APPLICATION NOTE

Application of the TEA1112 and TEA1112A transmission circuits

AN95050

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Abstract

The TEA1112 and TEA1112A are bipolar transmission circuits for use in electronic telephone sets. They are added to the range of well-known transmission circuits of the TEA1060-family.

This report contains a detailed description of the circuit blocks of the TEA1112 and TEA1112A. Two application examples of the TEA1112 are given. The report handles the consecutive steps to design or to adjust the basic application with these ICs. The EMC behaviour of an evaluation board with the TEA1112 or TEA1112A is included.

The general notation in this report for both ICs, TEA1112 and TEA1112A, is: ***TEA1112/A****.*

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Keywords

Telecom
Analog telephone set
Speech transmission IC
TEA1112/A
Supply for a LED

Date: 11 November, 1995

Summary

This report is intended to provide application support for designing electronic telephone sets with the bipolar transmission ICs TEA1112 and TEA1112A.

It contains a detailed description of the several circuit blocks of both ICs as well as the possible settings to adjust the DC and transmission characteristics.

Two application examples of the TEA1112 are given by means of descriptions, settings, measurement results and performances. The report handles the consecutive steps to design or to adjust the basic application with the TEA1112/A.

An evaluation board for the TEA1112 or TEA1112A has been made. The results of the EMC measurements are shown in this report.

The general notation in this report for both ICs, TEA1112 and TEA1112A, is: **TEA1112/A.**

CONTENTS

Tables and figures

1. INTRODUCTION

The TEA1112/A offer all the speech and line interface functions required in electronic telephone sets. They perform the interface between the telephone line and transducers such as microphone capsule(s), earpiece, loudspeaker (in case of LI or HF functions) as well as dialler circuit for DTMF and pulse dialling.

Moreover, they offer a hook-status indicator by means of LED output. Both ICs have a MUTE function to switch between conversation and dialling as well as a MMUTE function to disable the microphone channel to give some privacy (furthermore, this MMUTE function enables the sending DTMF channel, if needed for some specific applications).

The difference between the TEA1112 and the TEA1112A concerns the MUTE and MMUTE inputs. For TEA1112, the MUTE and MMUTE functions are active for a high level at the inputs; while for TEA1112A, the $\overline{\text{MUTE}}$ and $\overline{\text{MMUTE}}$ functions are active for a low level on these inputs. TABLE 1 shows the enabled channels depending on the levels on these two inputs. It can be seen that the MUTE function acts on both sending and receiving channels, while the MMUTE function only acts on the sending channel.

TABLE 1 Channel selection

TEA1112				
MUTE	‘LOW’		‘HIGH’	
MMUTE	‘LOW’	‘HIGH’	‘LOW’	‘HIGH’
Microphone	ON	OFF	OFF	OFF
DTMF	OFF	ON	ON	ON
Earpiece	ON	ON	OFF	OFF
Confidence Tone	OFF	OFF	ON	ON
TEA1112A				
$\overline{\text{MUTE}}$	‘LOW’		‘HIGH’	
$\overline{\text{MMUTE}}$	‘LOW’	‘HIGH’	‘LOW’	‘HIGH’
Microphone	OFF	OFF	OFF	ON
DTMF	ON	ON	ON	OFF
Earpiece	OFF	OFF	ON	ON
Confidence Tone	ON	ON	OFF	OFF

The report is divided into two parts. The first part, up to chapter 3, gives a detailed description of the different circuit blocks of the TEA1112/A consisting of operating principles, settings of DC and transmission characteristics and performances of the different functions.

The second part describes two application examples of the TEA1112 by means of descriptions, settings, measurement results and performances. The consecutive steps to design or to adjust the basic application of the TEA1112/A are handled.

An evaluation board with the basic application of the TEA1112/A is available [9]. The results of the RF immunity tests of this board are shown in this report extended with a brief description of the board and the layout of the board wiring.

2. BLOCK DIAGRAM AND PINNING

The block diagram of TEA1112/A is shown by means of Fig.1. The pinning is shown in Fig.2 and Fig.3.

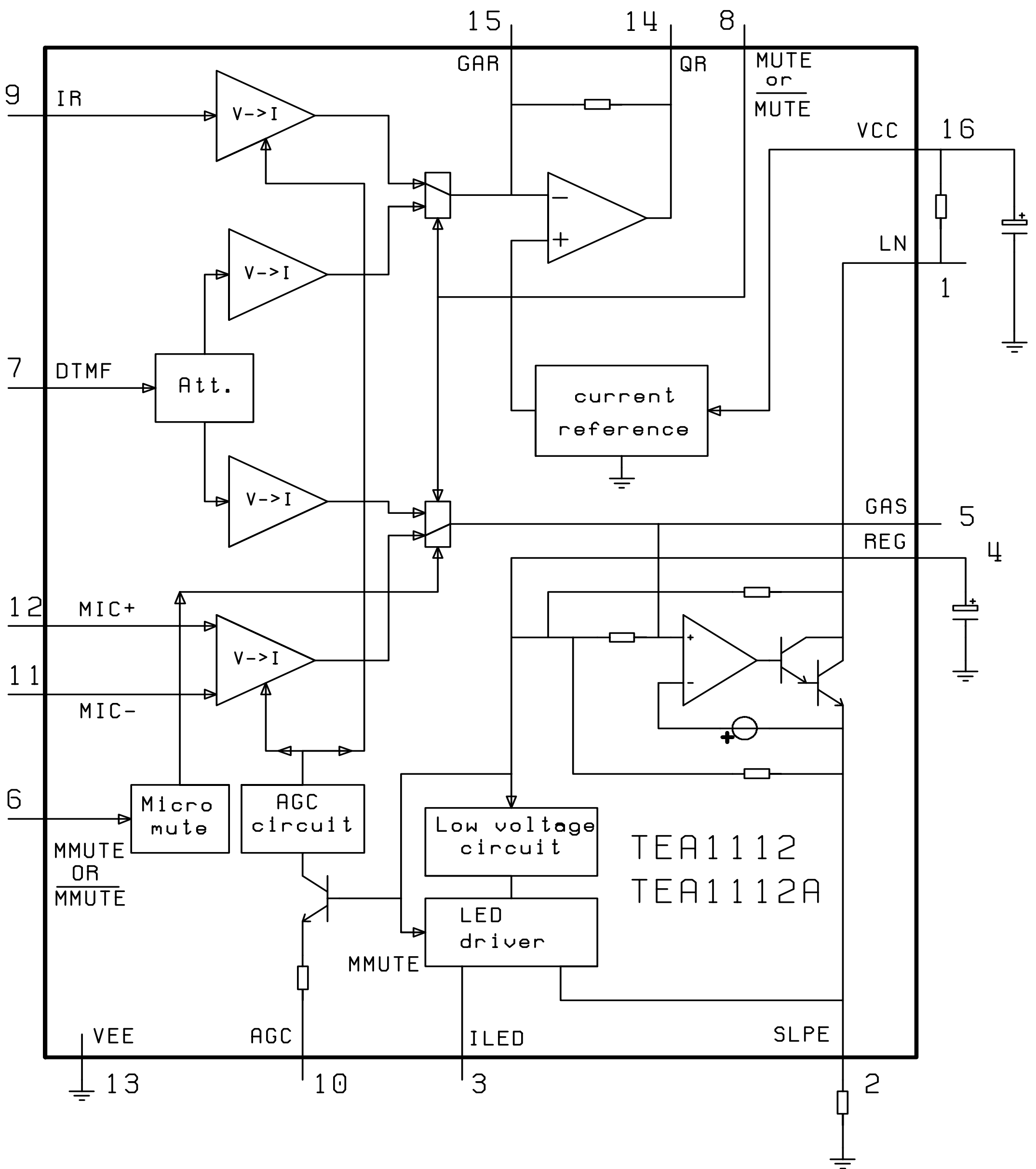

Fig.1 TEA1112/A Block Diagram

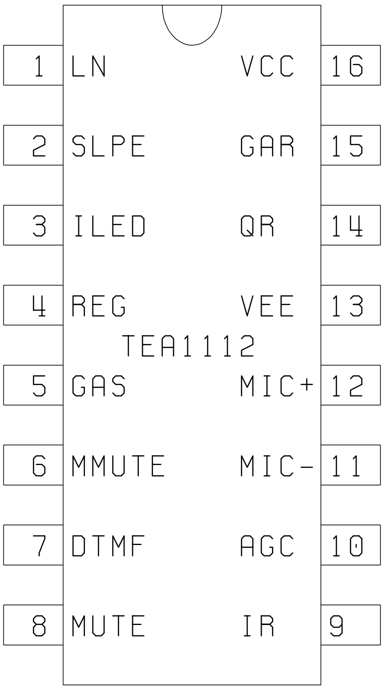

Fig.2 TEA1112 pinning

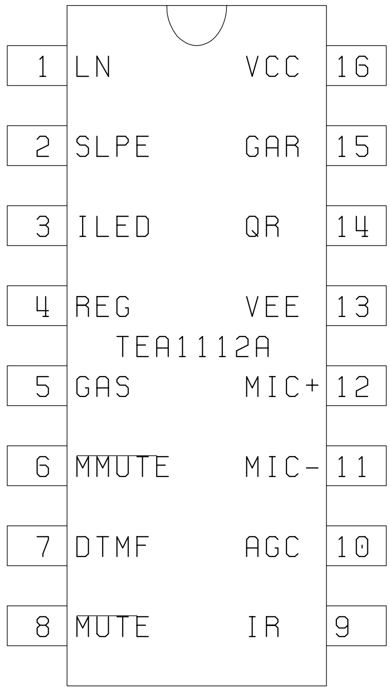

Fig.3 TEA1112A pinning

Pin	Name	Description
1	LN	Positive line terminal
2	SLPE	Slope adjustment
3	ILED	Current available to drive a LED
4	REG	Line voltage regulator decoupling
5	GAS	Sending gain adjustment
6	MMUTE	Microphone mute input
7	DTMF	Dual-Tone Multi Frequency input
8	MUTE	Mute input
9	IR	Receiving amplifier input
10	AGC	Automatic gain control
11	MIC-	Non-inverting microphone input
12	MIC+	Inverting microphone input
13	VEE	Negative line terminal
14	QR	Receiving amplifier output
15	GAR	Receive gain adjustment
16	VCC	Supply voltage for speech and peripherals

Pin	Name	Description
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15	GAR	Receive gain adjustment
16	VCC	Supply voltage for speech and peripherals

3. DESCRIPTION OF THE IC

All the curves shown in this section result from the measurement of a typical sample. All the component names refer to the basic application of the IC shown in Fig.4.

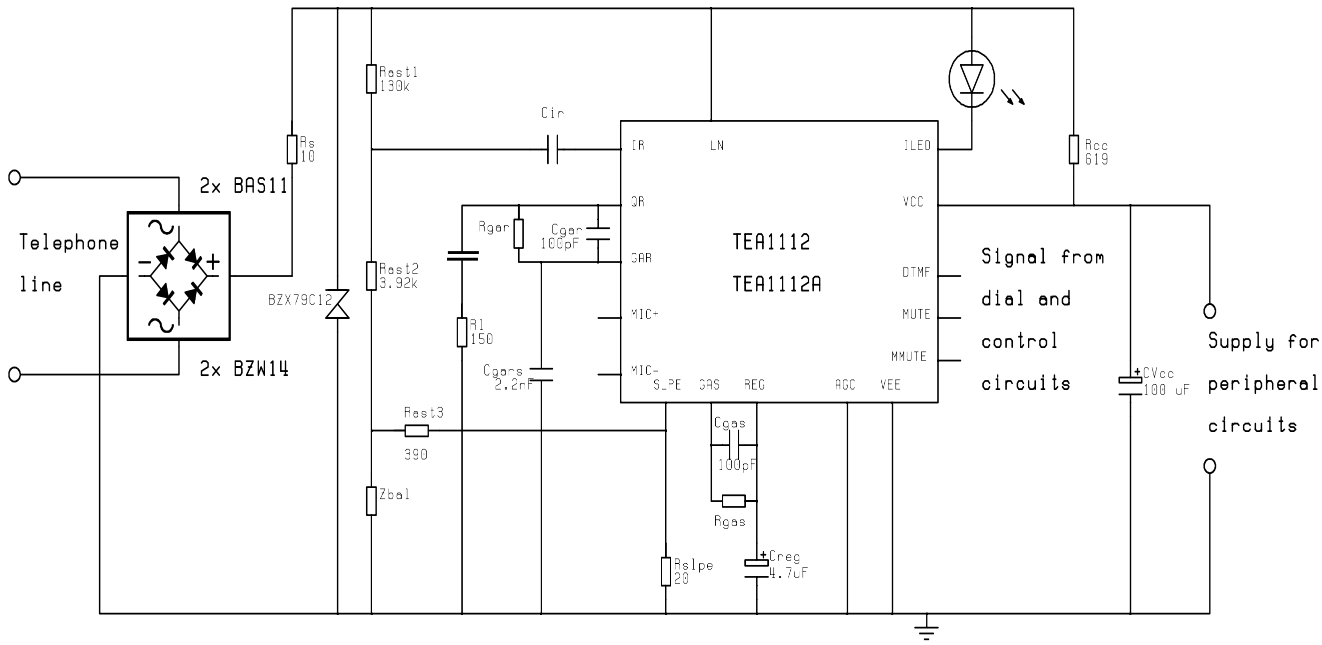

Fig.4 Basic application used for measurement

3.1 Supply; pins LN, SLPE, VCC, REG.

3.1.1 TEA1112/A Supply

Principle of operation

The supply for the TEA1112/A is obtained from the telephone line. The ICs generate a stabilized voltage (called VREF) between pins LN and SLPE. This reference voltage, typically 3.35 V, is temperature compensated. The voltage at pin REG is used by the internal regulator to generate the stabilized VREF voltage and is decoupled by a capacitor Creg connected to VEE. For effective operation of the telephone set, the TEA1112/A must have a low resistance to DC and a high impedance to speech signals. The Creg capacitor, converted into an equivalent inductance (as mentioned in the set impedance section), realizes this set impedance conversion from its DC value (Rslpe) to its AC value (Rcc in the audio frequency range). The DC voltage at pin SLPE is proportional to the line current.

The general supply configuration is shown in Fig.5

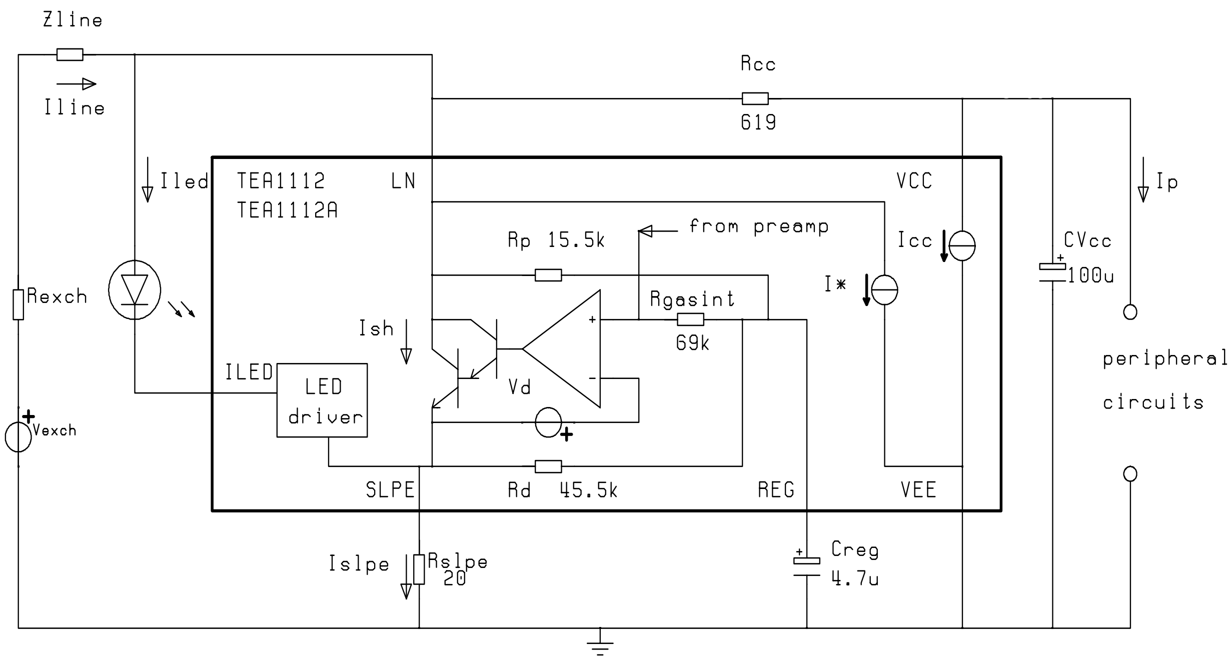

Fig.5 Supply configuration

The ICs regulate the line voltage at the pin LN. The voltage on pin LN can be calculated as:

VLN = VREF + Rslpe x Islpe (1)

Islpe = Iline - Icc - Ip - I* = Iled + Ish (2)

Iline: Line current

Icc: Current consumption of the IC

Ip: Supply current for peripherals

I*: Current consumed between LN and VEE

Iled: Supply current for a LED component

Ish: Excess line current shunted to SLPE (and VEE) from LN

The DC line current Iline flowing into the set is determined by the exchange supply voltage Vexch, the feeding bridge resistance Rexch, the DC resistance of the telephone line Rline and the voltage across the set including diode bridge.

Below a threshold line current (Ith is typically equal to 7.5 mA) the internal reference voltage (generating VREF) is automatically adjusted to a lower value. This means that more sets can operate in parallel with DC voltage down to an absolute minimum voltage of 1.6 V excluding the diode bridge. For line currents below this threshold current, the circuit has reduced sending and receiving performances. This is called the low voltage area.

The internal circuitry of the TEA1112/A is supplied from pin VCC. This supply voltage is derived from the line voltage by means of a resistor (Rcc) and must be decoupled by a capacitor (Cvcc). Fig.6 shows the IC current consumption (Icc) as a function of the VCC supply voltage.

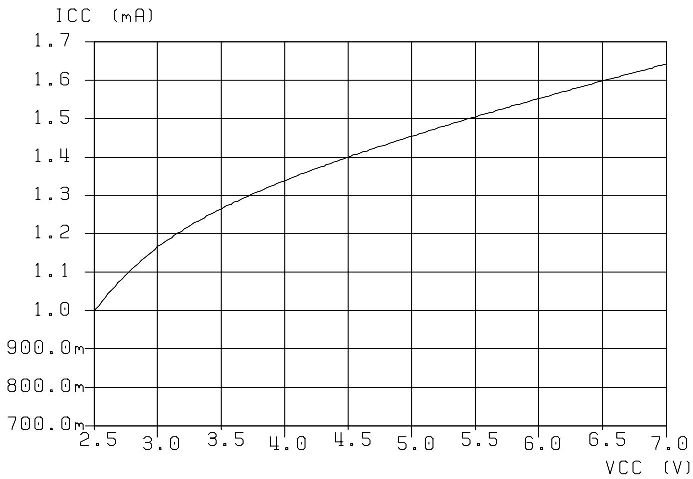

Fig.6 ICC versus VCC

Fig.7 shows the main DC voltages as a function of the line current, while Fig.8 shows the behaviour in the low voltage area.

