ERICSSON

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# PBL 3781/02 Low Voltage Speech Circuit

## Description

The PBL 3781/02 is a bipolar integrated speech circuit for use in electronic telephones. The circuit is designed to operate at low supply voltage, down to 1.3 V, making it usable when connected in parallel with other telephones.

An electret microphone can be used in either balanced or unbalanced configuration. The high gain, the good balance and low input impedance to ground (CMRR) of the microphone amplifier makes it also suitable for a dynamic microphone**.**

Gain regulation circuitry provides compensation for loop losses in both the transmit and receiver amplifiers.

The receiver amplifier has a balanced push-pull output stage for good driving capability even at low supply voltage.

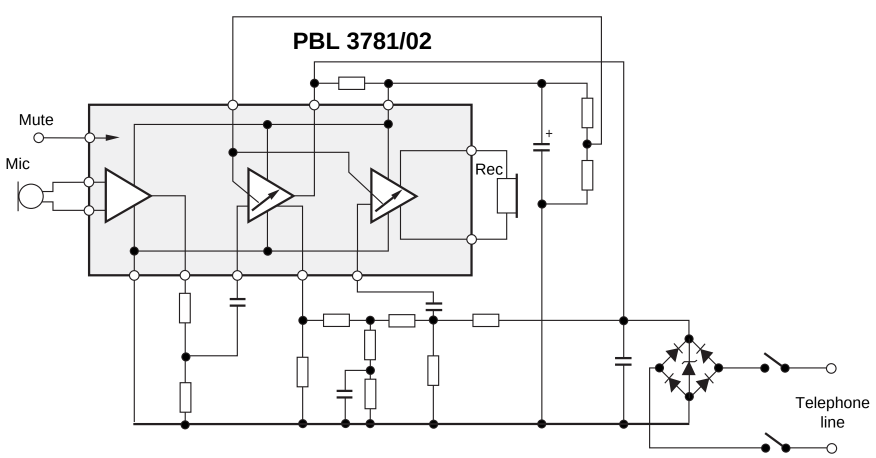
The PBL 3781/02 can drive low impedance receivers.

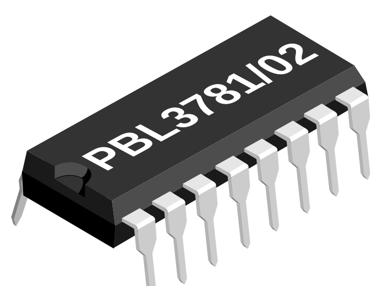
A straight-forward design procedure simplifies adaptation of the circuit to suit different transducers and battery feeding systems.

The impedance towards the line is set with external components. Both real and complex impedance towards the line can be handled.

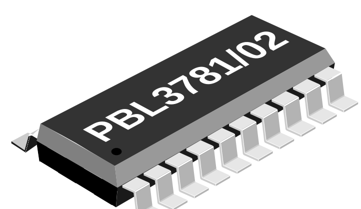
## Key Features

- Low voltage operation, down to 1.3 V DC.
- AC voltage swing down to 0.4 V.
- Transmit and receive gain regulation for automatic loop loss compensation.
- Differential microphone input for dynamic microphone.
- Balanced receiver output stage.
- 16-pin “batwing” DIP handles 1.5 W power dissipation.
- 20-pin small outline package handles 1.3 W power dissipation.




16-pin DIP package




20-pin SO package

*Figure 1. Functional diagram.*

# Maximum Ratings

| Parameter | Symbol | Min | Max | Unit |
|---|---|---|---|---|
| Line current, $T_{Amb}$ = 70 °C | | | | |
| Dual-in-line package | $I_L$ | | 150 | mA |
| Small Outline package | $I_L$ | | 130 | mA |
| Line voltage | | | | |
| Continuous | $V_L$ | | 15 | V |
| $t_p$ = 2 s | $V_L$ | | 18 | V |
| $t_p$ = 10 ms | $V_L$ | | 20 | V |
| Power dissipation, $T_{Amb}$ = 70 °C | | | | |
| Dual-in-line package | | | 1.5 | W |
| Small outline package | | | 1.3 | W |
| Operating temperature range | $T_{Amb}$ | -20 | +70 | °C |
| Storage temperature range | $T_{Stg}$ | -55 | +125 | °C |
| Input Voltage all inputs, except MUTE | | -0.5 | $V_{pin\ 6}$ + -0.5 | V |

