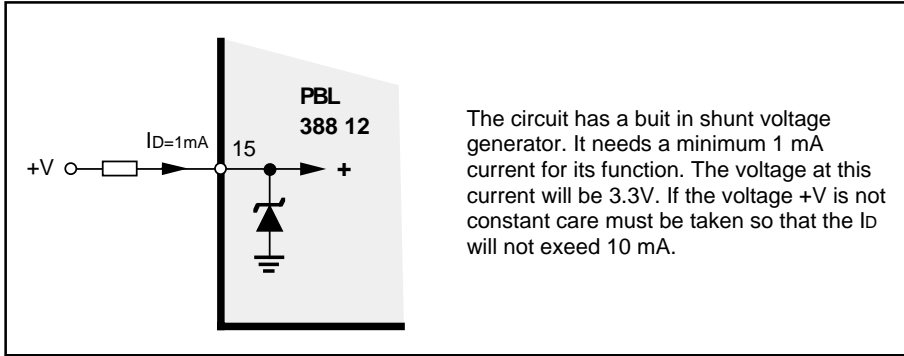
The general function of the background noise detector in the transmitting channel is to create a positive signal (in respect to the reference) so that, when coupled to the summing point at the CMP input, will counteract the signal from the transmitter level detector representing the actual sound pressure level at the microphone. This counteracts the noise from influencing the switching characteristics. The input signal to the background 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 2x (transmitting mode) and has on its output a RC network consisting of an internal resistor of  $100\text{k}$

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 ( $> 10\text{sec.}$ ) the voltage across C4 is pulled negative (relative to the reference) with a time constant set by C4 to e.g.  $5\text{sec.}$ . 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 background detector will not influence the

switching characteristic of the system. See fig. 11. There is a threshold of approx.  $50\text{mV}$  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 ( $50\text{dB}$  attenuation between the channels) this input can be left unconnected. To set the function to  $25\text{dB}$  attenuation the input has to be higher than  $600\text{mV}$  below  $V+$ . See figure 13. To set the circuit into a mute state (results in, reduced gain in receiver channel for the DTMF confidence tone in the loudspeaker and closed transmitter channel) a voltage below  $V_{\text{ref}}$  has to be connected to the input. By lowering the voltage at the input below  $0.9\text{V}$  a condition will emerge where both receiver and transmitter channels are closed. See fig. 11 and 15.



The circuit has a built-in shunt voltage generator. It needs a minimum 1 mA current for its function. The voltage at this current will be 3.3V. If the voltage  $+V$  is not constant care must be taken so that the  $I_D$  will not exceed 10 mA.

Figure 15. Circuit supply function.

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**Ordering Information**

| Package     | Temp. Range | Part No.                         |
|-------------|-------------|----------------------------------|
| Plastic SO  | -20 to 70°C | PBL 388 12/1SO                   |
| Plastic SO  | -20 to 70°C | PBL 388 12/1SO:T (Tape and Reel) |
| Plastic DIP | -20 to 70°C | PBL 388 12                       |