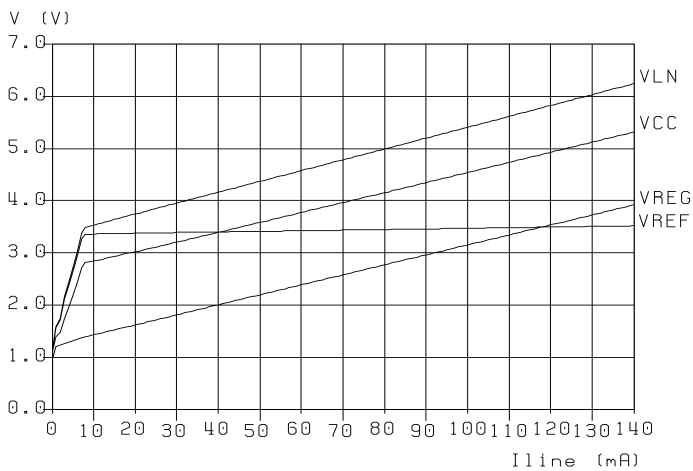

Fig.7 Main voltages versus line current

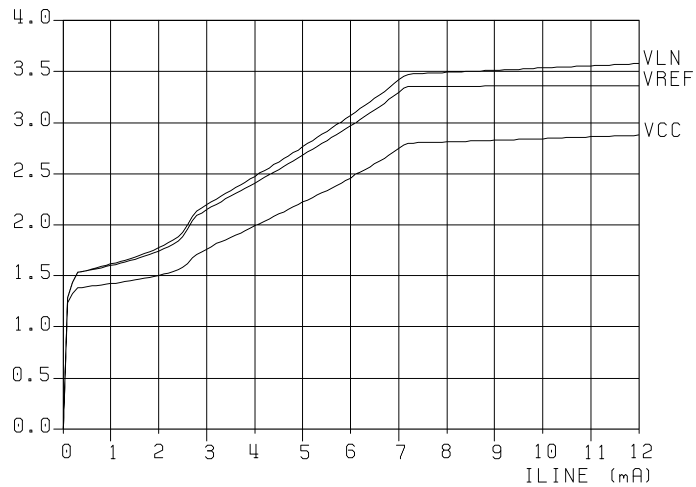

Fig.8 Low voltage behaviour

Adjustment

The reference voltage, VREF, can be adjusted by means of an external resistor Rva. It can be increased by connecting the Rva resistor between pins REG and SLPE, or decreased by connecting the Rva resistor between pins REG and LN. However this voltage reduction is possible, it is not recommended to use it, because it reduces the peripheral supply capability. Fig.9 shows the reference voltage, VREF, as a function of an Rva resistor. To ensure correct operation, the reference voltage is preferably not adjusted to a value lower than 3 V or higher than 7 V. These adjustments will slightly affect a few parameters: there will be a small change in the temperature coefficient of VREF and a slight increase in the spread of this voltage reference. Furthermore, the Rva resistor connected between REG and LN will slightly affect the set impedance (See section: 'Set impedance' 3.2).

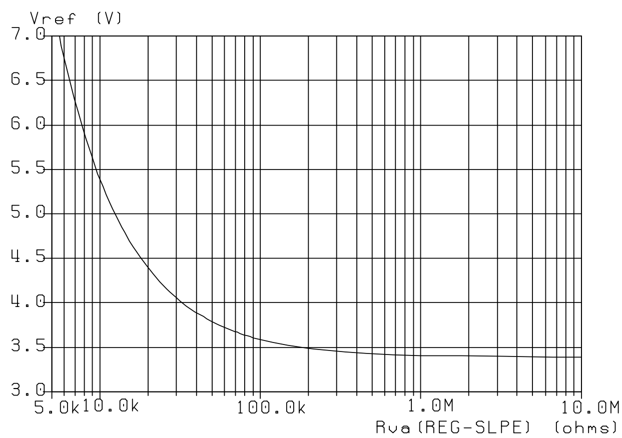

Fig.9 Influence of an Rva resistor between REG and SLPE on VREF

The DC slope of the voltage on pin LN is influenced by the Rslpe resistor as shown in Fig.10. The preferred value for Rslpe is 20 Ω. Changing this value will affect more than the DC characteristics. It also influences the microphone and DTMF gains, the LED supply current characteristic, the gain control characteristics, the sidetone level, the maximum output swing on the line and the low voltage current threshold Ith.

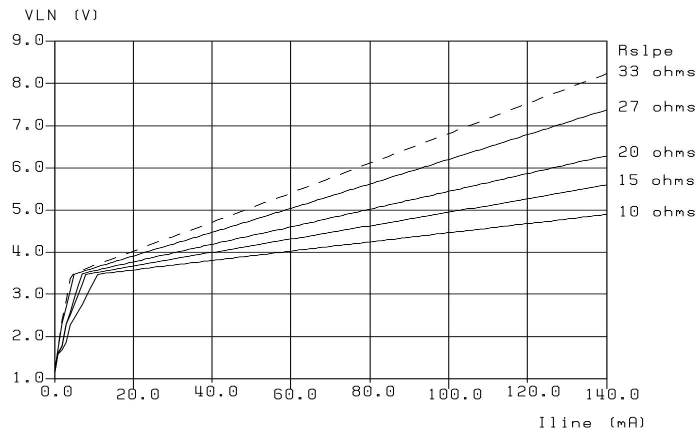

Fig.10 Influence of Rslpe on the DC slope of the line voltage

3.1.2 Supply for peripheral circuits

Principle of operation

The supply voltage at pin VCC is normally used to supply the internal circuitry of the TEA1112/A. However, a small current can be drawn to supply peripheral circuits having VEE as a ground reference. The VCC supply voltage depends on the current consumed by the IC and the peripheral circuits as shown by formula (3) (See also curves at Fig.11 and equivalent schematic of this supply point at Fig.12).

Rccint is the output impedance of the voltage supply point. As can be seen from Fig.6, the internal supply current Icc depends on the voltage on the pin VCC; it means that the impedance of the internal circuitry connected between VCC and VEE is not infinite. While supplying a peripheral circuit on VCC, the Ip supply current flows through the Rcc resistor, decreases the value of the voltage on the pin VCC. This voltage reduction affects the Icc consumption and than the voltage drop across the Rcc resistor. So to calculate the voltage drop across this resistor, both effects must be taken into account. The impedance to use in combination with Ip is not Rcc but Rcc in parallel with the impedance of the internal circuitry connected between VCC and VEE. That is what is called Rccint. For a line current equal to 15 mA and Rcc equal to 620Ω, this Rccint impedance is equal to 550Ω. The worst case for Rccint is Rcc.

$$VCC = VCCo - Rccint * (Irec + Ip) \quad (3)$$

$$VCCo = VLN - Rcc * Icc$$

Irec = internal current necessary to supply the earpiece amplifier to realize an AC peak voltage Vq across the earpiece impedance Rl

$$Irec = \frac{Vq}{\pi \times Rl}$$

Rccint = is due to the fact that Icc slightly varies with the voltage on VCC. A worst case value for Rccint is Rcc

Rccint = Rcc // (internal impedance between VCC and VEE)

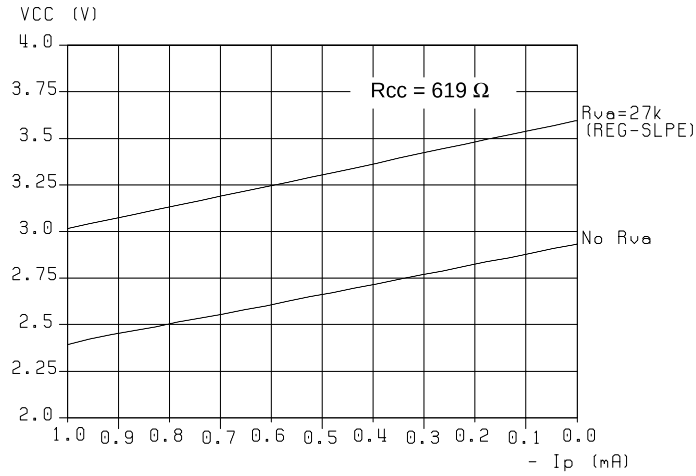

Fig.11 VCC supply voltage versus Ip consumed current for Irec = 0

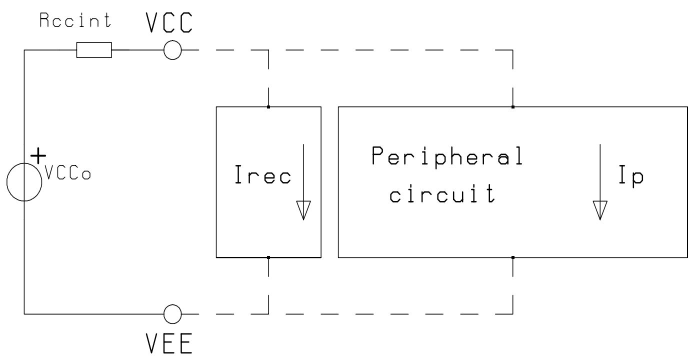

Fig.12 VCC supply point: equivalent schematic

As VCC is limited to a minimum value to ensure correct functioning, Ip will be limited to a maximum value. The limit is imposed by the requirement to maintain a minimum permitted voltage between VCC and SLPE which is called Vmin. So the maximum current available depends on the DC settings of the IC: VREF, Rcc, Rslpe and the required AC signal level at the line and receiver outputs. To simplify the calculation, we will use the worst case for Rccint which is Rcc. It gives:

$$VCC = VLN - Rcc(Icc + Irec)$$

$$VCC = VREF + Rslpe(Iline - Icc - irec) - Rcc(Icc + Irec)$$

$$VCCmin = Vmin + Rslpe(Iline - Icc - Irec - Ip)$$

$$Ipmax = \frac{VCC - VCCmin}{Rcc}$$

$$Ipmax = \frac{VREF - Vmin}{Rcc - Rslpe} - \frac{Rcc}{Rcc - Rslpe}(Icc + Irec)$$

$$Vmin = 1.7V + v\ln\left(\frac{Rslpe}{Zline||Rcc}\right)$$

Adjustment

As the impedance connected between LN and VCC also determines the set impedance, the easiest way to increase the current capability of the supply point VCC is to increase the reference voltage VREF by connecting an Rva resistor between REG and SLPE (see Fig.11). The maximum preferable value of VREF = 7 V; see *Adjustment* in section 3.1.1.

3.2 Set Impedance

Principle of operation

The ICs behave like an equivalent inductance that present a low impedance to DC (Rslpe) and a high impedance (Rp) to speech signals. Rp is an integrated resistance in the order of 15.5 kΩ +/- 15%. It is in parallel with the external RC filter realized by Rcc and Cvcc. Thus in the audio frequency range the set impedance is mainly determined by the Rcc resistor. Fig.13 shows an equivalent schematic for the set impedance, while Fig.14 shows measurement results of the set impedance and the Balance Return Loss (BRL). BRL measures the matching of the set impedance to a reference impedance of 600Ω (in this case) according to the formula:

$$\mathrm{BRL} = 20\left(\log\frac{|\mathrm{Zset} + 600\Omega|}{|\mathrm{Zset} - 600\Omega|}\right)$$

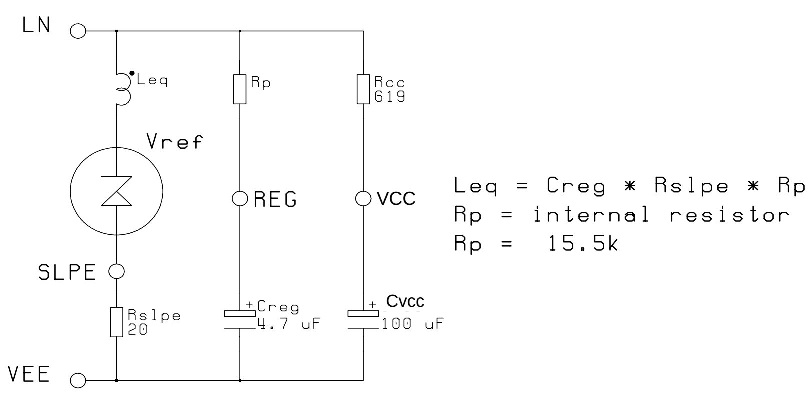

Fig.13 Equivalent set impedance

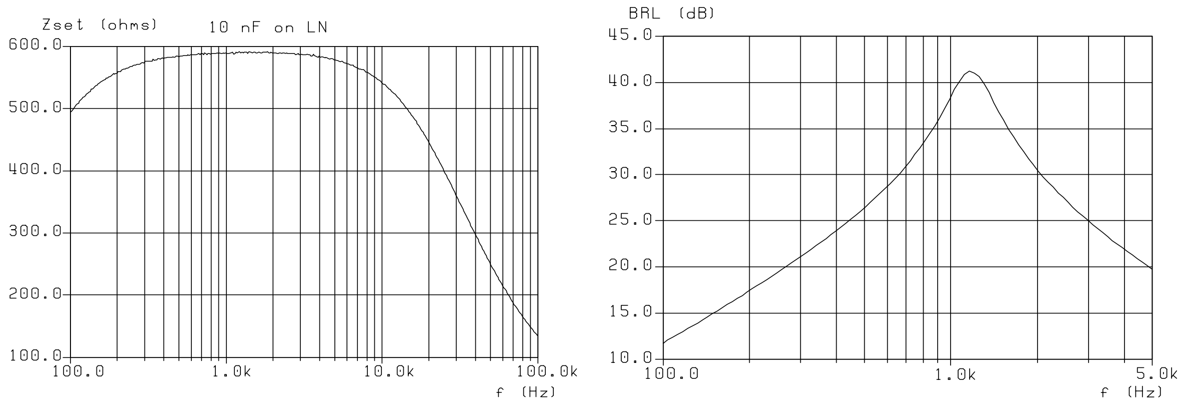

Fig.14 Set impedance and Balance Return Loss at 600 ohms reference impedance

Adjustment

When decreasing the reference voltage VREF, a resistor is connected between LN and REG in parallel of Rp (See Fig.13) so, slightly modifying the set impedance.

If complex set impedance is required, the Rcc resistor must be replaced by an equivalent complex network. Keep in mind that the DC resistance of this network influences the VCC voltage and current supply capability. (See section 3.1.2 'Supply for peripheral circuits')

3.3 Supply for a LED; pin ILED

Principle of operation

The TEA1112/A give an on-hook / off-hook status indication. This is done by a current available to drive a LED connected between pins ILED and LN. In the low voltage area, which corresponds to low line current condition, no current is available for this LED. For line currents higher than a threshold, Iled starts at 18mA typically, the Iled current increases proportionally to the line current (with a ratio of approximately one third). The Iled current is internally limited to 19.5 mA (typical value). See curves shown in Fig.15.

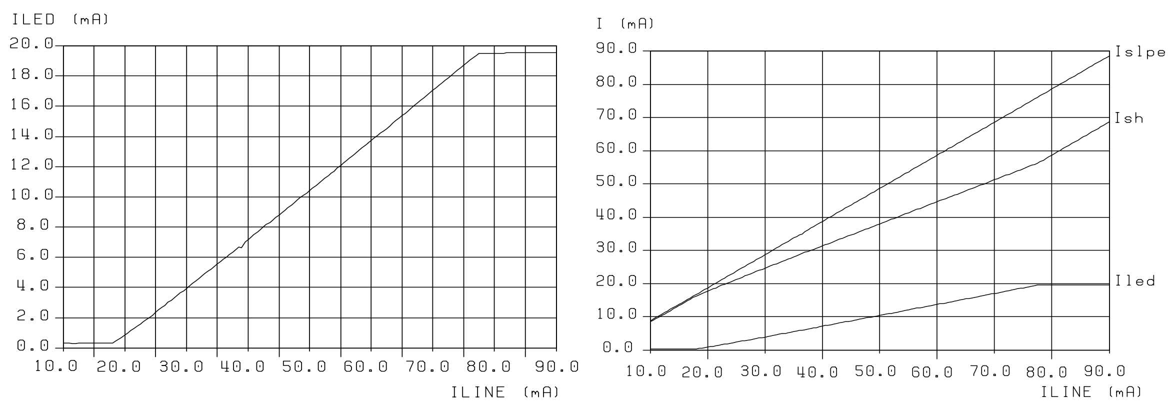

Fig.15 LED supply current versus the available line current

As the LED driver is connected to SLPE, all the Iled supply current will flow through the Rslpe resistor. Consequently, the AGC characteristics are not disturbed.

Adjustment

The ICs have been designed for use with all kind of LED's as long as the voltage across this device, at 20 mA current flowing through it, is lower than VREF - 0.8 V. The start and stop line currents as well as the maximum Iled current are internally fixed.

If no LED is required, the ILED output can be shorted to SLPE to avoid a floating pin.

3.4 Microphone amplifier; pins MIC+, MIC-, GAS

Principle of operation

In Fig.16 the block diagram of the microphone amplifier of the TEA1112/A is depicted.The microphone amplifier has symmetrical very high input impedances. The input impedance between pins MIC+ and MIC- is typically 64 kΩ (2 x 32 kΩ) with maximum tolerances of +/- 15%. Thanks to this high input impedance, the ICs are suitable for several kinds of microphones: dynamic, piezoelectric or electret microphones with symmetrical or a-symmetrical drives (See Fig.17 for some examples).

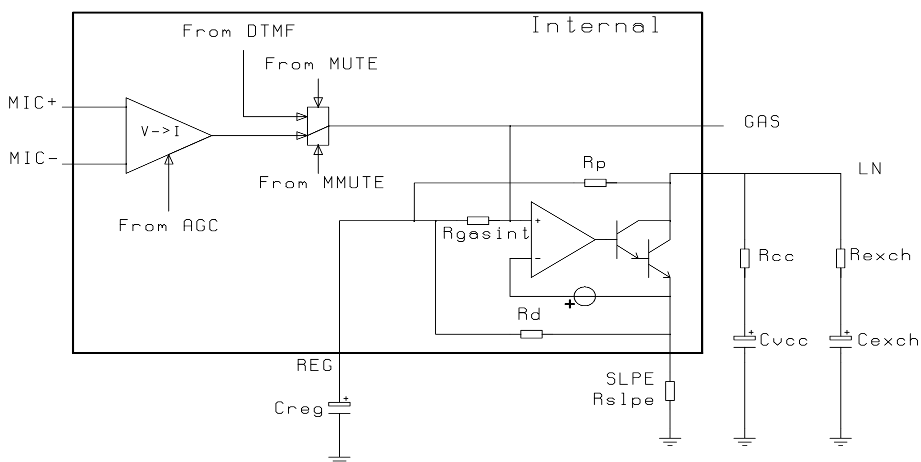

Fig.16 Microphone channel

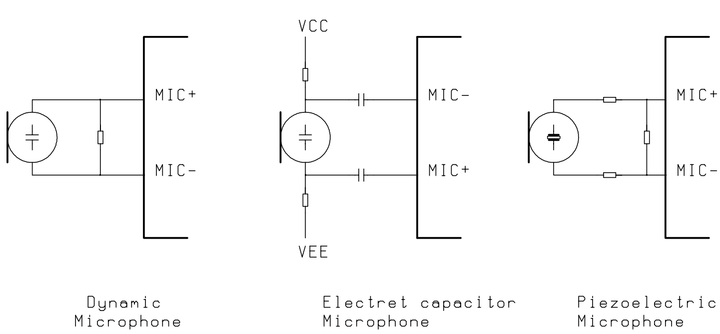

Fig.17 Microphone arrangements examples

As can be seen in Fig.16, the microphone amplifier itself is built up out of two parts: a pre-amplifier which realizes a voltage to current conversion, and an end-amplifier which realizes the current to voltage conversion. The overall gain (Gvtx) of the microphone amplifier from inputs MIC+/MIC- to output LN is given by the following equation

$$Gvtx = 20 \times \log Avtx$$

$$Avtx = 1.31 \times \frac{Rgasint}{Rrefint} \times \frac{Ri||Zline}{Rslpe} \times \alpha$$

with:

Ri = the dynamic set impedance, Rcc||Rp, typically 619 Ω || 15.5 kΩ

Rgasint = internal resistor realizing the current to voltage conversion, typically 69 kΩ with a spread of +/- 15%

Rrefint = internal resistor determining the current of an internal current stabilizer, typically 3.4 kΩ with a spread of +/- 15%(correlated to the spread of Rgasint)

Zline = load impedance of the line during the measurement

α = gain control factor varying from 1 at Iline = 15 mA to 0.5 at Iline = 75 mA when AGC function is applied; see chapter 3.8.

Using these typical values in the equation, we find a gain equal to:

Gvtx = 20 x log Avtx = 52 dB

at Iline = 15 mA

The different gain controls (AGC, MUTE, MMUTE) act on the microphone pre-amplifier stage, modifying its transconductance.