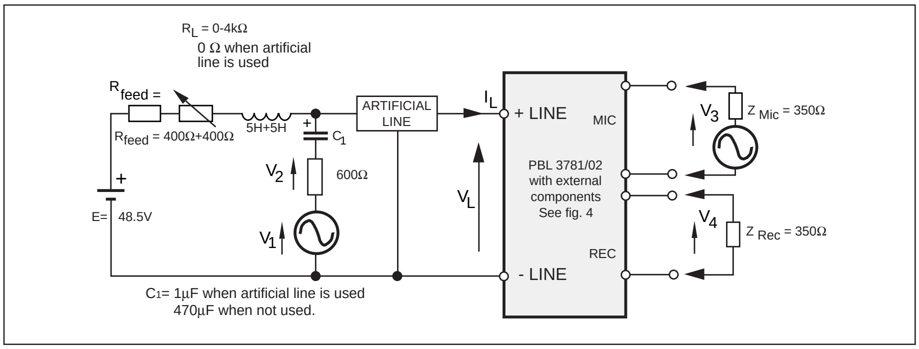



*Figure 2. Test set up without rectifier bridge.*

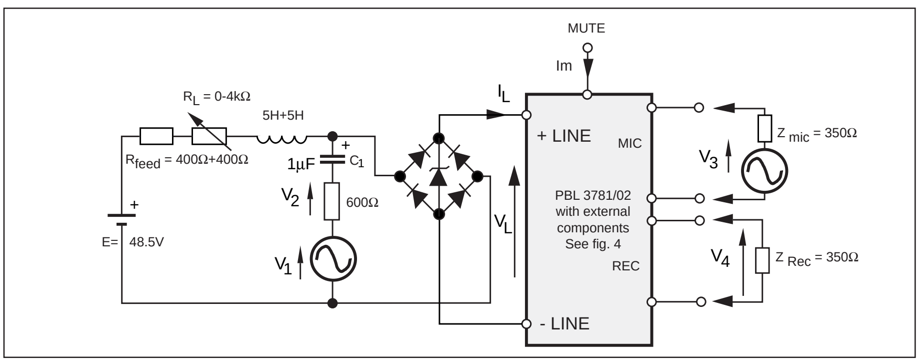



*Figure 3. Test set up with rectifier bridge.*

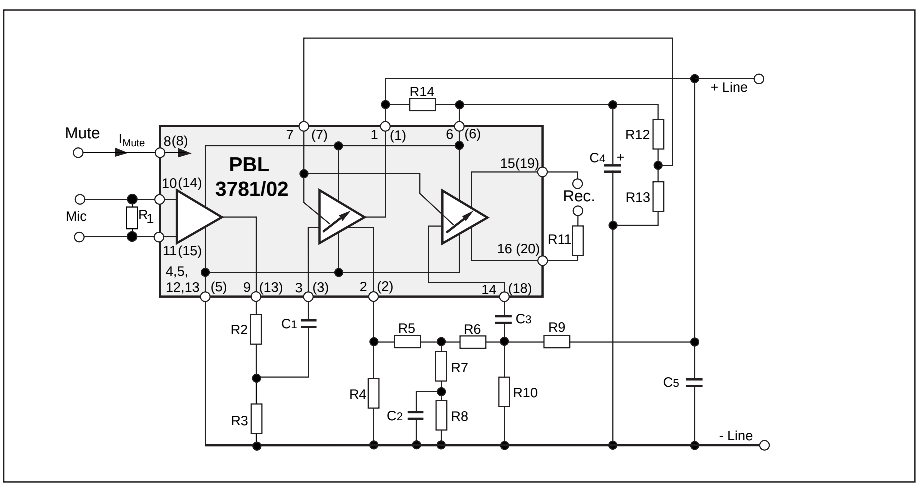



*Figure 4. PBL 3781/02 with external components for test-circuits in figures 2 and 3. SO-pin number within brackets.*

*R1 = 1.8kΩ*
*R2 = 9.6kΩ*
*R3 = 3.9kΩ*
*R4 = 75Ω*
*R5 = 240Ω*
*R6 = 6.2kΩ*
*R7 = 47Ω*
*R8 = 800Ω*
*R9 = 62kΩ*
*R10 = 11kΩ*
*R11 = 310Ω*
*R12 = 47kΩ*
*R13 = 39kΩ*
*R14 = 830 Ω*
*C1 = 150nF*
*C2 = 0.22 µF*
*C3 = 47nF*
*C4 = 68µF*
*C5 = 15nF*

## Electrical Characteristics

$T_{Amb}$ = 25 °C. Measured using test circuit of fig. 2 and 3 without artificial cable, unless otherwise noted.

| Parameter | Ref. fig. | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Line voltage, $V_L$ | | $R_4$ = 47 Ω | | | | |
| | 2 | $I_L$ = 2.5 mA | | 1.3 | | V |
| | 2 | $I_L$ = 10 mA | | 3.0 | | V |
| | 2 | $I_L$ = 100 mA | | 8.5 | | V |
| | | $R_4$ = 75 Ω | | | | |
| | 2 | $I_L$ = 2.5 mA | | 1.5 | | V |
| | 2 | $I_L$ = 10 mA | | 3.2 | 3.9 | V |
| | 2 | $I_L$ = 100 mA | | 11.1 | 13.6 | V |
| Maximum transmitting gain, $V_2$, $V_3$ | | $20 \bullet {}^{10}\log (V_2/V_3)$, f = 1kHz | | | | |
| | 2 | $R_L$ = 0 Ω, $R_2$ = 0 Ω, $R_3$ = ∞, $R_4$ = 47 Ω | | 57 | | dB |
| | 2 | $R_L$ = 900 Ω, $R_2$ = 0 Ω, $R_3$ = ∞, $R_4$ = 47 Ω | | 62 | | dB |
| Transmitting gain, gain versus line resistance, $V_2$, $V_3$. See figure 6. | | $20 \bullet {}^{10}\log (V_2/V_3)$ f = 1 kHz, (adjustable with $R_2$ & $R_3$) | | | | |
| See note1. | 2 | $R_L$ = 0 Ω | 41 | 43 | 45 | dB |
| | 2 | $R_L$ = 400 Ω | 43.5 | 45.5 | 47.5 | dB |
| | 2 | $R_L$ = 900 Ω | 46 | 48 | 50 | dB |
| Transmitting gain, range of regulation | 2 | f = 1 kHz , $R_L$ = 0 to 900 Ω | 3 | 5 | 7 | dB |
| Transmitting frequency response | 2 | 200-3400 Hz | -1 | | +1 | dB |
| Change of transmitting gain at mute | | f = 1 kHz | | | | |
| | 2 | $R_L$ = 0 Ω– 900 Ω | | 60 | | dB |
| Maximum receiving gain, $V_4$, $V_1$ | 2 | $20 \bullet {}^{10}\log (V_4/V_1)$, f = 1 kHz | | | | |
| | 2 | $R_L$ = 0 Ω, $R_{10}$ = ∞, $R_{11}$ = 0 Ω | | -8 | | dB |
| | 2 | $R_L$ = 900 Ω, $R_{10}$ = ∞, $R_{11}$ = 0 Ω | | -3 | | dB |
| Receiving gain, gain versus line resistance, $V_4$, $V_1$ | | $20 \bullet {}^{10}\log (V_4/V_1)$ f = 1 kHz, (Adjustable with R10) | | | | |
| See note 2. | 2 | $R_L$ = 0 Ω | -18.5 | -16.5 | -14.5 | dB |
| | 2 | $R_L$ = 400 Ω | -16 | -14 | -12 | dB |
| | 2 | $R_L$ = 900 Ω | -13.5 | -11.5 | -9.5 | dB |
| Receiving gain, range of regulation | 2 | f = 1 kHz, $R_L$ = 0 to 900 Ω | 3 | 5 | 7 | dB |
| Receiving frequency response | 2 | 200-3400 Hz | -1 | | +1 | dB |