Adjustment and performance

The microphone gain can be decreased by connecting a resistor Rgas between pins GAS and REG. It can be adjusted from 52 dB down to 39 dB to suit application specific requirements. The gain dependency to this external resistor is calculated in equation (4) and shown in Fig.18 at 1 kHz and for a typical sample. The gain adjustment by an external Rgas resistor connected between pins GAS and REG may slightly change the gain spread.

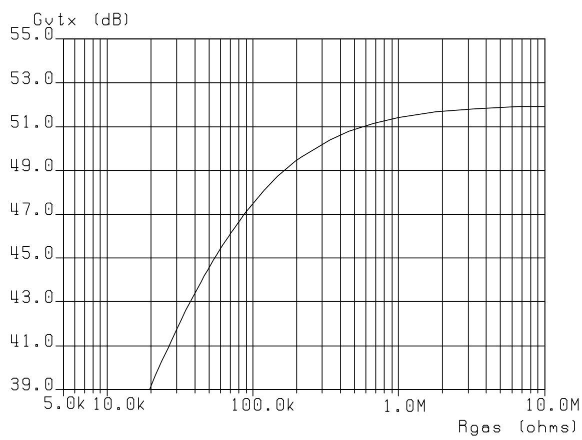

Fig.18 Microphone gain function of the Rgas resistor connected between GAS and REG

$$Gvtx = 20 \times \log\left(1.31 \times \frac{Rgasint||Rgas}{Rrefint} \times \frac{Ri||Zline}{Rslpe} \times \alpha\right) \qquad (4)$$

A capacitor Cgas is generally connected between pins GAS and REG to provide a first order low pass filter, which cut-off frequency is determined by the product Cgas x (Rgasint || Rgas). Fig.19 shows the frequency response of the microphone amplifier at different temperatures (Cgas = 100 pF, Rgasint = 69 kΩ , no external Rgas).

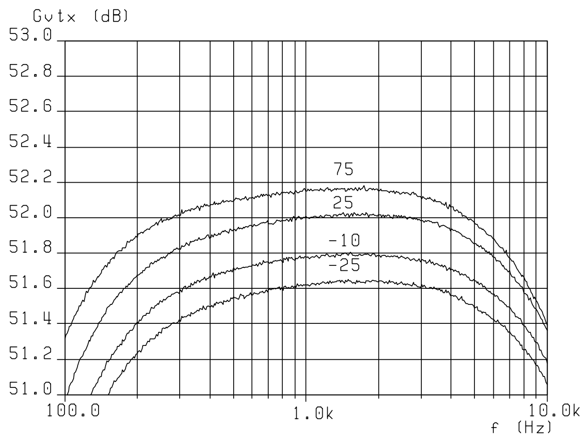

Fig.19 Microphone gain versus frequency: influence of temperature

Fig.20 shows the distortion of the signal on the line as a function of the microphone input signal for two different gains, at nominal DC settings. The inputs of the microphone amplifier can handle signals up to 18 mVrms with less than 2% Total Harmonic Distortion (THD). For overall gains (Gvtx) larger than 40 dB, the distortion will be determined by the output stage (clipping of the line signal). So Fig.20 a) shows a saturation due to the output stage, while Fig.20 b) shows a saturation due to the input stage.

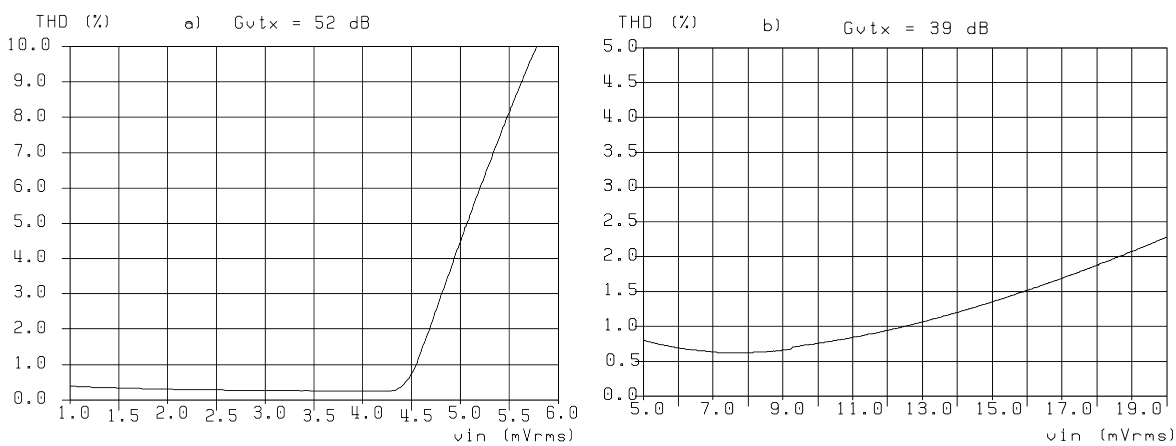

Fig.20 Distortion on the line as a function of the input signal for two microphone gains

Fig.21 shows the distortion of the line signal versus the rms voltage on the line at line currents equal to 4 mA and 15 mA at the nominal gain of 52 dB.

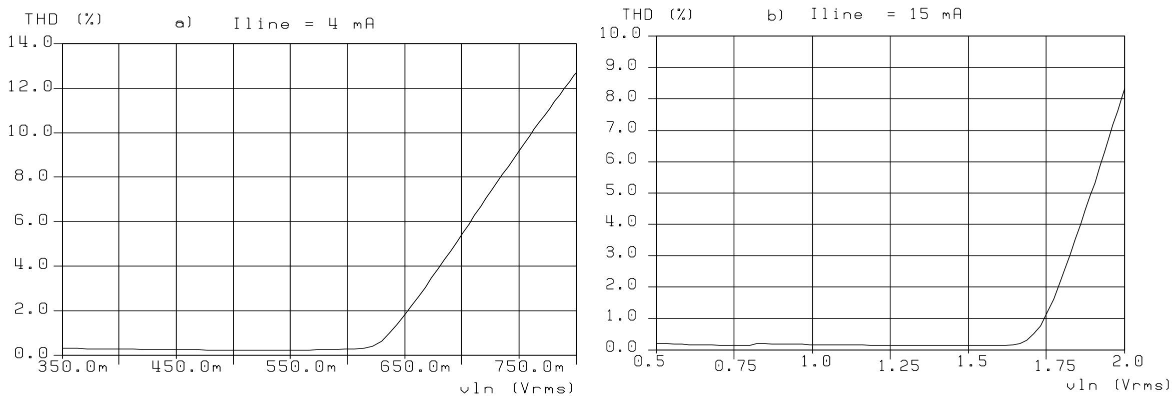

Fig.21 Distortion of the line signal versus the rms voltage on the line

To obtain optimum noise performance on the line, the microphone inputs must be loaded. Fig.22 shows the noise on the line (psophometrically weighted; P53 curve) as a function of the line current and the microphone gain with a 200Ω connected between the microphone inputs (typical application). These curves show the sensitivity of the noise to the microphone gain. The noise measures -79.5 dBmp at minimum send gain.

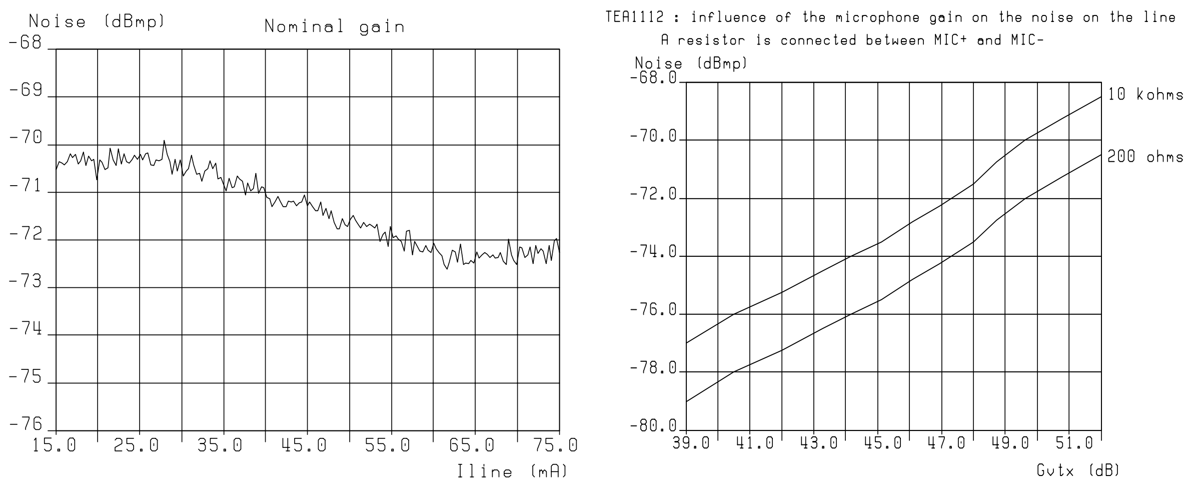

Fig.22 Noise on the line versus the line current and the microphone gain

The amplifier gain is temperature compensated. The gain adjustment by an external Rgas resistor connected between pins GAS and REG may slightly change the temperature coefficient; see reference [2].

Fig.23 shows the common mode rejection ratio at 15 mA and at nominal microphone gain. Two curves are present on this figure. The first one is the spectrum of the signal on pin LN when a sending signal is applied on pin MIC-, pin MIC+ being shorted to VEE by a decoupling capacitor. The second curve is the spectrum of the signal on pin LN when an sending signal is applied on the microphone inputs, MIC+ and MIC- being shorted. Both signals are at a frequency of 1 kHz. The difference between the two curves at this frequency gives the CMRR.

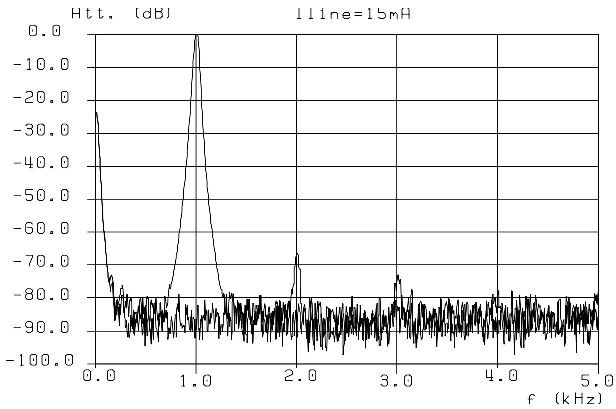

Fig.23 Common mode rejection ratio

3.5 MMUTE function (TEA1112 only); pin MMUTE

Principle of operation

The microphone mute function realizes an electronic switching between the microphone amplifier and the sending DTMF amplifier. This function disables the microphone channel to provide such kind of privacy and in the same time enables the DTMF channel if needed for some specific applications. If a high level is applied to the MMUTE input, the sending DTMF channel is activated, while the microphone amplifier is disabled. The microphone amplifier can be enabled (depending on the MUTE level; see TABLE 1) by either applying a low level (< 0.3 V typically) at the MMUTE input or leaving it open. Fig.24 shows the microphone amplifier gain reduction and the input current as a function of the input voltage on MMUTE. The threshold voltage level is 0.68 V typically (base-emitter junction) with a temperature coefficient of -2 mV/^{o}C.

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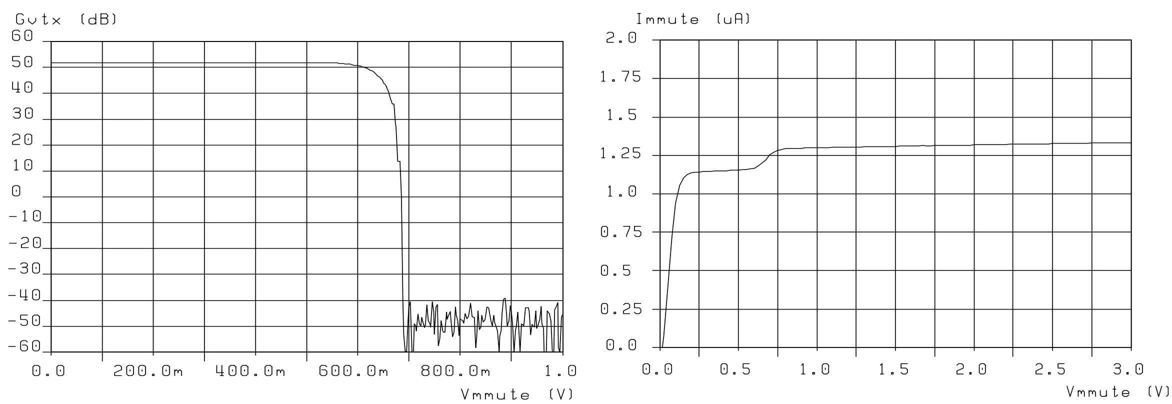

Fig.24 Microphone gain and MMUTE input current vs Vmmute

The microphone mute function has no effect on the receiving channel which is fully determined by the MUTE level.

Performance

Fig.25 shows the microphone amplifier gain reduction at Iline = 15 mA for an input signal at 1 kHz. Two curves are drawn in this figure. The first one shows the spectrum of the signal on the line in speech condition when a signal is applied on the microphone inputs. The second curve shows the same signal in DTMF condition. Both signals are at a frequency of 1 kHz. The difference between the two curves at this frequency gives the gain reduction.

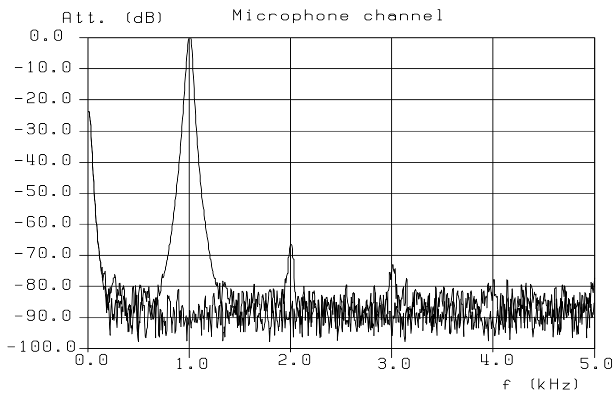

Fig.25 Microphone gain reduction in MMUTE condition

The MMUTE function works down to a voltage on VCC equal to 1.6V (Iline = 2.5 mA in the basic application). Below this threshold, the microphone amplifier stays always enabled independently of the MMUTE input level.

The maximum voltage allowed at the MMUTE input is VCC + 0.4 V.

3.6 MMUTE function (TEA1112A only); pin MMUTE

Principle of operation

The MMUTE function realizes an electronic switching between the microphone amplifier and the sending DTMF amplifier. This function disables the microphone channel to provide such kind of privacy and in the same time enables the DTMF channel if needed for some specific applications. If a high level is applied to the MMUTE input, the microphone amplifier can be activated (depending on the MUTE level, See TABLE 1), while the DTMF channel is disabled. The DTMF channel is enabled by either applying a low level (< 0.3 V typically) at the MMUTE input or leaving it open. Fig.26 shows the microphone amplifier gain reduction and the input current as a function of the input voltage on MMUTE. The threshold voltage level is 0.68 V typically (base-emitter junction) with a temperature coefficient of -2 mV/^{o}C.

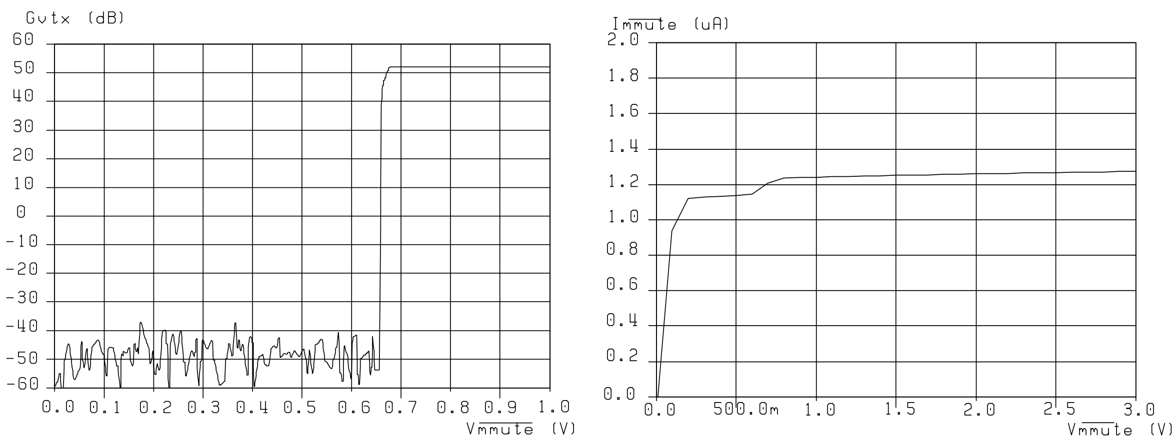

Fig.26 Microphone gain and MMUTE input current vs Vmmute

The $\overline{\text{MMUTE}}$ function has no effect on the receiving channel which is fully determined by the $\overline{\text{MUTE}}$ level.

Performance

Fig.27 shows the microphone amplifier gain reduction at Iline = 15 mA for an input signal at 1 kHz.Two curves are drawn in this figure. The first one shows the spectrum of the signal on the line in speech condition when a signal is applied on the microphone inputs. The second curve shows the same signal in DTMF condition. Both signals are at a frequency of 1 kHz. The difference between the two curves at this frequency gives the gain reduction.

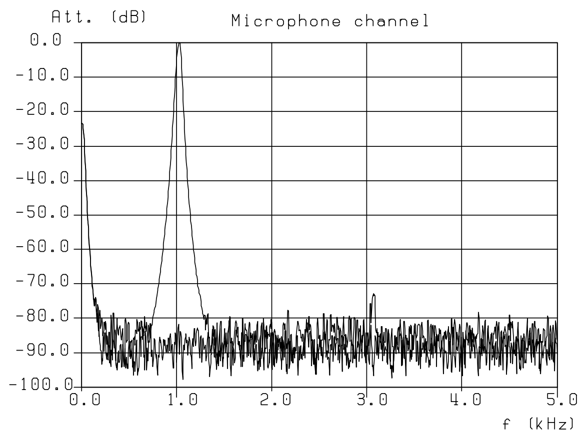

Fig.27 Microphone gain reduction in $\overline{\text{MMUTE}}$ condition

The $\overline{\text{MMUTE}}$ function works down to a voltage on VCC equal to 1.6V (Iline = 2.5 mA in the basic application). Below this threshold, the microphone amplifier stays always enabled independently to the $\overline{\text{MMUTE}}$ input level.

The maximum voltage allowed at the $\overline{\text{MMUTE}}$ input is VCC + 0.4 V

3.7 Receiving amplifier; pins IR, GAR, QR

Principle of operation

In Fig.28, the block diagram of the receiving amplifier of the TEA1112/A is depicted.

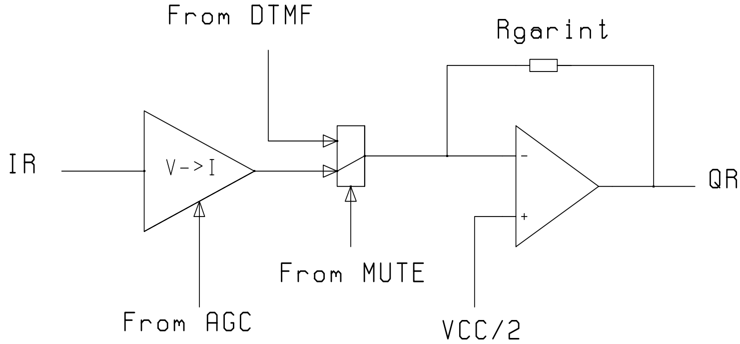

Fig.28 Receiving channel

The receiving amplifier has an a-symmetrical high input impedance between pins IR and VEE. It is equal to 20 kΩ with maximum tolerances of +/- 15%. The ICs are suitable for several kind of earpieces and can drive either dynamic, magnetic or piezo-electric earpieces (See Fig.29 for some arrangements examples).