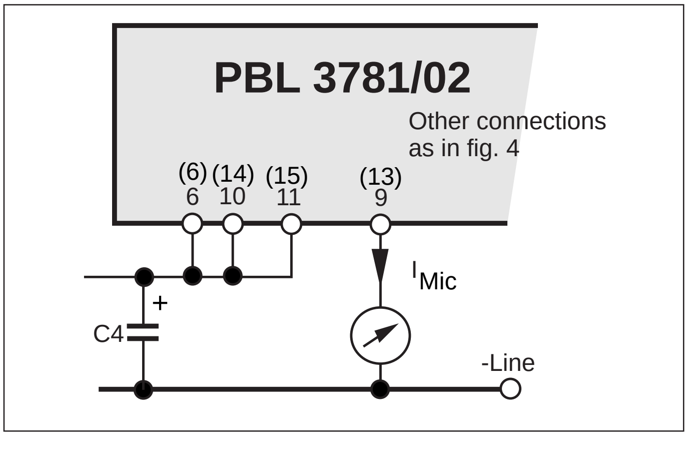



*Figure 5. Microphone amplifier used as a DC-current supply.*

| Parameter | Ref. fig. | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Input impedance microphone amplifier | 2, 4 | f = 1 kHz | | 2.5(//1.8 note 3) | | kΩ |
| Transmitter dynamic output level, $V_2$ | 2 | 200-3400 Hz, THD ≤ 2 %, $I_L$ = 20-100 mA | | 1.5 | | $V_{Peak}$ |
| Transmitter maximum output level, $V_2$ | 2 | 200-3400 Hz, $I_L$ = 0-100 mA, $V_3$ = 0-1 V | | 3.5 | | $V_{Peak}$ |
| Receiver output impedance | 2, 4 | f= 1 kHz | | 6 (+310 note 3) | | Ω |
| Receiver dynamic output level , $V_4$ | 2 | 200-3400 Hz, THD ≤ 2 %, $I_L$ = 20-100 mA | | 0.5 | | $V_{Peak}$ |
| Receiver maximum output level,$V_4$ | 3 | 200-3400 Hz, $I_L$ = 0-100 mA, $V_1$ = 0-50 V | | 1 | | $V_{Peak}$ |
| Transmitter noise level, $V_2$ | 2 | Psophometric weighted relative to 1 Vrms, $R_L$ = 0 | | -70 | | $dB_{Psoph}$ |
| Receiver noise level,$V_4$ | 2 | A-weighted, relative to 1 Vrms, with artificial cable: 0-5 km , Ø = 0.5 mm 0-3 km, Ø = 0.4 mm | | -80 | | $dB_A$ |
| DC current to external microphone amplifier, $I_{Mic}$ | 5 | Pins 10 and 11 to pin 6 $I_L$ = 10-150 mA, DC-current at pin 9 | 300 | | | µA |
| Mute current, $I_{Mute}$ | 4 | $I_L$ = 10-150 mA | 100 | | | µA |

When high sensitive receivers are being used, an external amplitude limiting circuit must be applied, such as two anti-parallel diodes across the output. This will prevent possible acoustic shocks that may cause permanent damage to the human ear.

**Note 1.** For a circuit with a gain of 41 dB at $R_L$ = 0 Ω, the gain will be minimum 46 dB as specified or maximum 48 at $R_L$ = 900 Ω since the gain regulation range must be less than 7 dB (B in fig. 6).
Correspondingly, if the gain is 45 dB at $R_L$ = 0 Ω, the gain will be maximum 50 dB as specified or minimum 48 at $R_L$ = 900 Ω since the gain regulation range must be more than 3 dB (A in fig. 6).

**Note 2.** For a circuit with a gain of -18,5 dB at $R_L$ = 0 Ω, the gain will be minimum -13,5 dB as specified or maximum -11,5 at $R_L$ = 900 Ω since the gain regulation range must be less than 7 dB (B in fig. 7).
Correspondingly, if the gain is -14,5 dB at $R_L$ = 0 Ω, the gain will be maximum -9,5 dB as specified or minimum -11,5 at $R_L$ = 900 Ω since the gain regulation range must be more than 3 dB (A in fig. 7).