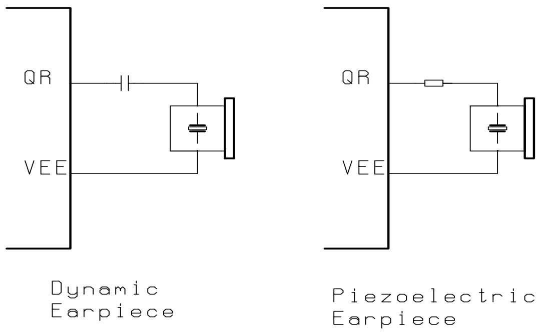

Fig.29 Earpieces arrangements examples

As can be seen in Fig.28, the receiving amplifier itself is built up out of two parts: a pre-amplifier which realizes a voltage to current conversion, and an end-amplifier which realizes the current to voltage conversion. The overall gain Gvrx of the receiving amplifier from input IR to output QR is given by the equation:

$$\text{Gvrx} = 20 \times \log \text{Avrx}$$

$$\text{Avrx} = \alpha \times 1.21 \times \frac{\text{Rgarint}}{\text{Rrefint}}$$

with:

Rgarint = internal resistor realizing the current to voltage conversion, typically 100 kΩ with a spread of +/- 15%

Rrefint = internal resistor determining the current of an internal current stabilizer, typically 3.4 kΩ with a spread of +/- 15% (correlated to the spread of Rgarint)

α = gain control factor varying from 1 at Iline = 15 mA to 0.5 at Iline = 75 mA, when AGC function is applied.

Using these typical values in the equation, we find a gain equal to:

Gvrx = 20 x log Avrx = 31 dB at Iline = 15 mA.

The gain controls, AGC and MUTE, act on the receiving pre-amplifier stage, modifying its transconductance.

Adjustment and performance

The receiving gain can be decreased by connecting a resistor Rgar between pins GAR and QR. It can be adjusted from 31 dB down to 19 dB to suit application specific requirements. The gain dependency to this external resistor is calculated in equation (5) and shown in Fig.30. The gain adjustment by an external Rgar resistor connected between pins GAS and REG may slightly change the gain spread.

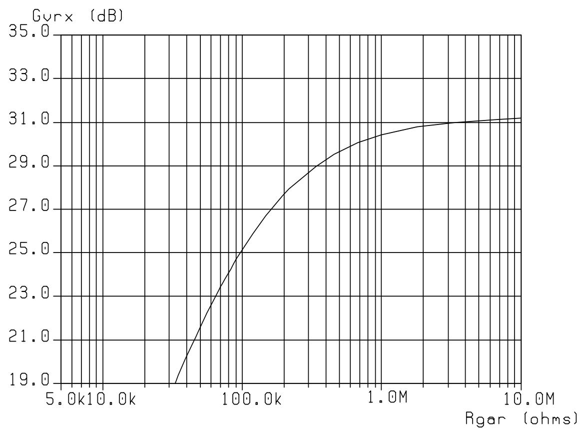

Fig.30 Receiving gain function of the Rgar resistor connected between GAR and QR

$$Gvrx = 20 \times \log\left(1.21 \times \frac{Rgarint||Rgar}{Rrefint}\right) \quad (5)$$

Two external capacitors Cgar (connected between GAR and QR) and Cgars (connected between GAR and VEE) ensure stability. The relationship Cgars >= 20 x Cgar should be fulfilled to ensure stability. The Cgar capacitor provides a first order filter, which cut-off frequency is determined by the relation Cgar x (Rgarint || Rgar). Fig.31 shows the frequency response of the receiving amplifier at different temperature (Cgar = 100pF, Cgars = 2.2 nF).

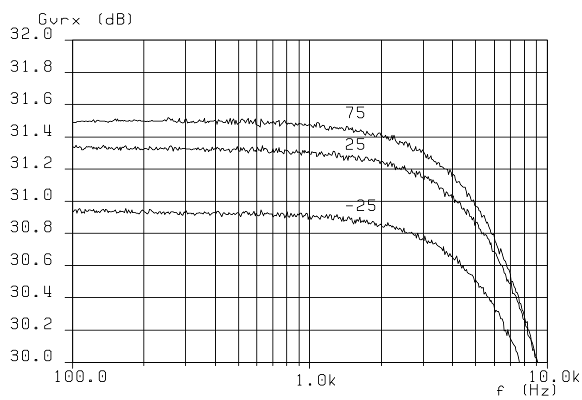

Fig.31 Receiving gain versus frequency: influence of temperature

The maximum output swing on QR depends on the DC line voltage, the Rcc resistor, the Icc current consumption of the circuit, the Ip current consumption of the peripheral circuits and the load impedance on QR. The receiving input IR can handle signals up to 18 mVrms with less than 2% THD. Fig.32 shows the distortion on QR as a function of the input voltage for a line current equal to 75 mA. The two curves correspond to a measurement with and without the AGC function which results in a difference of 6 dB in the receiving gain. With AGC, the gain is only 25 dB and the distortion is due to the input, while without AGC, the gain is 31 dB and the distortion comes from the output.

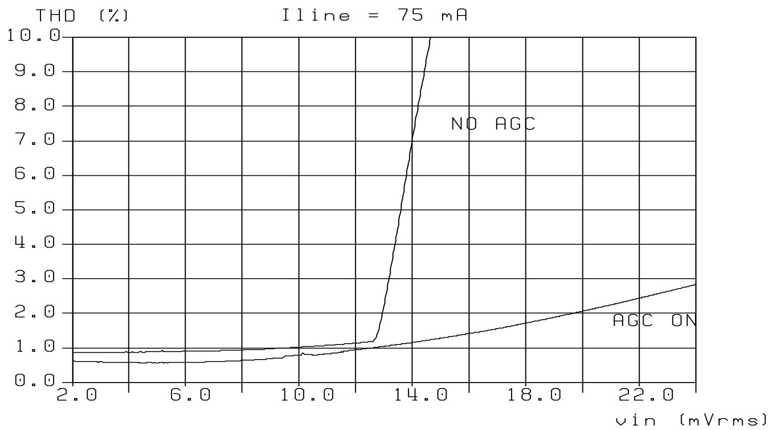

Fig.32 Distortion on QR versus the input signal on IR

The maximum level on QR for 2% THD increases with line current due to the increase of VCC and then is limited to a maximum value due to the input limitation.

Fig.33 shows the distortion of the signal on QR as a function of the rms voltage on QR at Iline = 15 mA for two different loads: 150 Ω and 450 Ω .

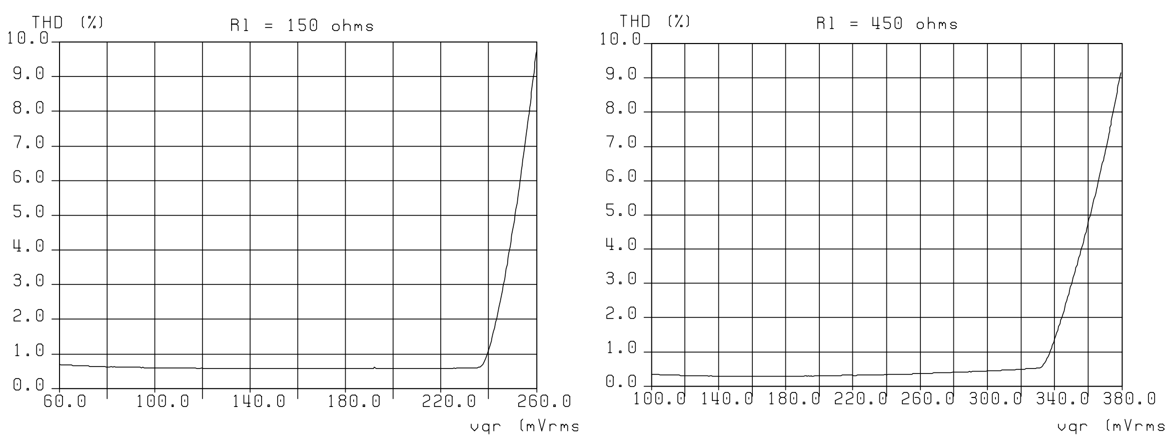

Fig.33 Distortion of the receiving signal for two loads

Fig.34 shows the noise on QR loaded with 150 Ω (psophometrically weighted; P53 curve) as a function of the line current. This curve has been done with an open input IR. With the anti-sidetone connected to the input, the noise generated on the line will add via the anti-sidetone circuitry to the equivalent noise at the input IR. The total noise generated at the earpiece output depends on the microphone amplifier gain that has been set, the sidetone suppression and the receiving amplifier gain. The influence of the AGC on the noise appears clearly in Fig.34.

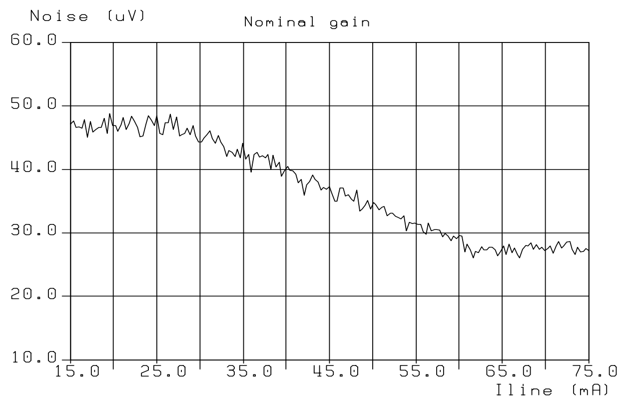

Fig.34 Noise on the earpiece

The amplifier gain is temperature compensated. The gain adjustment by an external Rgar resistor connected between pins GAR and QR may slightly change the temperature coefficient.

3.8 Automatic Gain Control; pin AGC

Principle of operation

The TEA1112/A perform automatic line loss compensation. The automatic gain control varies the gain of the microphone and receiving amplifiers in accordance with the DC line current. To enable the AGC function, the pin AGC must be connected to the pin VEE. For line currents below a current threshold, Istart (typical 26 mA), the gain control factor α is equal to 1, giving the maximum value for the gains Gvtx and Gvrx. If this threshold current is exceeded, the gain control factor α and the gain of both controlled amplifiers are decreased. When the line current reaches a second threshold current, Istop (typical 61 mA), the gain control factor α is limited to its minimum value equal to 0.5, giving the minimum value for the gains Gvtx and Gvrx. The gain control range of both amplifiers is typically 5.85 dB. This corresponds to a line length of 5 km for a 0.5 mm diameter twisted pair copper cable with a DC resistance of 176 Ω/km and an average attenuation of 1.2 dB/km.

Adjustment and performance

The ICs have been optimized for use with an exchange supply voltage of 48V, a feeding bridge resistance of 2 times 300 Ω and the previously described line. To fit with other configurations, a resistor, Ragc, can be connected between pins AGC and VEE. This allows to increase the threshold currents Istart and Istop. Fig.35 shows the control of the microphone gain versus the line current for different values of Ragc.

If no AGC function is required, the AGC pin must be open circuit. So no gain control is applied, the gain control factor α stays at 1 and both controlled gains have their maximum value.

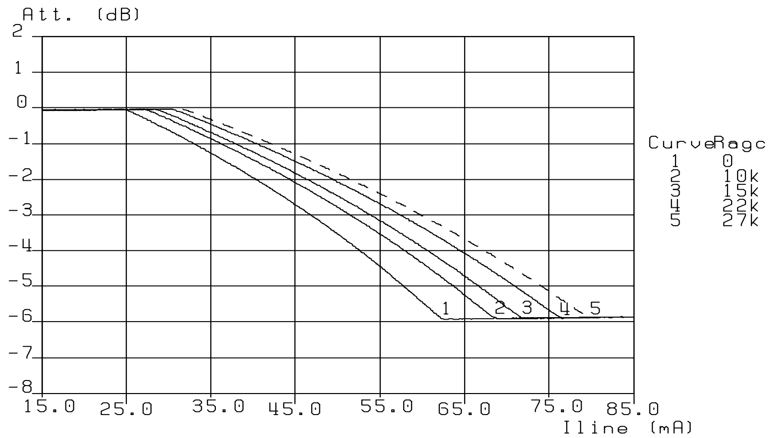

Fig.35 Automatic gain control on the microphone amplifier

3.9 DTMF amplifier; pin DTMF

Principle of operation

In Fig.36 the block diagram of the DTMF channel of the TEA1112/A is depicted.

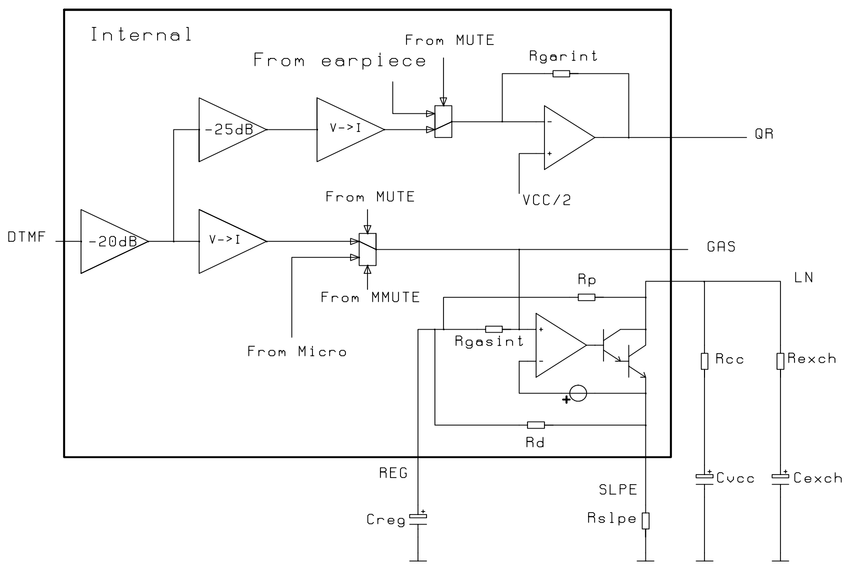

Fig.36 DTMF channel

The DTMF amplifier has an a-symmetrical high input impedance. The impedance between DTMF and VEE is typically 20 kΩ with maximum tolerances of +/- 15%. The DTMF amplifier is built up out of three parts: an attenuator by a factor 10, a pre-amplifier which realizes the voltage to current conversion and the same end-amplifier as the microphone amplifier. No AGC is applied on the DTMF channel.

Fig.37 shows the frequency response of the DTMF amplifier at 15 mA at different temperatures (Cgas = 100 pF).

Adjustment and performance

When a resistor Rgas is connected between GAS and REG to decrease the microphone gain, the DTMF gain varies in the same way: the DTMF gain is 26.5 dB lower than the microphone gain without control of AGC.

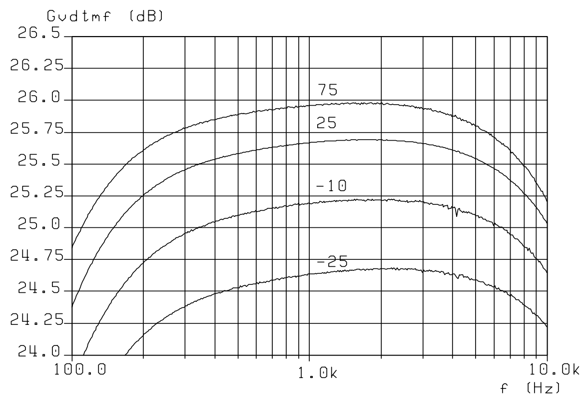

Fig.37 DMTF gain versus frequency: influence of temperature

The input of the DTMF amplifier can handle signals up to180 mVrms with less than 2% THD. Fig.38 shows the distortion of the line signal versus the rms input voltage for two different gains.

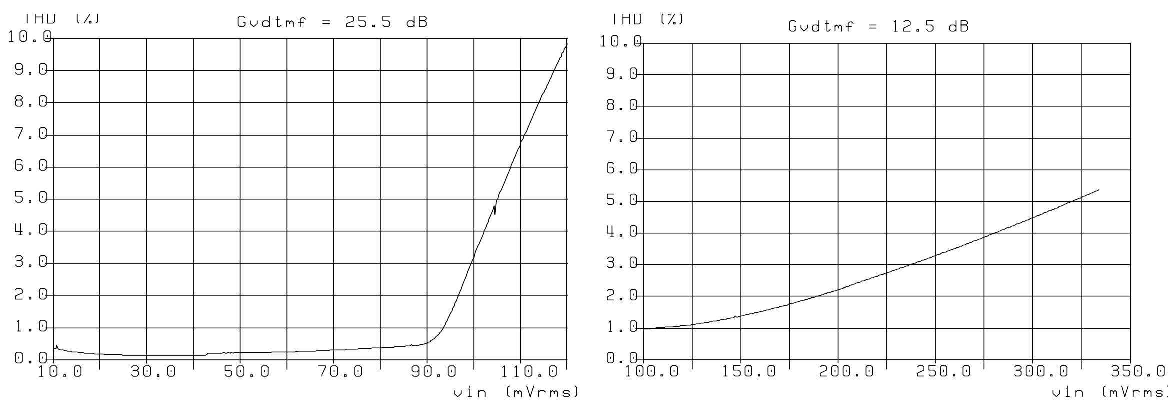

Fig.38 Distortion on the line function of the DTMF input signal for two different gains

3.10 MUTE function (TEA1112 only); pin MUTE

Principle of operation

The mute function realizes an electronic switching between the speech mode and the dialling mode. If a high level is applied to the MUTE input, the DTMF input is enabled and both microphone and receiving amplifiers are disabled. In this mode a confidence tone is provided in the earpiece. The microphone and receiving amplifiers are enabled by either applying a low level (< 0.3 V typically) at the MUTE input or leaving it open; (keep in mind that the microphone channel depends on the MMUTE level; See TABLE 1). In this case, the DTMF input is disabled.

Fig.39 shows the microphone amplifier gain reduction and the input current as a function of the voltage on MUTE. The threshold voltage is 0.68 V typically (base-emitter junction) with a temperature coefficient of -2 mV/ ^{o}C.

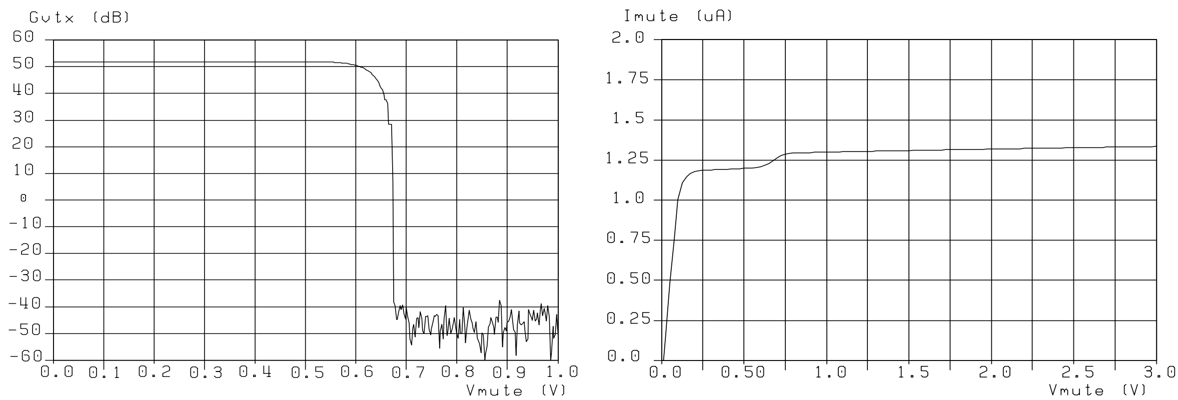

Fig.39 Microphone gain attenuation and MUTE input current vs Vmute

Adjustment and performance

Fig.40 shows the microphone and receiving gains reduction at Iline = 15 mA for an input signal at 1 kHz.Two curves are drawn on each graphic. The first one shows the spectrum of the signal on the line (QR) in speech condition when a signal is applied on the microphone inputs (IR input). The second curve shows the same signal in DTMF condition. Both signals are at a frequency of 1 kHz. The difference between the two curves at this frequency gives the gain reduction.

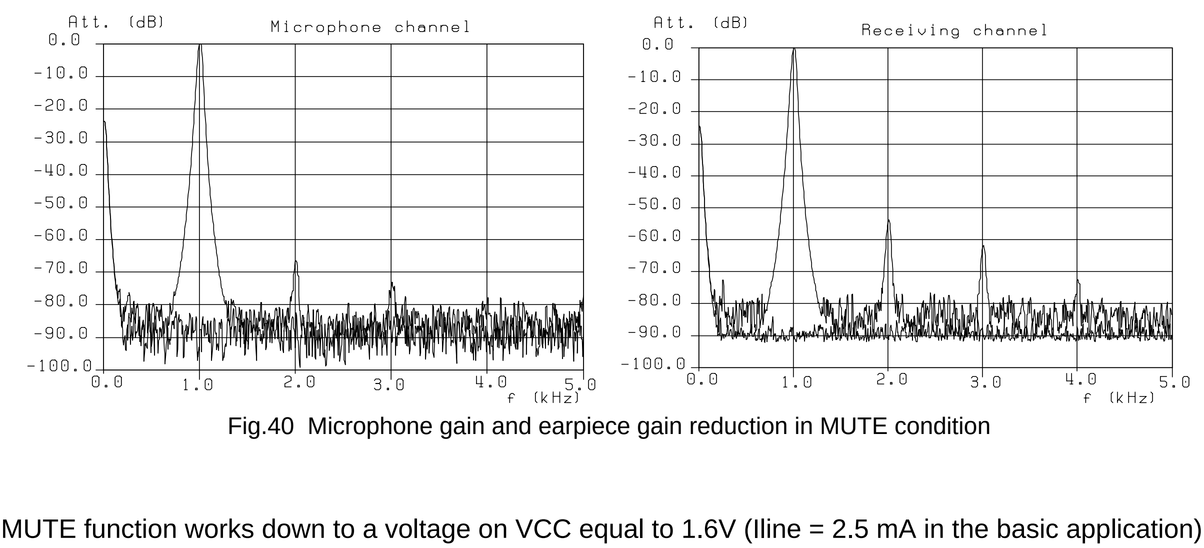

Fig.40 Microphone gain and earpiece gain reduction in MUTE condition

The MUTE function works down to a voltage on VCC equal to 1.6V (Iline = 2.5 mA in the basic application). Below this threshold, the microphone amplifier stays always enabled independently of the MUTE input level.

The maximum voltage allowed at the MUTE input is VCC + 0.4V.

3.11 $\overline{\text{MUTE}}$ function (TEA1112A only); pin $\overline{\text{MUTE}}$

Principle of operation

The $\overline{\text{MUTE}}$ function realizes an electronic switching between the speech mode and the dialling mode. If a high level is applied to the $\overline{\text{MUTE}}$ input, the microphone and receiving amplifiers are enabled and the DTMF input is disabled; (keep in mind that the microphone channel depends on the $\overline{\text{MMUTE}}$ level; See TABLE 1). The DTMF input is enabled by either applying a low level (< 0.3 V typically) at the $\overline{\text{MUTE}}$ input or leaving it open. In this mode a confidence tone is provided in the earpiece and the microphone and receiving amplifiers are disabled. Fig.41 shows the microphone amplifier gain reduction and the input current as a function of the voltage on $\overline{\text{MUTE}}$. The threshold voltage is 0.68 V typically (base-emitter junction) with a temperature coefficient of -2 mV/ ^{o}C.

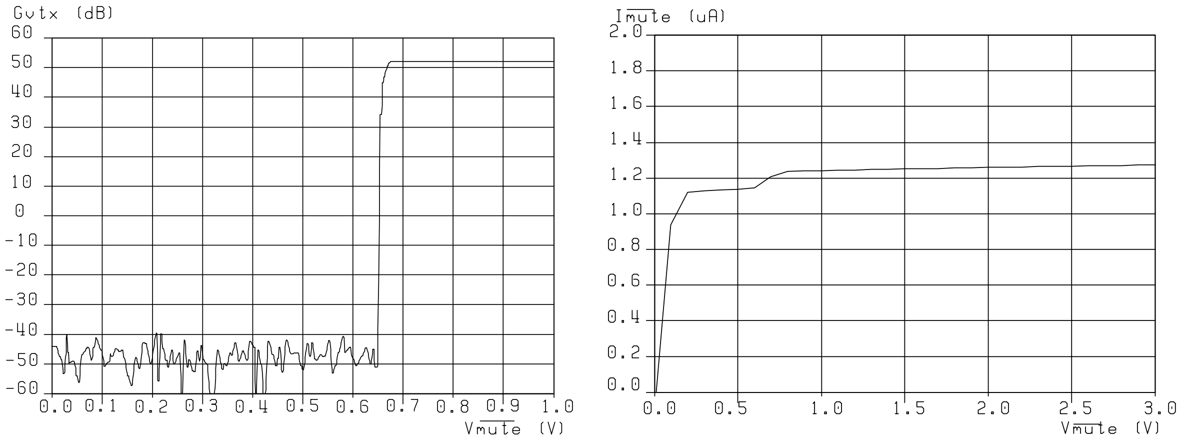

Fig.41 Microphone gain attenuation and $\overline{\text{MUTE}}$ input current vs $\overline{\text{Vmute}}$

Adjustment and performance

Fig.42 shows the microphone and receiving gains reduction at Iline = 15 mA for an input signal at 1 kHz. Two curves are drawn on each graphic. The first one shows the spectrum of the signal on the line (QR) in speech condition when a signal is applied on the microphone inputs (IR input). The second curve shows the same signal in DTMF condition. Both signals are at a frequency of 1 kHz. The difference between the two curves at this frequency gives the gain reduction.

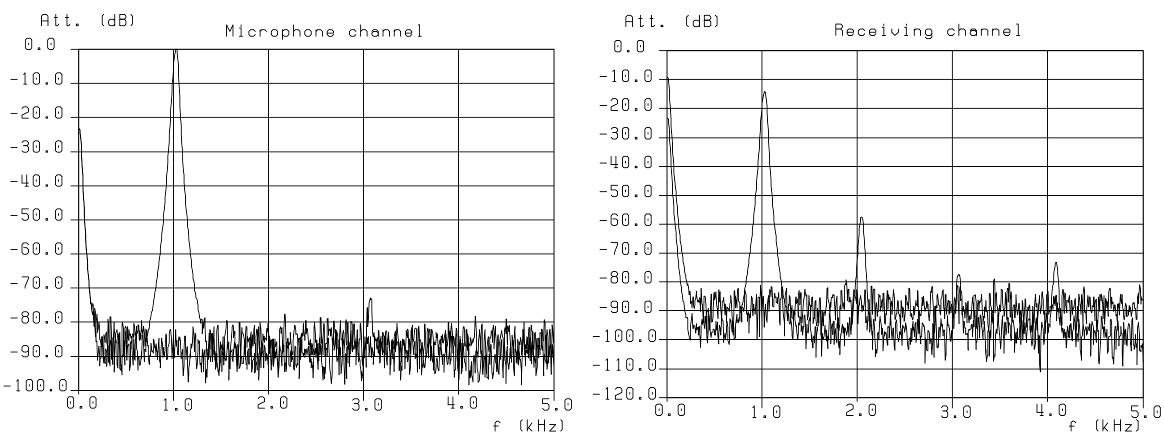

Fig.42 Microphone gain and earpiece gain reduction in $\overline{\text{MUTE}}$ condition

The $\overline{\text{MUTE}}$ function works down to a voltage on VCC equal to 1.6V (Iline=2.5 mA in the basic application). Below this threshold, the microphone amplifier stays always enabled independently of the $\overline{\text{MUTE}}$ input level.

The maximum voltage allowed at the $\overline{\text{MUTE}}$ input is VCC + 0.4V.

3.12 Anti-sidetone circuitry

Principle of operation

To avoid the reproduction of microphone signals in the earpiece, the anti-sidetone circuit uses the microphone signal from pin SLPE to cancel the microphone signal at the input IR of the receiving amplifier. The anti-sidetone bridge already used for the TEA106x family or a conventional Wheatstone bridge as shown in Fig.43 may be used as the basis for the design of the anti-sidetone circuit.

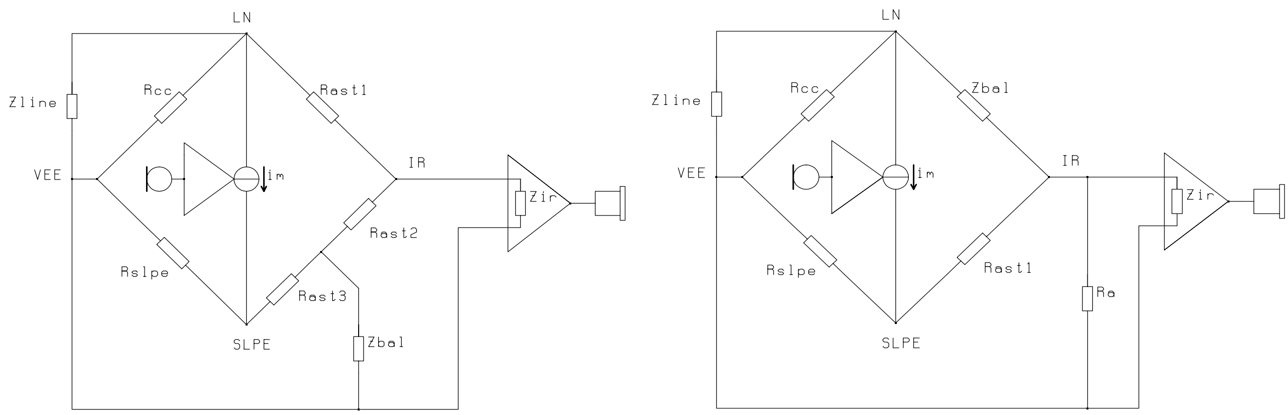

Fig.43 TEA106X family anti-sidetone bridge (left) and Wheatstone bridge (right)

The TEA106x family anti-sidetone bridge has the advantage of a relatively flat transfer function in the audio frequency range between pins LN and IR, both with real and complex set impedances. Furthermore, the attenuation of the bridge for the received signal (between pins LN and IR) is independent of the value chosen for Zbal after the set impedance has been fixed and the condition shown in equation (6) is fulfilled. Therefore, re*adjustment* of the overall receive gain is not necessary in many cases.

The Wheatstone bridge has the advantages of needing one resistor fewer than the TEA106x family bridge and a smaller capacitor for Zbal. But the disadvantages include the dependence of the attenuation of the bridge on the value chosen for Zbal and the frequency dependence of that attenuation. This necessitates some readjustment of the overall receive gain.

3.12.1 TEA106x family bridge

The anti-sidetone circuit is composed of: Rcc//Zline, Rast1, Rast2, Rast3, Rslpe and Zbal. Maximum compensation is obtained when the following conditions are fulfilled:

Rslpe x Rast1 = Rcc x (Rast2 + Rast3) (6)

k = (Rast2 x (Rast3 + Rslpe)) / (Rast1 x Rslpe)

Zbal = k x Zline

The scale factor k is chosen to meet the compatibility with a standard capacitor from the E6 or E12 range for Zbal.

In practice, Zline varies strongly with the line length and line type. Consequently the value for Zbal has to be chosen to fit with an average line length giving satisfactory sidetone suppression with short and long lines. The suppression further depends on the accuracy with which Zbal equals this average line impedance.

Example

Let's optimize for a line length of 5 km 0.5 mm diameter copper twisted pair with an average attenuation of 1.2 dB / km, a DC resistance of 176Ω / km and a capacitance of 38 nF / km. The approximate equivalent line impedance is shown in Fig.44

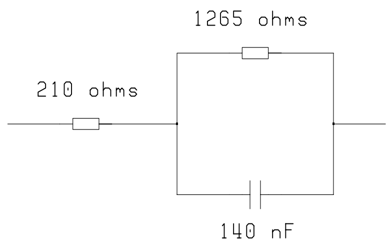

Fig.44 Equivalent average line impedance

For compatibility of the capacitor value in Zbal with a standard capacitor from the E6 series (220nF):

$$k = \frac{140nF}{220nF} = 0.636$$

For Rast3, a value of 3.92 kΩ has been chosen. So using the previous equations, we can calculate Zbal, Rast1, Rast2. We find Rast1= 130 kΩ, Rast2 = 390 Ω, and for Zbal 130Ω in series with (220nF//820Ω).

The attenuation of the received line signal between LN and IR can be derived from equation (7)

$$\frac{Vir}{Vln} = \frac{Zir||Rast2}{Rast1 + (Zir||Rast2)} \qquad (7)$$

if Rast2 >> (Rast3//Zbal).

With the values used in the example, it gives 32 dB at 1 kHz.

Zir is the receiving amplifier input impedance, typically 20 kΩ.

3.12.2 Wheatstone bridge

The conditions for optimum suppression are given by:

$$Zbal = \frac{Rast1}{Rslpe} \times \frac{Rcc \times Zline}{Rcc + Zline}$$

Also for this bridge type, a value for Zbal has to be chosen that corresponds with an average line length.

The attenuation of the received line signal between LN and IR is given by:

$$\frac{Vir}{Vln} = \frac{Rast1||Zir||Ra}{Zbal + (Rast1||Zir||Ra)}$$

Ra is used to adjust the bridge attenuation; its value has no influence on the balance of the bridge.

4. APPLICATION EXAMPLE 1 - LOW VOLTAGE BASIC SET -

Two application examples are described in this report; a ‘low voltage basic set’ in this chapter and a ‘handsfree application with on-hook dialling’ in chapter 5. Both examples are general purpose applications for exchanges with voltage regulation. Fine tuning is required to fulfil specific country requirements. Both applications have been build and tested on their functionality.

4.1 Description of the application

An application example for a low voltage basic telephone set is shown in Fig.45 and Fig.46. It is build up with the TEA1112 transmission IC and a discrete ringer circuit as shown in Fig.45, and the PCD3332-3 pulse/tone repertory dialler/ringer IC PCD3332-3 according Fig.46. The interconnections between both figures are indicated. The application offers the following features:

- Transmission functions with adjustable parameters as described for the TEA1112 in chapter 3.
- Microphone mute function
- Pulse, DTMF and mixed mode dialling, redial, 13-number repertory dialling as specified in [1]
- Ringer signal detection and melody generation

The application is build up around the TEA1112. The individual settings of the TEA1112 are for 600 Ω set impedance and 2.5 V minimum supply voltage for the PCD3332-3 at dialling. The several blocks of the application are briefly described in this chapter; details concerning the performances are given in chapter 4.2.

The **TEA1112** in this application cannot be replaced by the **TEA1112A** version because of the inverted MUTE and MMUTE ($\overline{\text{MUTE}}$ and $\overline{\text{MMUTE}}$) of the TEA1112A.

Polarity guard and protection

One diode bridge is applied for the transmission circuit part as well as for the ringer stage to ensure proper functioning independent of the polarity of the line voltage respectively to rectify the ringer signal. Protection is achieved by a break-over diode D18 between the A-B/B-A terminals, the current limiting components R20 and TR3, the 11 V zenerdiode Z5 between LN and VEE of the transmission IC and by a 5.6 V zener diode Z13 between VDD and VSS of the PCD3332-3.

The current limiter R20 and TR3 provides protection against current surges exceeding 150 mA. It is not designed for continuous limitation of the line current.

The voltage across the ringer output stage is limited at 24 V by means of the zener diodes Z11 and Z13 and diode D12.

Interrupter

The interrupter consists of TR1, P-channel enhancement D-MOS BSP304A, and inverter TR2 controlled by the DPN/FLN open drain output of the PCD3332-3. When the handset is lifted, cradle switch S1 changes from ringer state (on-hook) to transmission state (off-hook); DPN/FLN is high resulting in a conducting TR1.

Interruption of the line current is achieved by a low DPN/FLN level.

Speech / transmission

The TEA1112 stabilizes the DC voltage between LN and SLPE. It delivers the supply voltage VCC for internal use and for the PCD3332-3 via diode D16. VCC is buffered by C7 while VDD is buffered by C35. The set impedance will be mainly determined by the impedance of the network between LN and VCC. This application has a set impedance of about 600 Ω realised by R1 = 619 Ω and R2 = 0 Ω.