**Note 3.** External resistor in test set up.

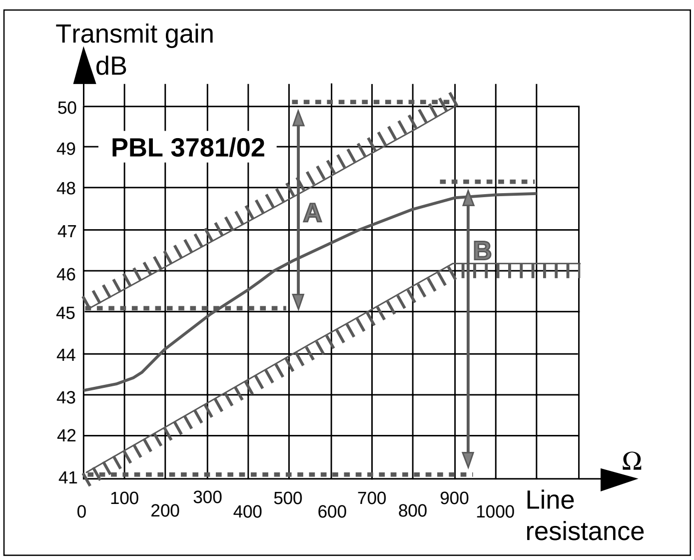



*Figure 6. Transmitting gain, gain versus line resistance.*

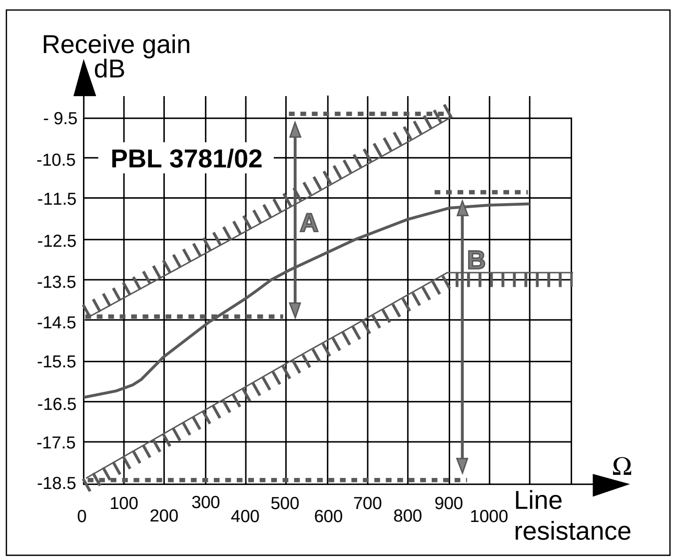



*Figure 7. Receiving gain, gain versus line resistance.*

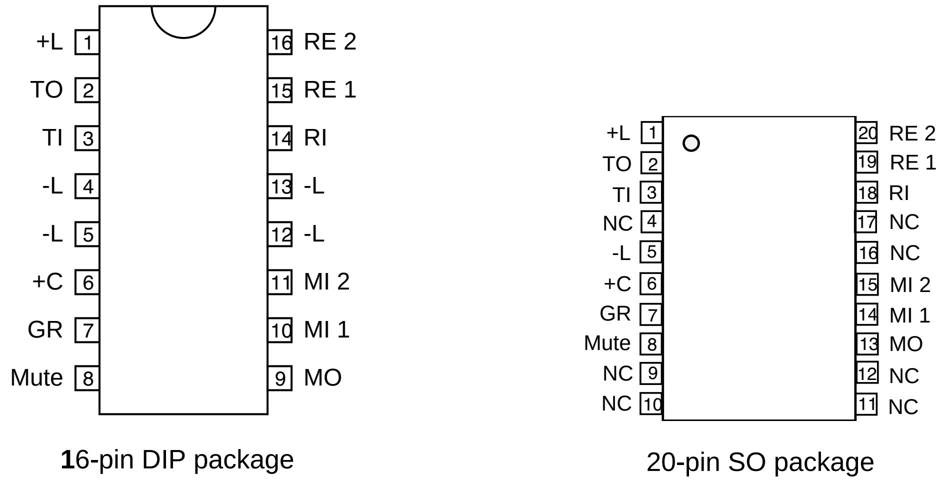



*Figure 8. Pin configuration,16 -pin DIP and 20-pin SO package.*

## Pin Descriptions

Ref. figs. 4 and 8.

| DIP | SO | Name | Description |
|---|---|---|---|
| 1 | 1 | + L | Output of the DC-regulator and transmit amplifier. This pin is connected to the line through a polarity guard diode bridge. |
| 2 | 2 | TO | Output of the sidetone balancing signal. This pin is connected to a resistor $R_4$, 47 Ω to 100 Ω, which sets the DC series-resistance of the circuit. The output has a low AC output impedance, and the signal is used to drive a sidetone balancing network $R_5$, $R_7$, $R_8$ and $C_2$. |
| 3 | 3 | TI | Input of the transmit amplifier. |
| 4, 5, 12,13 | 5 | -L | The negative power terminal, connected to the line through a polarity guard diode bridge. |
| 6 | 6 | +C | This pin is the positive power supply terminal for most of the circuitry inside the PBL 3781/02 (about 1 mA current consumption). The majority of the line current however, passes through the TO and +L pins (see above). The +C pin must be connected to a decoupling capacitor, $C_4$ of 47 to 150 µF. |
| 7 | 7 | GR | Control input for the gain regulation circuitry. |
| 8 | 8 | MUTE | MUTE input that requires min. 100 µA, to mute the microphone and receiver amplifiers. |
| 9 | 13 | MO | Output of the microphone amplifier. When electret microphones are used, this pin can be connected as a current generator output. See functional description for pins 10 and 11 below. |
| 10 | 14 | MI1 | Inputs of the microphone amplifier. The input impedance at these pins is approx, 2.5 kΩ. |
| 11 | 15 | MI2 | Connecting pins 10 and 11 to pin 6, (+C) switches pin 9 (MO) to a current generator output, that sources about 300 µA for an external electret buffer amplifier. |
| 14 | 18 | RI | Input of receiver amplifier. Input impedance approx. 35 kΩ. |
| 15,16 | 19,20 | RE1, RE2 | Receiver amplifier output. The output can drive low impedance receivers. |
| | 4,9 10,11 12,16 17 | NC | Not connected |

## Functional Description

The PBL 3781/02 contains a DC-regulator, microphone amplifier, transmit amplifier and a receiver amplifier.

The DC-regulator determines the voltage/current characteristics of the circuit. Looking from the line, the circuit acts as a reference voltage of approx. 2.8 volts in series with a resistor (externally set). The voltage reference is derived from a bandgap reference, which provides for temperature-stable DC-characteristics. To maintain operation even when the line voltage (inside polarity guard diode bridge) drops below 2.5 Volts, the circuit automatically changes to a lower reference voltage.

A microphone amplifier with a differential input stage, hence with a good common mode rejection, is provided for low-sensitivity magnetic or dynamic microphones. Connection of a standard electret microphone is shown in fig. 11, 14 and 15. The microphone amplifier can be used as a constant current source (300 µA) by connecting both inputs to circuit + (pin 6) figure 5.

The transmit amplifier receives its input signal from the microphone amplifier and from the DTMF-generator. The transmit output stage contains the previously described DC-regulator. The AC-gain is regulated with the line length (selectable), and the output level is amplitude limited to eliminate side tone distortion at high transmitting levels.

The side tone cancellation (or hybrid function) works as follows: A signal, opposite in phase from the transmit signal on the line, is taken from the transmit amplifier (pin 2) and fed through a side tone balancing network into the summing junction of the receiver amplifier. The (not inverted) signal from the line is added, and side tone cancellation occurs. Only the receive signal, is left at the input of the receiver amplifier.

The AC-gain of the receiver amplifier is regulated with the line length (if required). The output from the receiver amplifier can drive low-impedance medium sensitivity receivers. An internal clipping network limits the signal to the earphone, and prevents acoustic shocks.