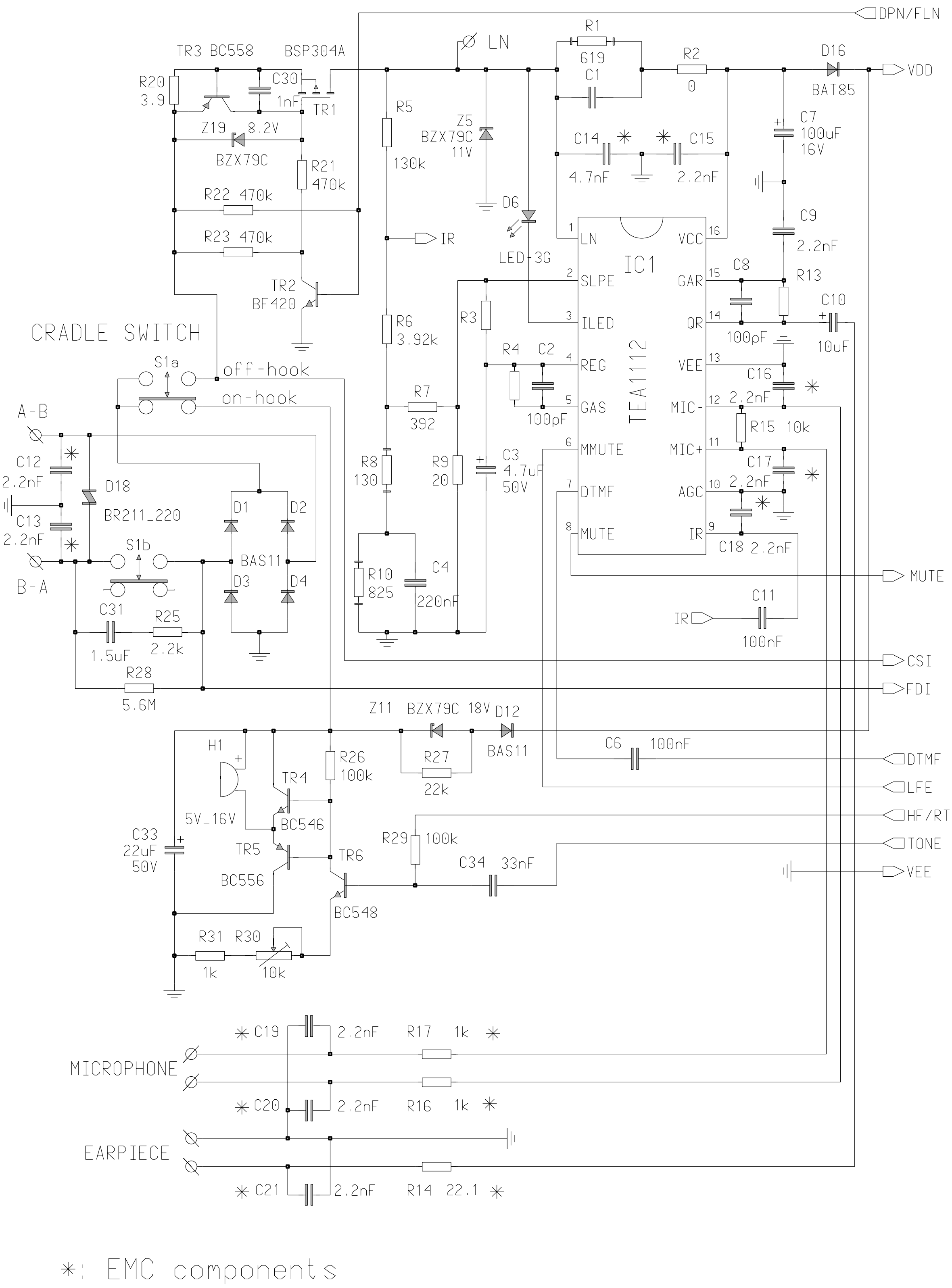

Fig.45 Application example 1; line interface TEA1112, discrete ringer

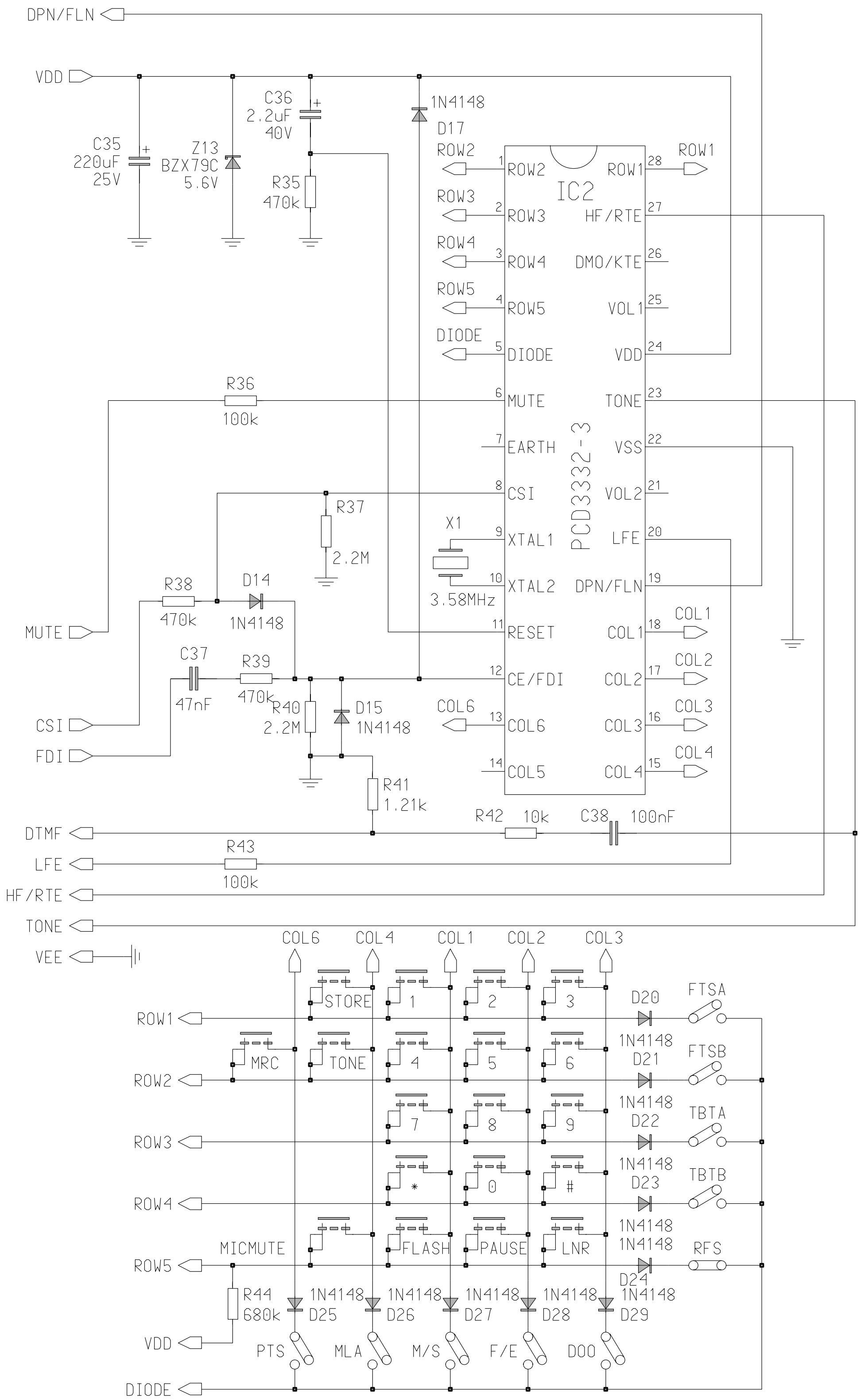

Fig.46 Application example 1; dialler/ringer PCD3332-3

Complex set impedance can be realised by means of the network R1, R2 and C1.

The application is intended for use with a dynamic microphone and dynamic earpiece. Use of an electret microphone requires a modification of the application. A supply has to be made from VCC while the gain has to be adapted by resistor R4 which has no value in Fig.45; see application example 2, chapter 5.

Buffer capacitor C7 is discharged heavily during the break periods at pulse dialing with the result that the VDD buffer capacitor C35 will not be charged during the whole dialling digit.

The supply voltage VCC has to be increased for pulse dialling applications, see chapter 4.2.

The microphone amplifier can be disabled by a high level at the MMUTE input pin. In this example is the MMUTE input coupled with output LFE of the PCD3332-3. LFE can be toggled by the ‘MICMUTE-key’ to disable or enable the handset microphone.

PCD3332-3 dialler/ringer

The dial parameters of the PCD3332-3 can be set by diode options to specific-country requirements. A single contact keypad matrix is connected with the corresponding COL and ROW I/O’s. This simple keypad offers no direct access of the stored numbers as proposed for application example 2. The ‘STORE-key’ and ‘MRC-key’ has to be used to store and recall telephone numbers. Diode switch MLA has to be open.

As explained before is the ‘MICMUTE-key’ applied to toggle the microphone amplifier during conversation by means of the LFE output. However, use of the ‘MICMUTE-key’ during ringing, toggles also the ringing melody.

Reset is performed by the internal reset of the PCD3332-3 mainly. Reset components C36-R35 compensates the spread of the internal reset voltage. Output DPN/FLN drives the interrupter to perform pulse dialling (PTS switch ‘closed’) and flash function (F/E switch ‘open”). The position of cradle switch S1 determines the CSI level during stand-by (CSI = low) and conversation mode (CSI = high).

Input CE/FDI is connected to the positive line wire and the diode-bridge to detect the operation mode of the PCD3332-3 in combination with CSI.

Resistor R36 in the MUTE wire is required to prevent discharging of the VDD capacitor during the break-periods at pulse dialling or flash when VCC is reduced below the VDD voltage level at MUTE is high.

Output TONE delivers the melody for the ringer circuit (at HF/RTE = high) and the DTMF dialling signal to the DTMF input of the TEA1112 via attenuator R41-R42.

ROW 5 of the PCD3332-3 is an open drain output which is pulled-up by R44.

Ringer circuit

The VDD capacitor is kept charged during stand-by to speed-up initialization of the PCD3332-3 at incoming calls; see ‘*Start-up’* in this chapter.

Supply of the ringer is delivered by the ringer signal from the exchange via the bridge and the series network C31-R25.

When CE becomes high and CSI is kept low the PCD3332-3 enters the ringer mode at frequencies of the ringer signal between 20 Hz and 57 Hz (RFS switch is ‘open’) or between 14 Hz and 75 Hz (RFS switch is ‘closed’). Output HF/RTE will be high during ringing to select the ringer circuit.

Volume control is performed by potentiometer R30. In application example 2 the volume of the ringer sound is controlled by means of the VOL1 and VOL2 outputs and the ‘VOL1/VOL2-keys’. This principle can be applied for this example also.

The ringer melody can be changed by means of the key-board buttons 1, 2 and 3.

4.2 Settings and performance of the application

4.2.1 DC behaviour

DC settings

The DC voltage at the A-B/B-A terminals is a result of the voltage drop across the TEA1112, line interrupter and diode bridge. The voltage drop across the TEA1112 depends on the setting of the reference voltage (VREF) between LN and SLPE and the voltage drop across R9 which depends of the line current.

Important for the minimum line voltage (A-B/B-A) is the minimum supply voltage VDD required by the PCD3332-3. VDD is supplied by VCC which depends on the resistance value of R1, or network between LN and VCC in case of complex impedance, and the total current consumption from VCC.

To guarantee a minimum VDD supply voltage of 2.5 V during DTMF as well as pulse dialling VCC has to be increased by an enlarged reference voltage of the TEA1112 by means of R3 between REG and SLPE.

In case of 600 Ω set impedance the A-B/B-A voltage measures 6.0 V at 20 mA line current to get a minimum VDD of 2.5 V at DTMF as well as pulse dialling; R3 = 40 kΩ. The minimum VDD level is reached at pulse dialling (long digits) when VCC decreases below the VDD level.

Fig.47 shows the line voltage VA-B across the A-B/B-A terminals as a function of line current Iline at nominal and increased line voltage by means of R3 = 40 kΩ.

Supply possibilities

VCC can be applied to supply peripherals such as the PCD3332-3 and an electret microphone. The possibilities are rather limited and depend in general of the LN-SLPE setting, the DC resistance of the network between LN and VCC and the total current consumption from VCC.

Take in account that the minimum VCC level, to keep the TEA1112 functioning, is about 2.0 V at 20 mA line current. Furthermore, the voltage difference between VCC and SLPE has to be more than 1.6 V, over the whole line current range (!), to keep the send stage fully functional.

Start-up

After connecting the application with the line supply the very first time, the handset has to be lifted to charge the VCC and VDD supply capacitors. The set is operational within 200 ms at 20 mA line current.

During on-hook the VDD capacitor C35 is kept charged by R28. The DC current in this stand-by mode has to be more than 6 µA.

Start-up after off-hook (t = 0, VDD capacitor has been charged) is given in Fig.48 by means of the voltage VA-B across the set and the supply voltages VCC and VDD versus time. The set is supplied from an exchange voltage of 48 V while the line current is 20 mA during off-hook. R3 = 40 kΩ.

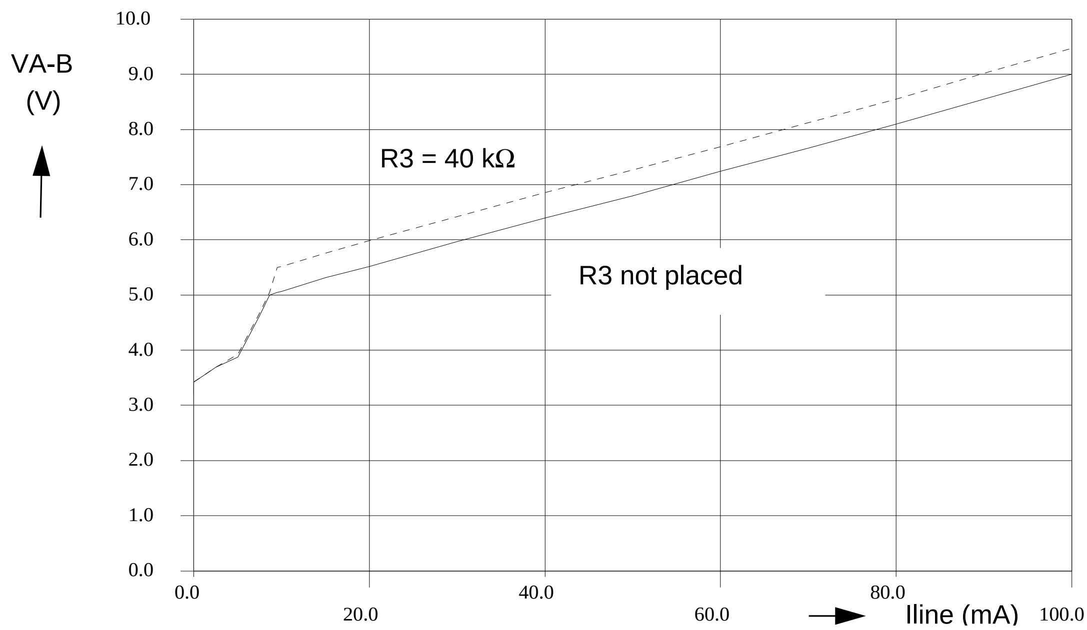

Fig.47 Line voltage across the set as a function of line current

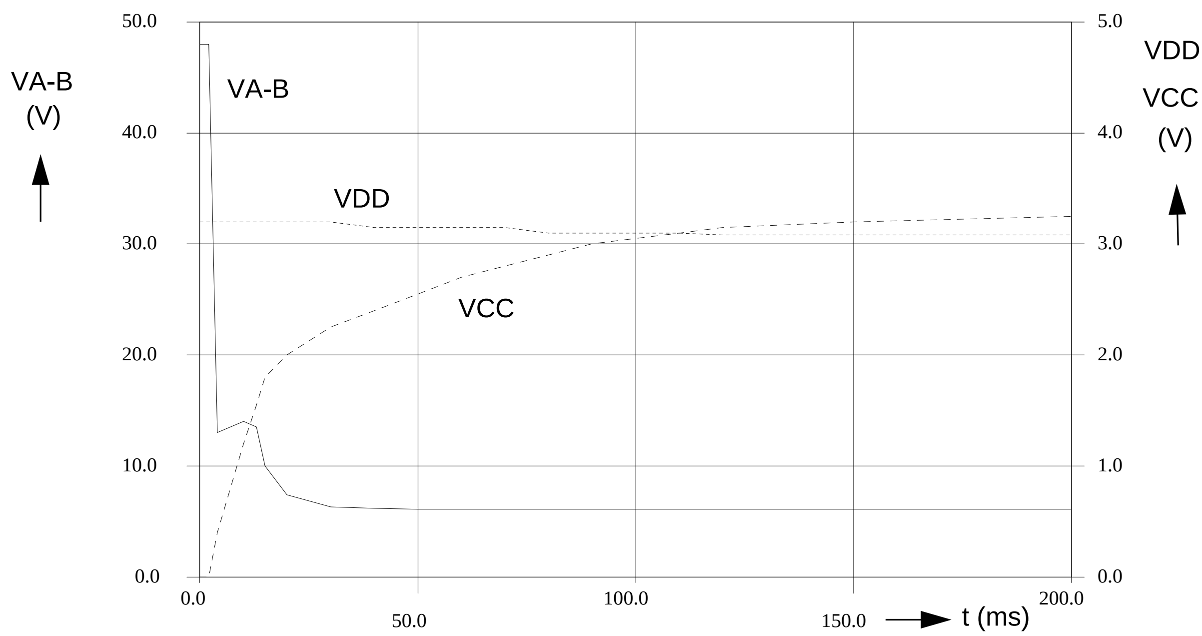

Fig.48 Start-up after off-hook

4.2.2 Transmission

Set impedance and BRL

A set impedance of 600 Ω can be realised with R1 = 619 Ω, while for complex set impedance the network between LN and VCC has to be defined.

Fig.49 shows the BRL (dB) of a ‘600 Ω set’ measured with 600 Ω reference. In the same graph is given the BRL (dB) of a ‘complex set’ consisting of R1 = 825 Ω, C1 = 115 nF and R2 = 220 Ω measured with a reference impedance of 825 Ω // 115 nF + 220 Ω.

In case of complex set impedance the value of capacitor C3 has to be increased to meet BRL requirements.

In this example, at R1 = 825 Ω, C1 = 115 nF and R2 = 220 Ω, the value of C3 = 6.8 µF. To eliminate the influence of the transducers in the handset, they have been replaced by 200 Ω resistors during the measurement. The line current is 20 mA.

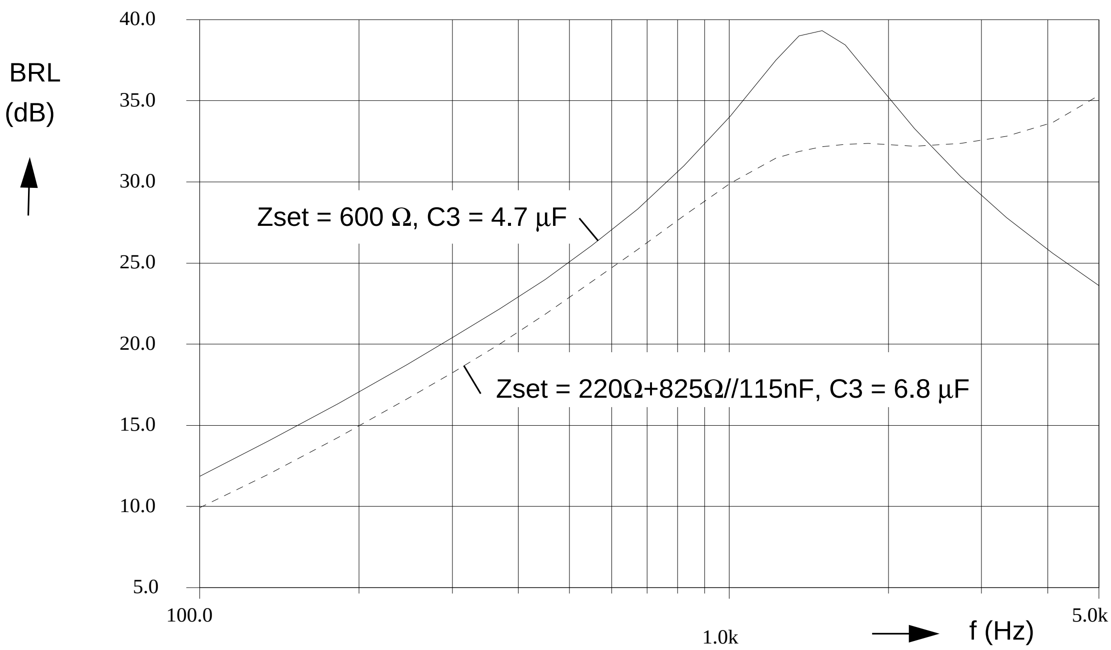

Fig.49 BRL of application example 1 at ‘real’ and ‘complex’ termination

Send and receive

This application is intended for use with a dynamic microphone. The total gain from microphone terminals to the line measures 50dB at 600 Ω set impedance and 600 Ω line load without AGC function. The internal setting of the TEA1112 is 52 dB typical, while about 2 dB is lost due the EMC components R16 and R17 (both 1 kΩ), in series with the MIC inputs, and the termination resistor R15 (10 kΩ) across the MIC inputs.

The send gain of the TEA1112 may be decreased to a minimum of 39dB according [2]. The overall send gain results in 37 dB with R4 = 20 kΩ.

The maximum swing of the line signal measures 5.5 dBm over the frequency range 300 Hz - 3400 Hz, at 600 Ω set impedance, 600 Ω line load and 20 mA line current. Capacitor C30 between the gate-source of TR1 keeps TR1 conducting at negative swings of the line signal; it improves the maximum swing of the line signal at lower frequencies.

The overall receive gain from line to earpiece is about –2.5 dB at an earpiece impedance of 150 Ω. This is due to the attenuation of 32 dB from line to IR input, the internally determined gain of the receive stage of 31 dB typically and the 1.5 dB attenuation due to EMC component R14 (22 Ω). The gain values are given without activated AGC function.

The receive gain can be reduced from 31 dB to 19 dB minimum by means of resistor R13. At R13 = 100 kΩ the receive gain is reduced by 6 dB which result in an overall receive gain of –8.5 dB typically.

Send and receive gains are internally defined by on-chip resistors. Reduction of these gains by external resistors (R4, R13) result in matching inaccuracies.

Side tone / AGC

Reproduction of the (electrical) microphone signal in the earpiece is reduced by the anti-sidetone circuit consisting of the components R5, R6, R7 and Zbal with R8, R10 and C4. The principle of the applied TEA1060-family bridge is given in chapter 3.12 and fully described in [8].

In case AGC is not applied (pin AGC open) the anti-sidetone circuit has to be re-calculated for a mean cable length of < 5 km. Readjustment of the balance circuit is necessary for other cable types, different line length, etc.

4.2.3 Dialling

DTMF dialling

The DTMF signal from the TONE output of the PCD3332-3 is attenuated by the network R41 and R42 and applied to the DTMF input of the TEA1112. Resistor R41 is in parallel to the input impedance of the DTMF amplifier (20 kΩ typ.). During dialling, MUTE is high, the signal is amplified by the DTMF stage and transferred to the line resulting in a total level of –6 dBm at 600 Ω set impedance and 600 Ω line load. The gain of the DTMF stage is 25.5 dB typical.

A reduction of the microphone gain by means of external resistor R4 reduces also the DTMF gain and transmitted signal levels. The attenuation network R41-R42 has to be redefined to correct the reduced signal transfer.

Take in account that VDD decreases during DTMF dialling because of the enlarged current consumption of the PCD3332-3 in this mode.

Pulse dialling / Flash

The line current will be interrupted by the electronic interrupter (TR1) under control of the DPN/FLN signal. During progress of the dialled digit (or flash) the PCD3332-3 has to be supplied by the stored energy of C35 because the level of VCC is too low to charge-up this capacitor. The value of buffer capacitor C35 has a value of 220 µF to keep the VDD supply level at >2.5 V.

Fig.50 shows the voltage at the A-B/B-A terminals, supply voltages VCC and VDD and the line current during dialling of a ‘zero’ at R3 = 40 kΩ, Vexchange = 48 V and 20 mA line current. The VDD voltage is reduced to about 2.5 V at the end of dialling phase as a test result for this application example. Take into account that VDD could be < 2.5 V at worst case conditions.

The selectable maximum FLASH time of the PCD3332-3 is 600 ms. At flash-times of 600 ms the VDD voltage remains > 2.5V.

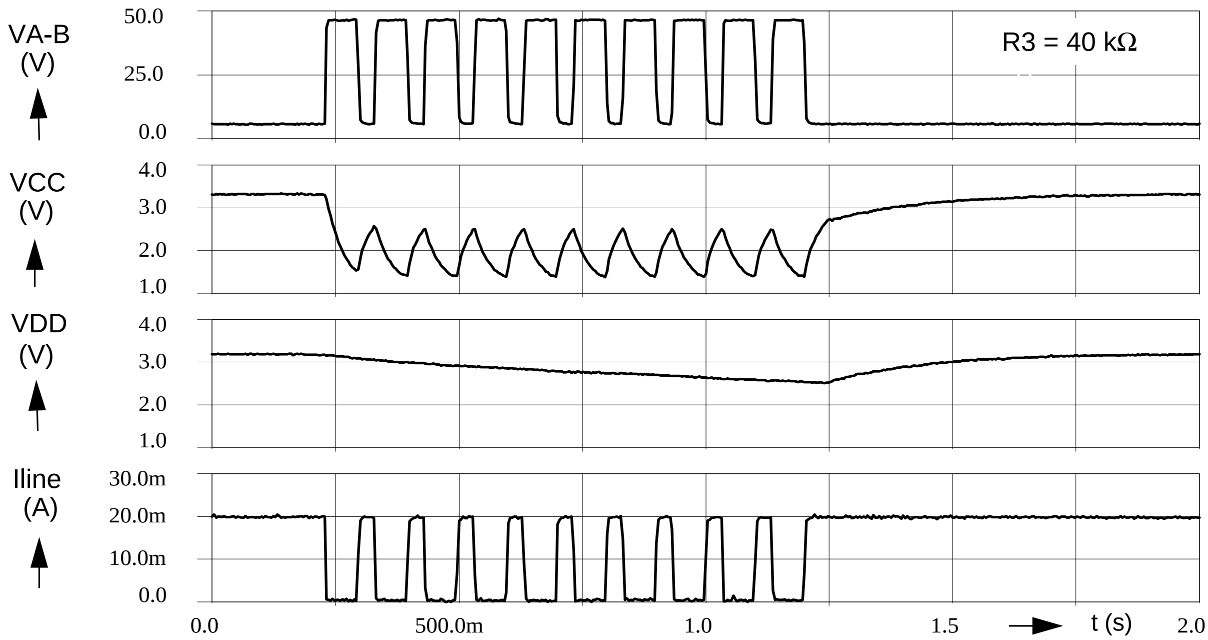

Fig.50 Behaviour of application example 1 during pulse dialling at 20 mA

5. APPLICATION EXAMPLE 2 - HANDSFREE SET -

5.1 Description of the application

The circuit diagram of the handsfree application is split-up in three figures. It consists of an electronic hook switch, TEA1112 transmission IC and discrete ringer circuit as shown in Fig.51, the TEA1093 handsfree application Fig.52 and the PCD3332-3 pulse/tone repertory dialler/ringer IC according Fig.53. Interconnections between Fig.51 and Fig.52 are indicated by means of net-in/net-out symbols while interconnections between Fig.51 and Fig.53 are given by offpage-symbols.

The application offers:

- Pulse, DTMF and mixed mode dialling, redial, 13-number repertory dialling with the PCD3332-3 [1]
- Transmission functions with adjustable settings as described for the TEA1112; chapter 3
- Handset operation
- Handsfree operation
- Ringer signal detection, melody generation and volume control.

Line connection / electronic hook switch / interrupter

The transmission circuitry and the ringer stage are connected with the line by two separate diode bridges to ensure proper functioning of the application independent of the polarity of line voltage and to rectify the ringer signal. The two zener-diodes Z14 and Z15 in series with the ringer bridge reduce the line-load from the ringer stage during transmission.

The application is protected against over-voltages at the line input by break-over diode D18. Components R20 and TR3 limit the current through TR1 when the line current exceeds about 150mA. This current limiter is not designed for continuous limitation of the line current. It only provides protection against current surges.

The electronic hook-switch / interrupter TR1 is controlled by inverter TR2 via the DPN/FLN open drain output of the PCD3332-3. During off-hook when the handset is lifted, or when the ‘HOOK-key’ is activated, DPN/FLN is high resulting in a conducting TR1. Conducting of TR2 is initiated by the high ohmic resistor R22 and is taken over by R24. Interruption of the line current is achieved by DPN/FLN is low.

When the application is connected with the line supply the very first time, the electronic hook-switch is switched-on for a short time resulting in a quick charge-up of the supply capacitors of VCC and VDD.

During stand-by the VDD capacitor is kept charged by means of R28.

Handset / Handsfree application

The handsfree circuit TEA1093 is connected between the positive line wire, which is connected to LN of the TEA1112 via R11 and R12, and SLPE of the TEA1112. The current into LN of the TEA1112 is as low as 3mA to have most of the line current available for the loudspeaker function of the TEA1093. Resistor R12 keeps the TEA1093 operational at saturation the line signal at large negative amplitudes.

The base microphone (HF-mic) or the handset microphone (HS-mic) are switched to the MIC input of the TEA1093 by means of TR7 respectively TR8 depending on the HF/RTE level of the PCD3332-3. Handsfree is switched-on when HF/RTE = high resulting in transfer of the HF-mic signal to the transmit input of the TEA1093 (MIC). Handset mode is achieved at HF/RTE is low; the HS-mic is operational while the TEA1093 is forced into the transmit mode by a low level of MUTER generated by TR9. Transmit or receive state is under control of the duplex controller of the TEA1093.

The discrete switching circuitry for the microphones could be replaced by the 74HC4053 multiplexer/demultiplexer IC as applied in [7].

The transmit output signal between MOUT and MICGND (in HS or HF mode) is transferred to the MIC inputs of the TEA1112 via attenuator R42, R43 and R15. The signal between the MIC inputs is amplified to the line.

The receive signal is transferred to the QR output of the TEA1112 and offered to the HS earpiece and RIN1 of the TEA1093. RIN2 is connected to VEE which is the ground reference of the receive signal of the TEA1112.

The signal between RIN1 and RIN2 is amplified by means of the loudspeaker amplifier and supplied to the loudspeaker. Volume control is performed by a simple potentiometer R41.

Transmit and receive gains of the transmit and receive channels of the TEA1093 and TEA1112 are in conformity with the sensitivities of the applied microphones, earpiece and loudspeaker; see ‘Settings and performances of the application’; chapter 5.2. The TEA1112 is described in chapter 3 of this report while the settings of the duplex controller of the TEA1093 are according the Application Note of the TEA1093 [3] and the demonstration model of the TEA1093 [4].

PCD3332-3 dialler/ringer

A single contact 6 x 5 matrix keypad is connected with the corresponding COL and ROW I/O’s. The keypad includes 10 memory keys, M0 to M9, for direct access of the stored numbers in case the MLA diode switch is closed. PCD3332-3 output DPN/FLN drives the electronic hook-switch to perform pulse dialling and flash function (F/E diode option not applied).

Reset is performed by the internal reset of the PCD3332-3 mainly. Reset components C71-R71 compensates the spread of the internal reset voltage. Input CE/FDI is connected to the positive line wire and the ringer bridge to detect the operation mode of the PCD3332-3 in combination with CSI. Series diode D17 in the positive line wire is applied to get a fast trailing edge of the CE pulse after on-hook or at line breaks.

Output MUTE is wired to the TEA1112 via R16 and to the TEA1093 via R52 and D20. This diode prevents levels at MUTET below the GND reference of the TEA1093.

Output TONE delivers the melody for the ringer circuit (at HF/RTE is high) and DTMF dialling signal to the DTMF input of the TEA1112 via the attenuator R41-R42.

The different modes of the PCD3332-3 are:

Stand-by mode: CE, CSI and HF/RTE are low during a specific time. The stand-by mode is left when CE goes high. It changes over to the ringer mode when an incoming ringer signal is detected, or changes over to the handset mode when CSI goes high or comes in the on-hook dialling or handsfree mode when the ‘HOOK-key’ is activated.

Ringer mode: CE = high, CSI = low resulting in HF/RTE = high. The ringer mode is left when CE goes low for time out (stand-by mode), when the handset is lifted (handset mode) or when the ‘HOOK-key’ is pressed (handsfree mode).

Handset mode: CE = high, CSI = high resulting in HF/RTE = low. The handset mode is left when the handset is put back on the cradle (stand-by mode) or when the ‘HOOK-key’ is pressed while the handset is put back (handsfree mode).

Handsfree mode: HF/RTE = high, CSI = low. This mode can be entered by pressing the ‘HOOK-key’. The handsfree mode can be left by pressing the ‘HOOK-key’ (stand-by mode) or by lifting the handset (handset mode).

Dialling operations are possible in the handset and handsfree mode. Pulse or DTMF dialling can be selected by diode switch PTS [1].

Ringer circuit

The discrete ringer stage from example 1 is extended in this application with volume control by keypad via the PCD3332-3 outputs VOL1 and VOL2. The sound pressure from the PXE (Murata PKM34EW-1224) can be changed by 4 steps. Maximum volume is obtained when both VOL1 and VOL2 are low.

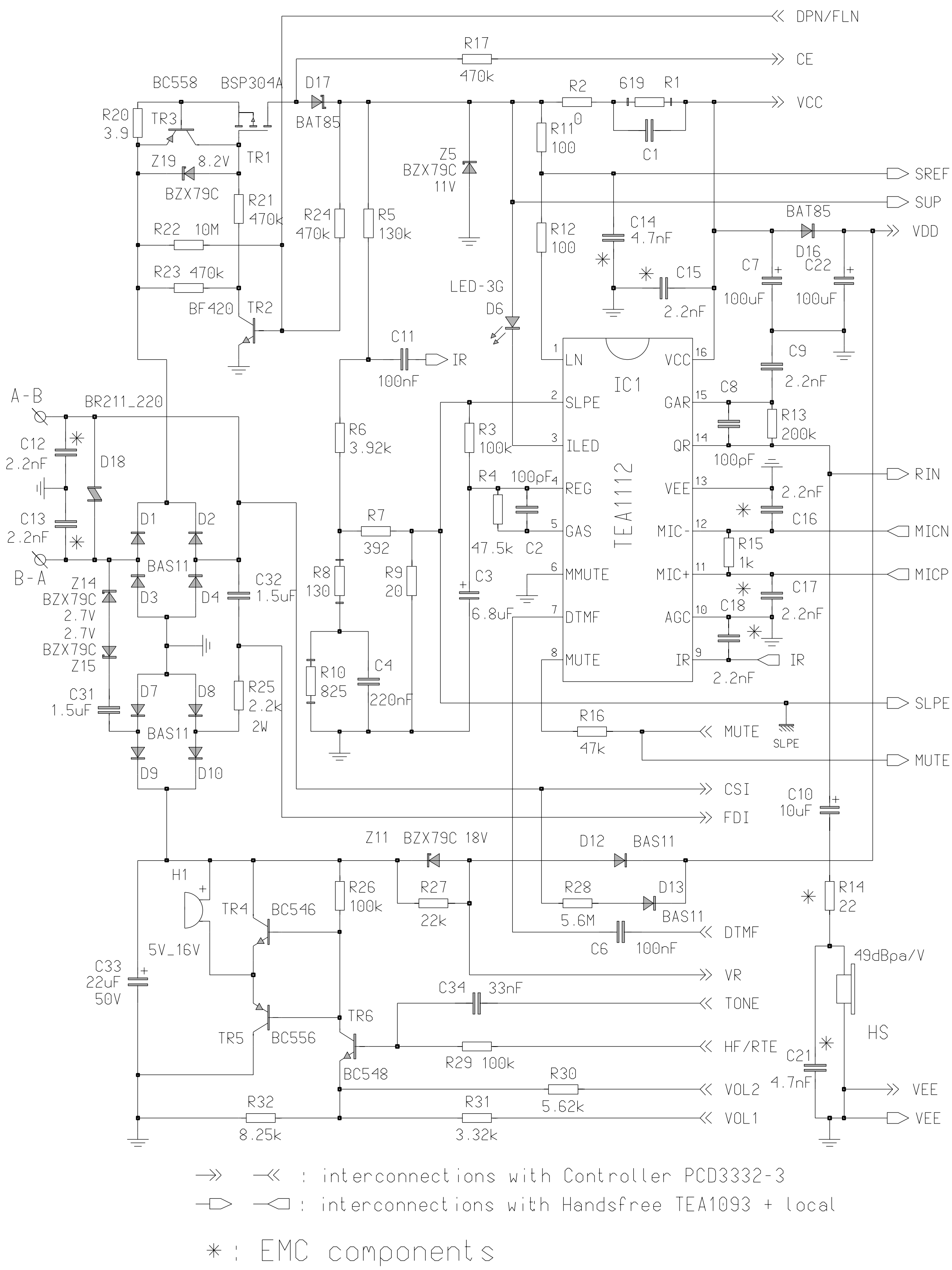

Fig.51 Application example 2; line interface TEA1112, electronic hook-switch and discrete ringer

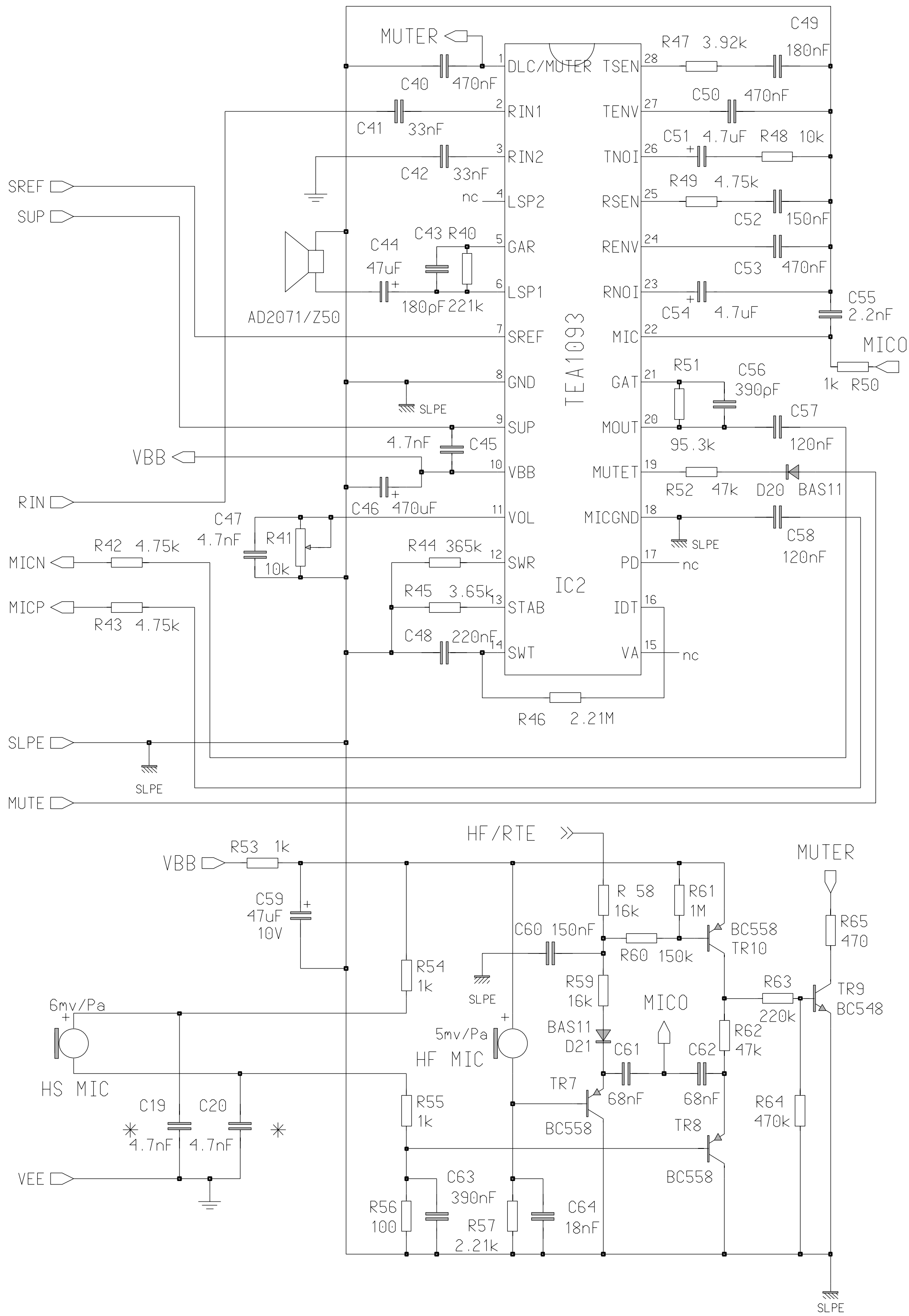

Fig.52 Application example 2; handsfree application TEA1093

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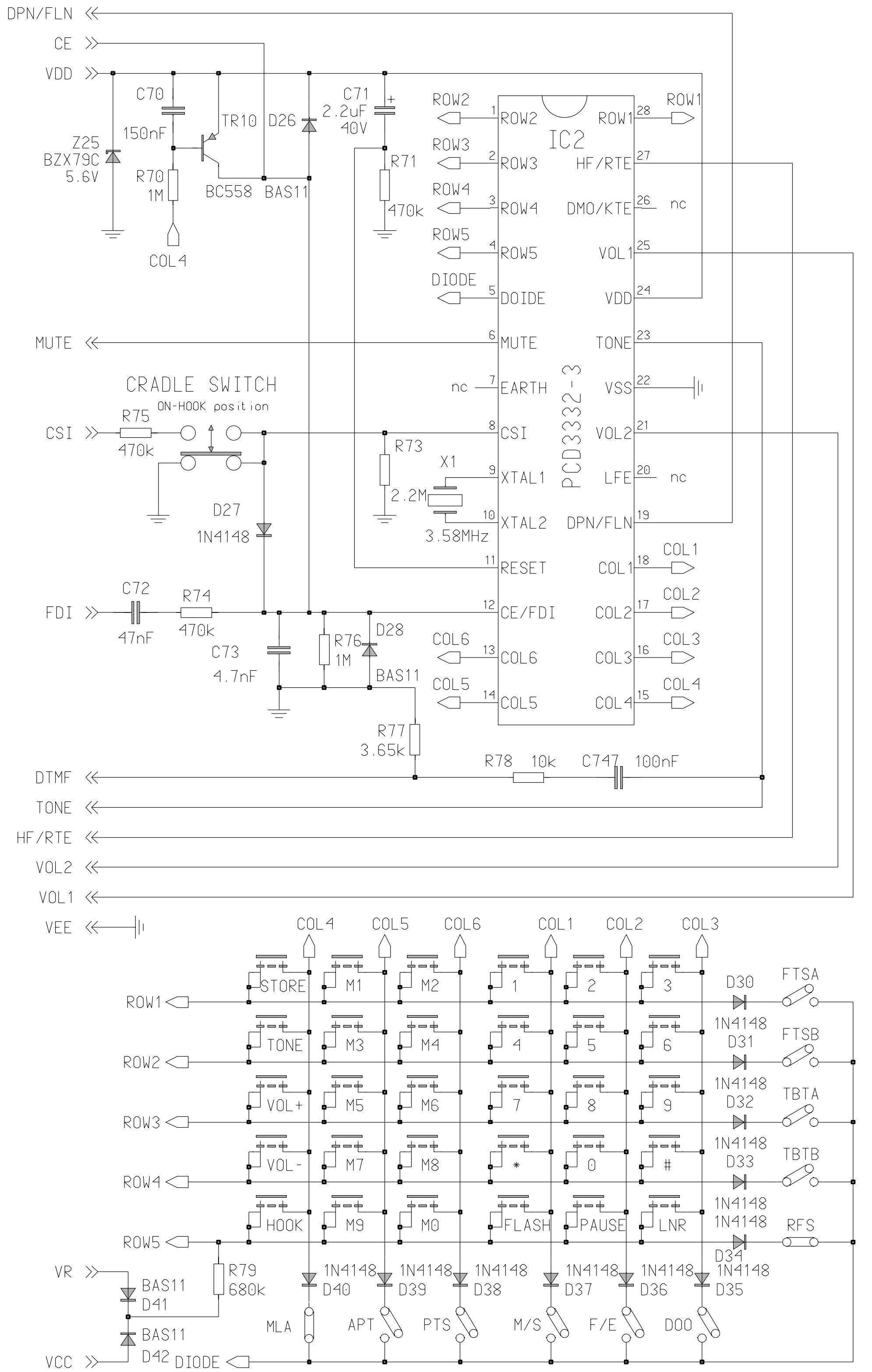


Fig.53 Application example 2; dialler/ringer PCD3332-3

5.2 Settings and performance of the application

DC settings

The stabilized voltage of the TEA1112 (VREF between LN and SLPE) is increased by means of R3 (100 kΩ) to adjust the voltage difference between SUP and VBB of the TEA1093 to 600mV. The voltage at the A-B/B-A line terminals measures 6.6 V at 20 mA. The DC slope of the Vline/Iline characteristic is about 45 Ω due to R20, R9 and the channel-resistance of TR1.