## Applications Information

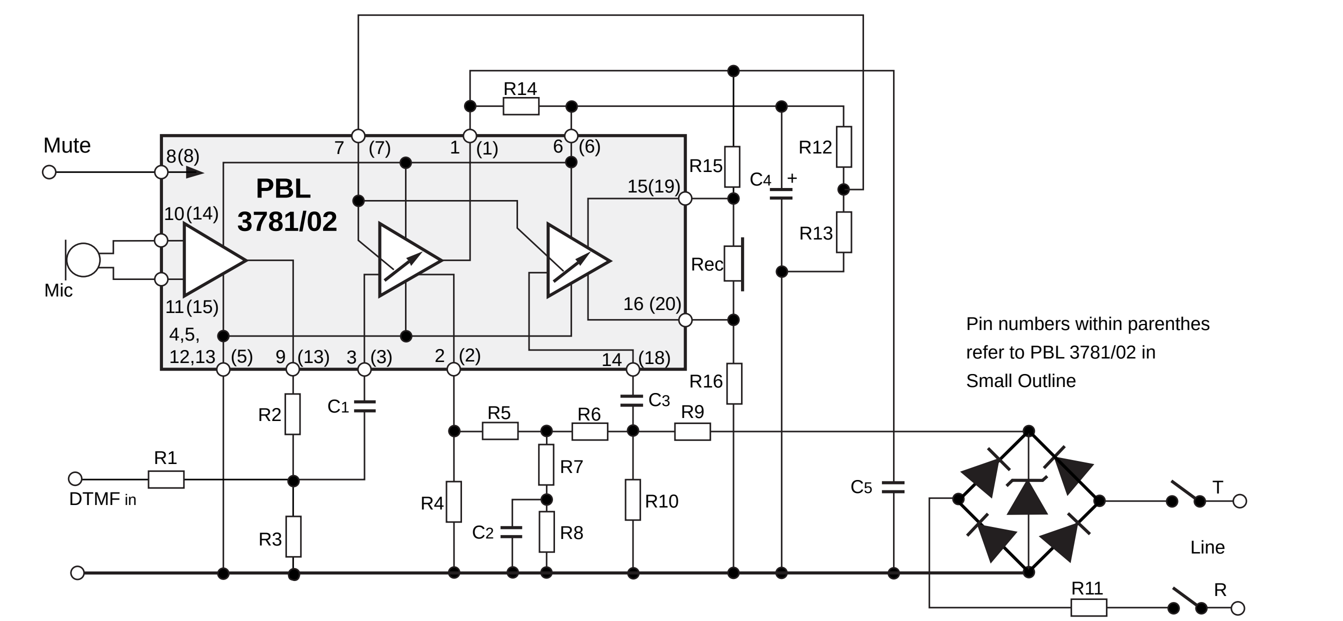
The PBL 3781/02 is a flexible circuit designed to meet specifications from telephone administrations all over the world. Adaptation to different battery feeding systems and transducers is made by selecting the values of a few external components. Figure 9 shows the PBL 3781/02 and associated components in a basic telephone speech network. To complete a design of an electronic telephone, the circuit needs to be supplemented by a tone ringer and a DTMF or pulse dialler circuit.

When proceeding through a design, some of the circuit adjustments will interact with each other. It is therefore recommended to set the parameters as follows in order to avoid interaction:

1. Impedance to the line.
2. DC-characteristics.
3. Microphone selection, transmitting gain and frequency response.
4. Gain regulation.
5. Side-tone level, receiving gain and frequency response.

### Impedance to the line

The output impedance of the circuit is determined by $R_{14}$ in parallel with $C_5$. $R_{14}$ is normally set to a value between




R1 = Adjust for DTMF levels
R2 = 12 kΩ
R3 = 4.7 kΩ
R4 = 75Ω
R5 = 300 Ω
R6 = 6.2 kΩ
R7 = 82 Ω
R8 = 800 Ω
R9 = 62 kΩ
R10 = 3.1 kΩ
R11 = 5 to 10 Ω
R12 = 47 kΩ
R13 = 36 kΩ
R14 = 910 Ω
R15 = 47 kΩ
R16 = 47 kΩ
C1 = 68 nF
C2 = 0.22 µF
C3 = 47 nF
C4 = 100 µF
C5 = 15 nF
Z = 15 V Zener diode , 5 W

Diodes are 1N4004

*Figure 9. Basic application for 48V, 2 X 400 ohms battery feeding system and dynamic microphone and receiver.*

600 and 900 Ω to satisfy the return loss requirement towards both real and complex impedances. $R_{14}$ also supplies the operating current for the majority of the circuit inside PBL 3781/02.

It is recommended to select a value near 900 Ω, in order to maximize the available output level from the transmit amplifier. A lower value of $R_{14}$ requires a larger capacitor $C_4$ to stabilize the supply voltage at pin 6.

### DC-characteristics

The DC-behaviour is adjusted by resistor $R_4$, which determines the slope of the V-I curve. For line currents above 10 mA, the circuit follows the equation:

$V_{circuit} \approx 2.8 + 1.1 \times R_4 \times I_{line}$.

The minimum working voltage is approximately 1.3 volts, which corresponds to about 2.5 mA line current with $R_4 = 47\ \Omega$.

$R_4$ should be selected to give a safe operating point at very short loops. A low value results in excessive current through the circuit, while a larger resistance may raise the voltage above the rated maximum. Suitable values of $R_4$ ranges from 47 to 100 Ω depending on the specified DC-characteristic.

### Microphone selection, transmitting gain and frequency response

The microphone amplifier section is intended for low-sensitivity dynamic microphones and provides about 26 dB voltage gain. A differential input stage (pins 10(14) and 11(15)) gives a good common mode rejection.

The total transmitting gain is adjusted by a resistive attenuator $R_2$ and $R_3$. Capacitor $C_1$ is inserted to give a low-frequency cut-off in the transmit path. The values of $R_2$ and $R_3$ should be selected to present about 3 kΩ source impedance for the transmit amplifier input at pin 3.

The transmit amplifier has a current generator output which means that the voltage gain is partly determined by the ratio between $R_{14}$ in parallel with the line impedance and $R_4$. The voltage gain from the input at pin 3 to the output (pin 1) varies approximately between 32 and 37 dB over the regulation range with R14 = 900 Ω, $R_4 = 47\ \Omega$ and a line impedance of 600 Ω. The available gain is therefore enough to enable an electret microphone to be connected directly to pin 3. In such a case, it is necessary to make a separate mute of the electret microphone since the transmit amplifier itself is not affected by the MUTE input.

A constant current generator at pin 9(13), which is switched off when the circuit is muted, is available if pins 10(14) and 11(15) are connected to pin 6. Another method of interfacing an electret microphone is shown in figure 11 and 14.

### Gain regulation (Loop loss compensation)

Automatic gain regulation (loop loss compensation) circuitry in the transmit and receiver amplifiers increases the gain with the loop length, see figure 10.

The control voltage for the gain regulation is fed into pin 7. By changing the resistive attenuator consisting of $R_{12}$ and R13, it is possible to change the location of the regulation curve to get a correct compensation in different battery feeding systems. The slope of the curve is mostly set by $R_4$. Typical values for $R_{12}$ and $R_{13}$, for some different feeding systems are shown in the following table:

| Battery feed | $R_4$ | $R_{12}$ | $R_{13}$ |
|---|---|---|---|
| No regulation all feedings: | | | |
| set for short line length | | 47 kΩ | ∞ |
| set for long line length | | ∞ | 0 Ω |
| Regulation: | | | |
| 48V, 2 x 200 Ω | 47 Ω | 43 kΩ | 30 kΩ |
| 48V, 2 x 400 Ω | 75 Ω | 47 kΩ | 39 kΩ |
| 60V, 2 x 600 Ω | 75 Ω | 47 kΩ | 39 kΩ |
| 48V, 2 x 800 Ω | 100 Ω | 43 kΩ | 56 kΩ |

The automatic gain regulation is inhibited by the mute signal. The microphone amplifier and the receiver amplifier are cut off. The gain at mute is always equal to the transmitter gain at short line length independent of if the regulation is used or if the gain is set for long line length. This allows DTMF-transmission without automatic gain regulation. A confidence tone is feed to the earphone via two 47 kΩ internal resistors connected to + line and - line.

Gain regulation can be cut off completely by tying pin 7 to ground (pins 4, 5, 12, 13 in DIP and (5) in Small Outline.

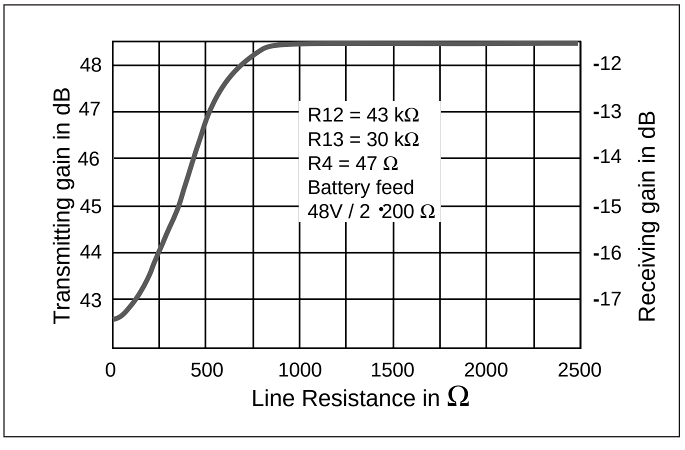



*Figure 10. Typical gain regulation curve.*

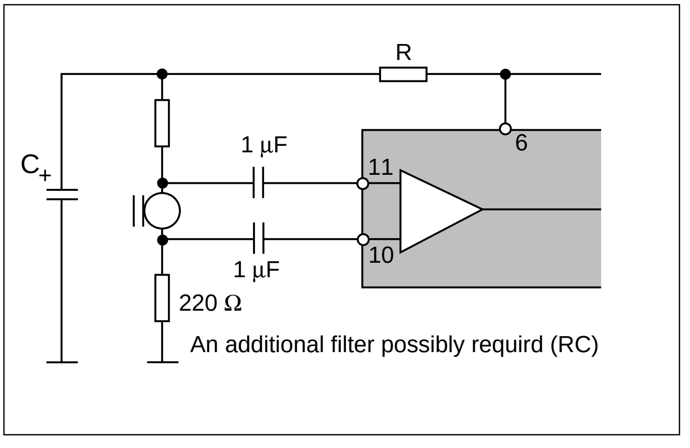



*Figure 11. Balanced electret microphone connection.*

**Side-tone level, receiving gain and frequency response**

Side-tone cancellation occurs at the input of the receiver amplifier (pin 14/(18)) which receives opposite-phased transmit signals from the line and the side-tone network respectively.

Resistor $R_5$ and the actual balancing network consisting of $R_7$, $R_8$ and $C_2$, simulates a first order approximation of the output impedance of the circuit and the line impedance. A practical sequence to determine the component values for the side-tone network is given below. Observe that some iterations and experimental work has to be carried out to find an optimum solution.

1. Choose the value of $R_5$ two to four times the value of $R_4$.
2. $R_7$, $R_8$ and $C_2$ should simulate the amplitude and phase response of the line impedance seen at the line terminals. The impedance level of the balancing network should be about one tenth of the line impedance. The values given in figure 9 are a good starting point for most cases.
3. The ratio between $R_6$ and $R_9$ should be set to make the signals coming from the line and from the side-tone network equal in amplitude so that cancellation occurs. The value of $R_6$ should be about an order of magnitude larger than the impedance level of the balancing network.
4. $R_{10}$ is selected to give the desired receiver gain.
5. Steps 2 to 4 above may have to be repeated to give the required side-tone level and receiver gain.

The coupling capacitor $C_3$ is needed for low-frequency cut-off in the receiver amplifier. The input impedance at pin 14 (18) is approximately 35 kΩ. A balanced push-pull output stage provides a good driving capability even at low supply voltage. The circuit can drive low-impedance (down to 150 Ω) receivers. High-inductance magnetic receivers may require a series resistor to define a correct driving impedance.

Internal clamping diodes in the output stage prevent excessive acoustic levels that may cause damage to the listener's ear.

**Tone dialling telephone**

Figure 14 and 15 shows tone and pulse dialling telephones based on the PBL 3781/02 and a CMOS mixed dialler IC for different feeding systems.

Diode $D_{10}$ is used to minimize the current consumption during line disconnect (power down). The diode is connected to the pulse output of the mixed dialler. The output is low during line disconnect and the diode forces the transmitter amplifier in the speech circuit to cut off. This prevents the capacitor $C_8$ to be discharged through the transmitter amplifier during line disconnect thereby reducing the time to normal condition when the line is connected again.

When using a CMOS DTMF-generator, a filtered supply voltage may be derived from pin 6 of the PBL 3781/02. The tones can be fed directly to the transmit amplifier input as indicated in figure 14 and 15. The mute input requires a minimum of 100 μA.

Since the line current passes through the speech network during pulse dialling, the pulses will be monitored in the receiver. However, by adding two balancing resistors of 47 kΩ at the receiver output terminals, this effect and the confidence tone is minimized ( $R_{15}$ and $R_{16}$ in fig. 9).

**Transmit level low distortion dynamic limiting ("soft clipping").**

The circuit diagram in fig. 12 shows a method to implement Peak Line Signal Level Control with low distortion, also called "soft clipping". The purpose of the circuitry is to reduce the risk of distortion that may occur if the line level is too high, in combination with excessive transmitting gain due to a high line impedance.

The fast attack, slow decay circuitry make use of the Gain Regulation input of the PBL 3781/02 to limit the line output signal level. Typical limiting characteristics is shown in fig. 13.

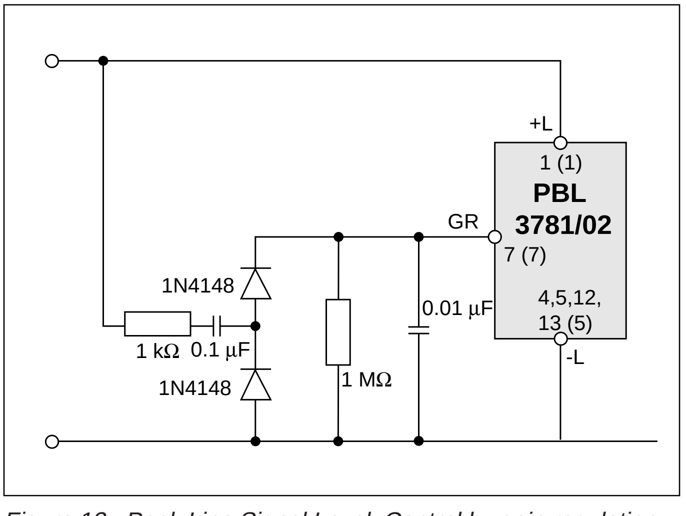



*Figure 12. Peak Line Signal Level Control by gain regulation.*

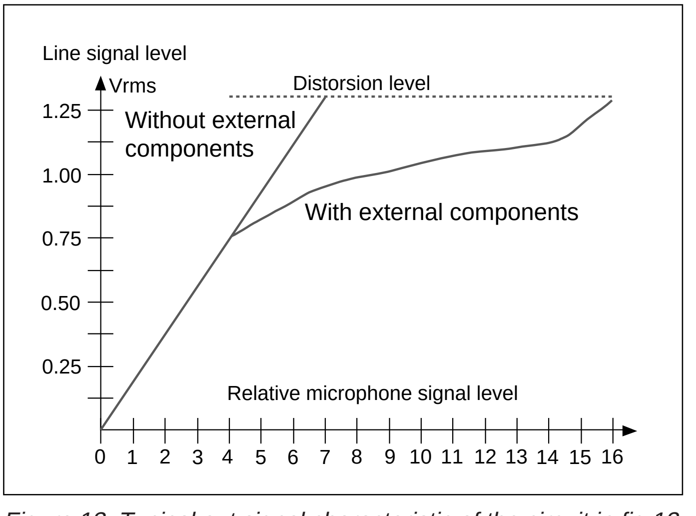
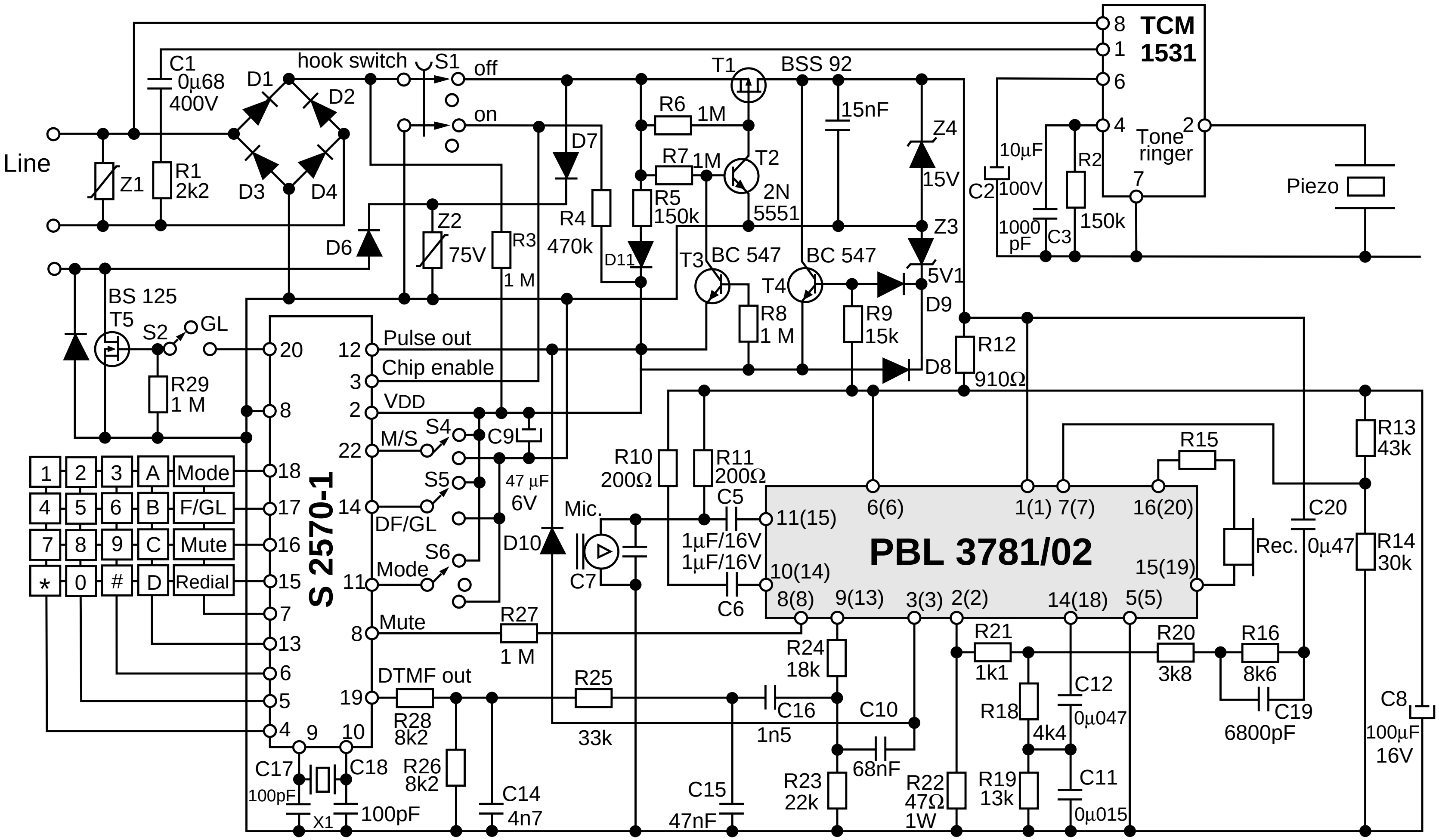
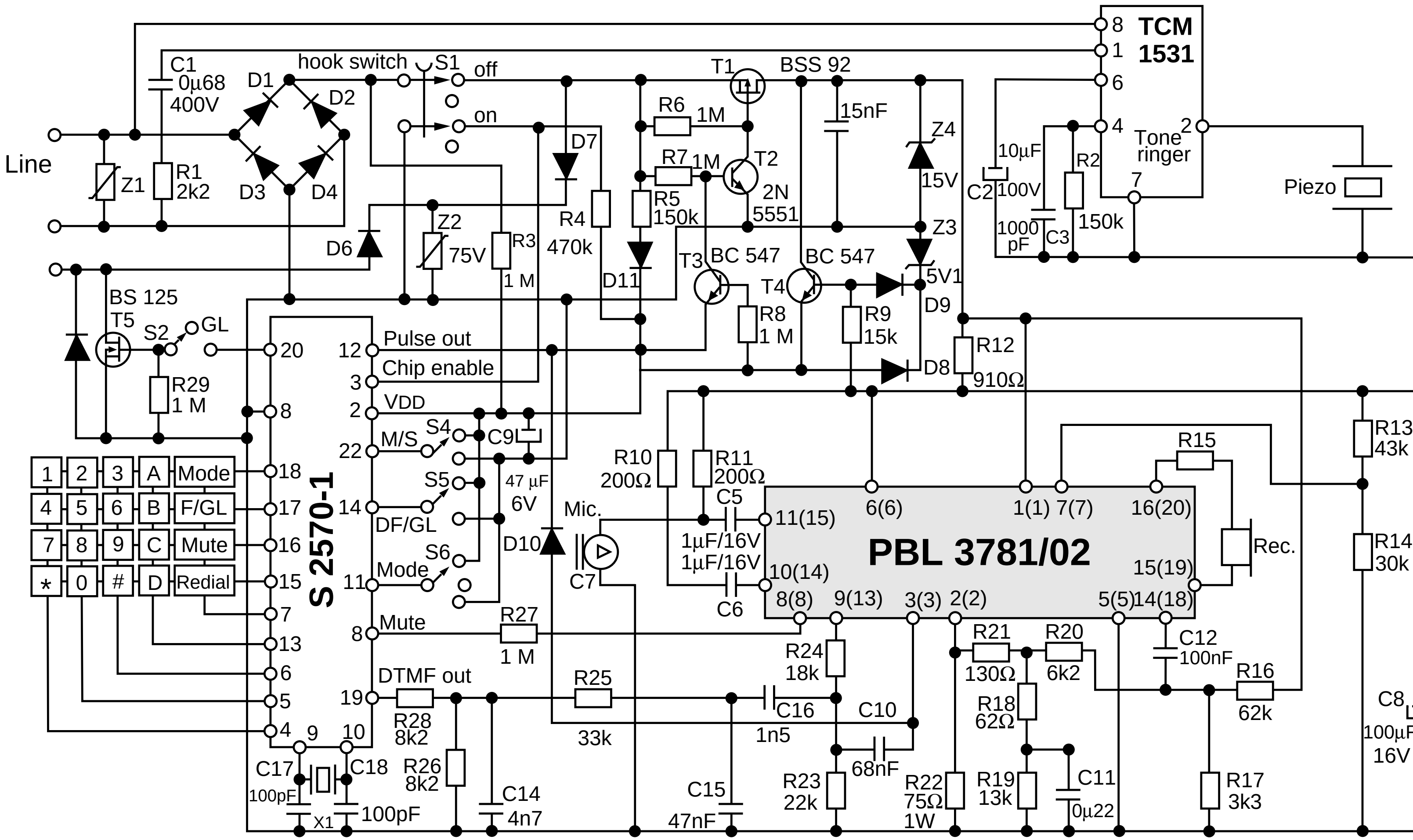



*Figure 13. Typical out signal characteristic of the circuit in fig.12.*




Pin numbers within parentheses refer to PBL 3781/02 in Small Outline.

*Figure 14. Typical tone-dialling telephone for 48V 2 x 200 Ω battery feeding system.*




Pin numbers within parentheses refer to PBL 3781/02 in Small Outline.

*Figure 15. Typical tone-dialling telephone for 48V 2 x 400 Ω battery feeding system.*

## Ordering Information

| Package | Temp. Range | Part No. |
|---|---|---|
| Plastic DIP | -20 to +70°C | PBL 3781/02N |
| Plastic SO | -20 to +70°C | PBL 3781/02SO |



Specifications subject to change without notice.

IC4 (92002) A-Ue



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