The stabilized voltage VBB (TEA1093) can be adjusted [3]. Take into account that VSUP–VBB has to be at least 600 mV to maintain maximum efficiency of the current switch of the TEA1093 at mean speech levels.

The line current can be split-up in:

- **Isup** flowing into SUP of the TEA1093 to supply the internal circuitry including loudspeaker amplifier and microphones
- **Iled** through D6 which is a function of the line current. Refer to chapter 3.3
- **Itr** flowing into LN of the TEA1112; realised by (VSUP–VSREF)/R11 = 0.32/100 = 3.2 mA typical
- **Ivcc** which includes the current consumption of the TEA1112, see chapter 3.1, and the current consumption of the PCD3332-3 in conversation mode [1]

Fig.54 shows these currents as a function of Iline in the conversation mode while Fig.55 gives the line voltage VA-B, supply voltages VCC and VDD both with respect to VEE, and the stabilized voltage VBB with respect to SLPE versus Iline.

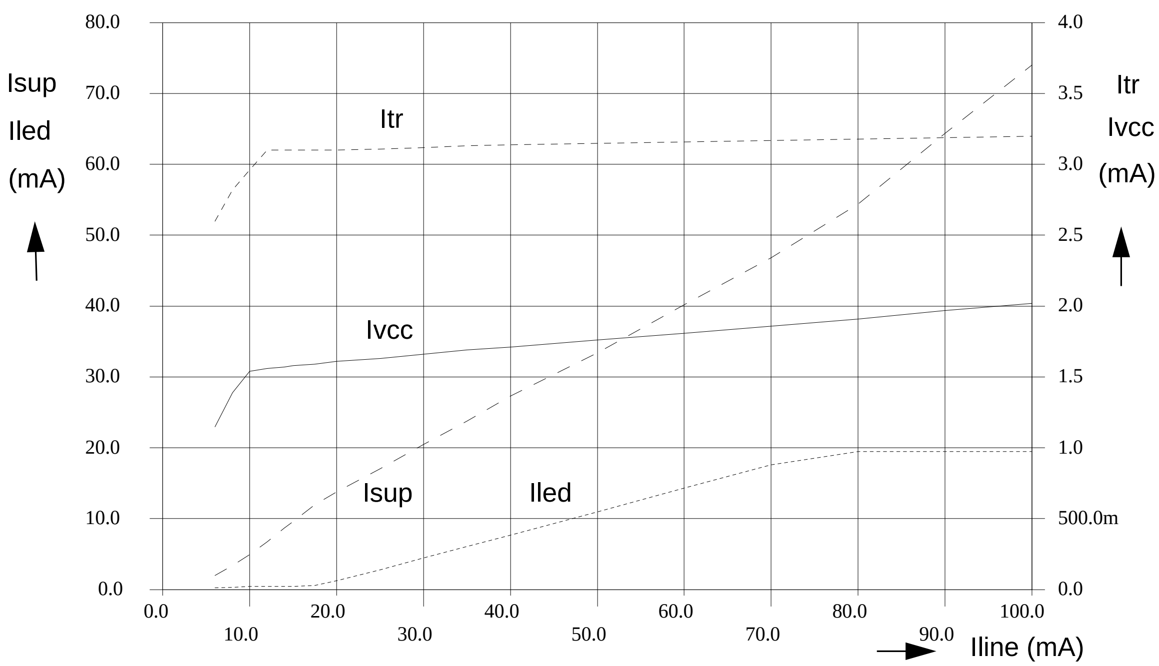


Fig.54 Currents Isup, Iled, Itr and Ivcc as a function of Iline

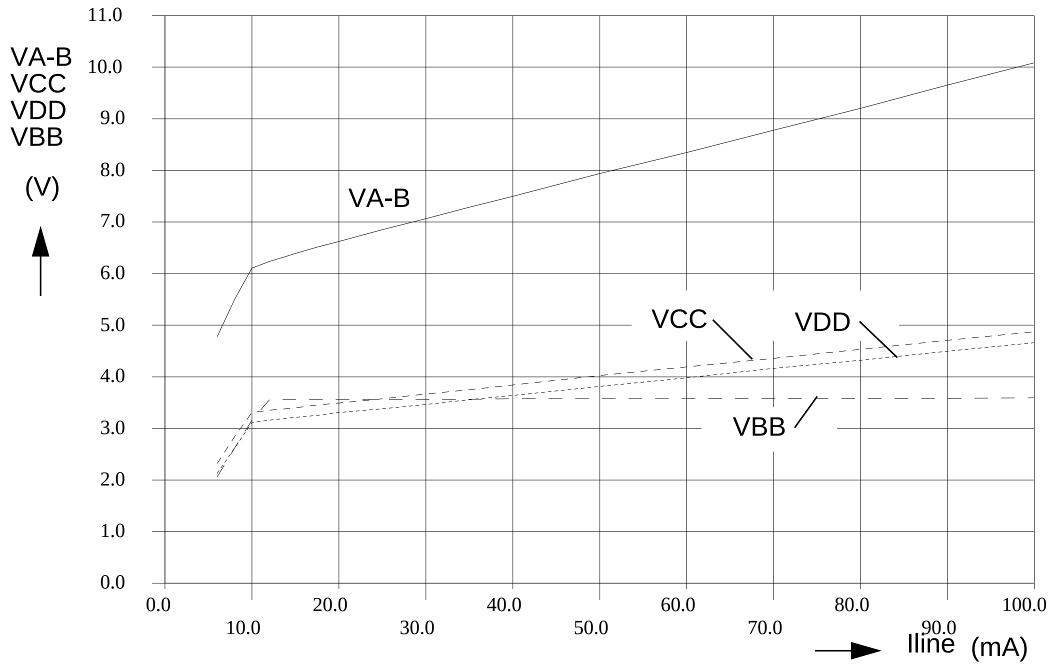


Fig.55 Voltages VA-B, VCC, VDD and VBB (with respect to SLPE) versus Iline

At 20 mA line current, the current into SUP measures 13.8 mA from which 5.5 mA (typ) is consumed by the internal circuitry of the TEA1093 and 250µA by the external circuitry connected to VBB. The remaining supply current to generate the loudspeaker signal (at 20 mA line current) is thus about 8 mA which gives a maximum output power of 15.8 mW theoretically into a 50 Ω loudspeaker. Measured is 12.5 mW at 20 mA; see also Fig.56.

Transmission

Transmit and receive gains are in conformity with the sensitivities of the proposed microphones, earpiece and loudspeaker and the performance of the application used as handset or handsfree set. The applied handset (Ericsson RLGN40201/8B6) contains an electret microphone with a sensitivity of –44.5 dBV/Pa (1 kHz, 2 kΩ load) and a dynamic earpiece of 150 Ω and 49 dBPa/V. The base contains the HF microphone with a sensitivity of –46 dBV/Pa (1 kHz, 2 kΩ load) and a 50 Ω loudspeaker (Philips type AD2071/Z50).

The overall transmit gain, at 600 Ω line load, from R56 or R57 to the line measures 48 dB as a result of 24 dB gain from R56 (or R57) to MOUT, 20 dB attenuation from MOUT to the MIC inputs of the TEA1112 and 44 dB gain from MIC inputs to the line. The default microphone gain of the TEA1112 is reduced to 44 dB by means of R4 (47.5 kΩ).

The receive gain from line to earpiece is –6.5 dB; from line to loudspeaker about 24 dB. The receive gain of the TEA1112 application is reduced from –1 dB default to –4.5 dB by means of R13 (200 kΩ). Volume control is achieved by potentiometer R41. A proposal for volume control by the PCD3332-3 can be found in [3], while a circuit realisation is offered in [6].

The BRL is more than 18 dB at 300 Hz to 3400 Hz, complex set impedance (R2 = 220 Ω, R1 = 825 Ω, C1 = 115 nF) and same reference impedance while measured without handset. C3 has to be at least 6.8 μF for complex set impedances but can be 4.7 μF for 600 Ω set impedance to meet BRL requirements.

Fig.56 shows the maximum power generated into a loudspeaker of 100 Ω, 50 Ω and respectively 25 Ω as a function of the available line current, with and without connected LED. The nominal VBB supply voltage measures 3.55 V. At the ‘rising edges’ of the curves the power is limited by the available supply current. The power in the ‘flat area’ of the curves is limited by the supply voltage VBB. The power in this area can be increased by an enlarged VBB voltage (VBB > 3.55 V) by means of a resistor between pin VA and pin GND of the TEA1093 [3]. Adjust in this case also the voltage at SUP, by means of R3, to get a minimum DC level of 600 mV between SUP and VBB.

The current consumed by the LED, see Fig.54, is not available for the handsfree loudspeaker function; it reduces the maximum power in the loudspeaker at lower line currents, as shown in Fig.56.

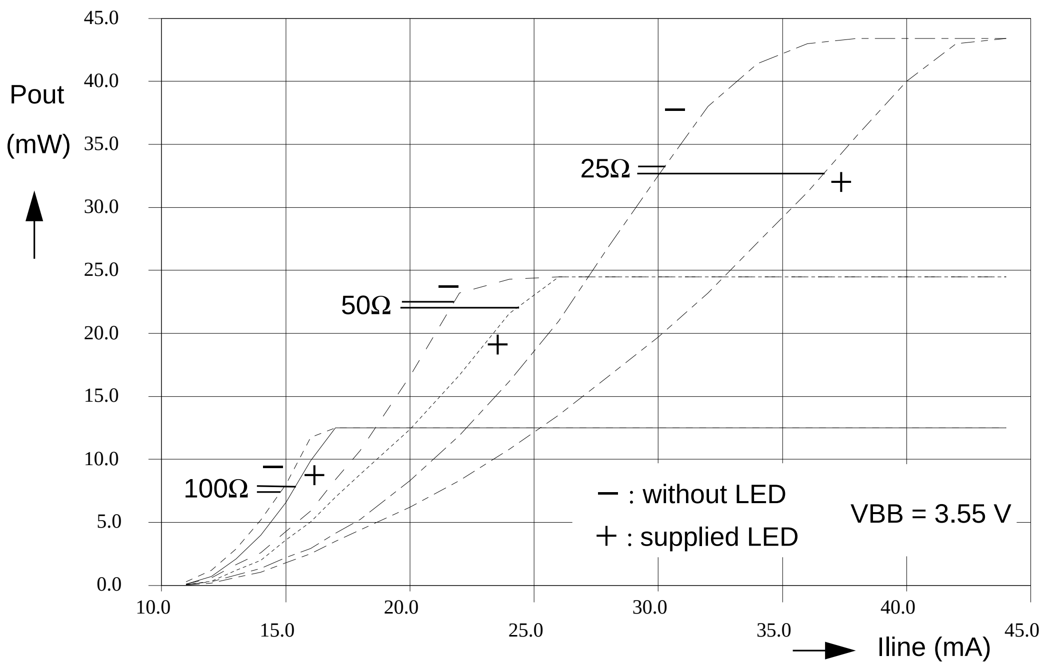


Fig.56 Maximum power into 100Ω, 50Ω respectively 25Ω loudspeaker versus Iline

Dialling

DTMF: The signal from the TONE output is attenuated by R77 and R78 (12.5 dB) and amplified by the TEA1112 (17.5 dB) to get a DTMF level of −6.5 dBm at 600 Ω line load.

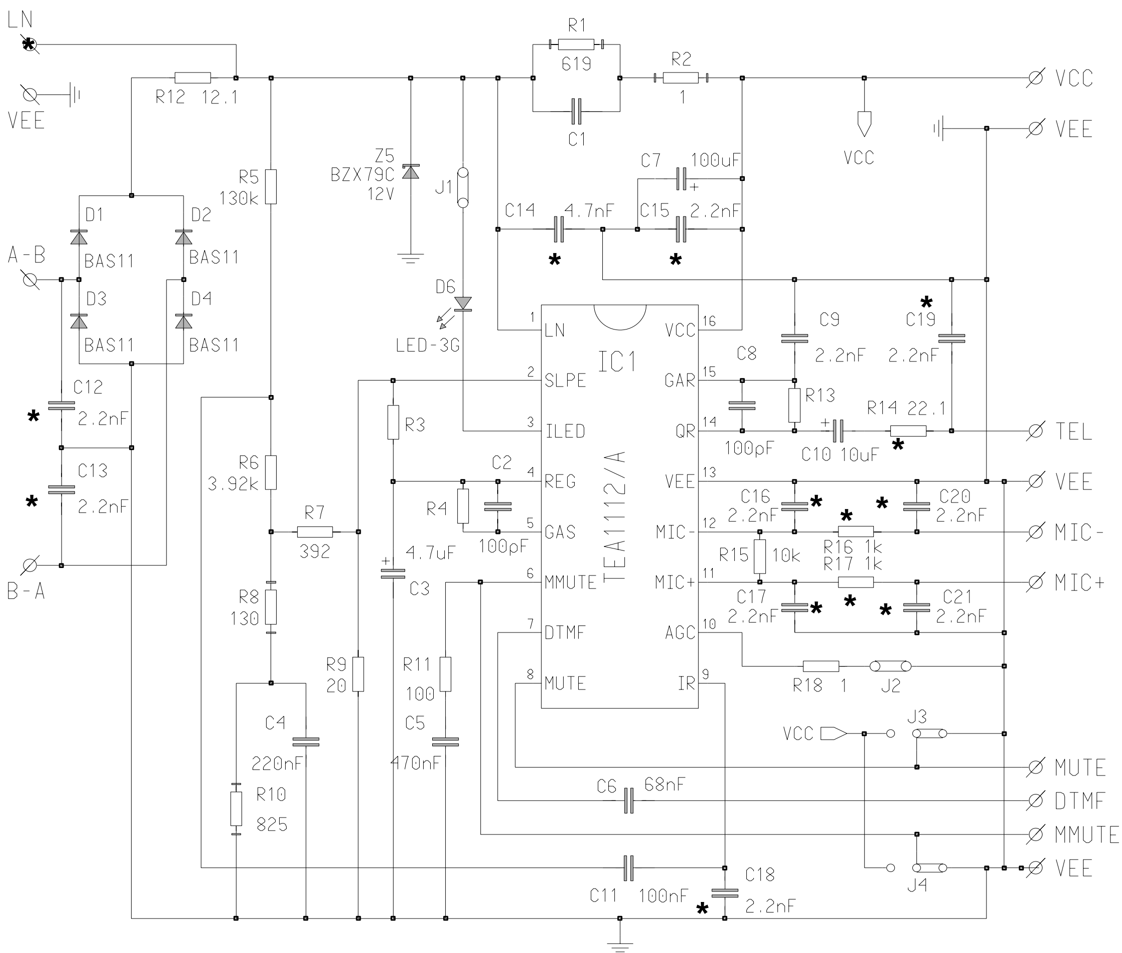
Pulse dialling: The line voltage of this application has been increased to create a voltage space of 600 mV between SUP and VBB of the TEA1093. This results in a VDD back-up level of more than 2.5 V during pulse dialling and flash times up to 600 ms (maximum selectable flash time).

6. DESIGN / ADJUSTMENT STEPS TEA1112/A APPLICATION

This chapter gives a number of adjustment steps which should be made to design or to adjust the basic application of the TEA1112/A. For every 'Adjustment' the 'Components' are given. The influence on the characteristics of the application and the considerations which have to be taken into account are added as 'Remarks'. The components refer to circuit diagram Fig.57 which is the application of evaluation board OM4776 as described in chapter 7.

Adjustment	**Component(s)**	**Remark(s)**
Set impedance	R1 or Z1	Zset depends mainly on R1 or network Z1 (R2 + R1//C1) for frequencies from 300 Hz up to 3400 Hz; R12 is in series with R1 or Z1. VCC supply depends on DC resistance of R1 or Z1.
BRL	R1 (Z1), C3	BRL depends on 'Set impedance' with respect to reference impedance (PTT requirement). Value of Leq (depends on the values of C3, R9 and resistor between LN and REG if applied) is important at the lower frequencies (300 Hz). Adapt C3 to improve BRL at 300 Hz if necessary. Value of C3 has also influence on the start-up time!
Side tone	Zbal (R8+R10//C4), R5, R6, R7	Depends on cable type, mean cable length, AGC function and Zset
DC slope	R12 (R9)	R12 is the best choice. Modification of R9 means also an adaption of Leq, VLN, low voltage threshold current, microphone gain, AGC function and side tone balancing.
VLN increase	R3 (REG-SLPE)	Refer to local PTT requirements. Increases VCC supply possibilities.
VLN decrease	R(LN-REG)	Reduces Leq; reduces the BRL at lower frequencies; see BRL. Reduces VCC supply voltage level; take in account the minimum operating level of VCC (2 V at 20 mA) and the minimum permitted voltage space between VCC and SLPE (1.6 V).
VCC supply	R1 (Z1), C1	VCC supply level depends on VLN, resistance of R1 or network (Z1) between LN and VCC and current consumption from VCC. Take in account the minimum operating level of VCC and the minimum voltage space between VCC and SLPE.
AGC	R18	Internally defined when AGC pin is connected to VEE. Adjustable by R18 to **increase** 'start and stop' currents in relation with Vexch and Rexch. See chapter 3.8. AGC function can be disabled by leaving pin AGC open.

Microphone gain	R4	Internally defined at 52 dB by internal resistance Rgasint. Can be reduced by R4. No matching of R4 with Rgasint. Take into account the attenuation from capsule to MIC inputs due to R16 and R17 with respect to R15 (in parallel with Zmic = 64 kΩ typ).
- High pass		Value of couple capacitors of microphone with respect to input impedance of external microphone network.
- Low pass	C2	Value of C2 in combination with R4//Rgasint.
- Supply		Electret microphone supplied from VCC via extra RC filter
DTMF gain		DTMF gain is microphone gain – 26.5 dB. Total DTMF gain has to be set by means of the attenuation network between DTMF generator and TEA1112/A DTMF input.
Receive gain	R13	Internally defined at 31 dB (from IR to QR) by internal resistance Rgarint. Can be reduced by R13. No matching of R13 with Rgarint. Take into account the attenuation from QR output to earpiece due to R14. Overall receive gain from line to earpiece depends on attenuation from line to IR input.
- High pass		C10 in combination with earpiece impedance. C11 in combination with source impedance and Zir (20 kΩ typ).
- Low pass	C8	Value of C8 in combination with R13//Rgarint
- Stability	C9	C9 has to be 20 x C8
MUTE	TEA1112	MUTE is active high. MUTE from dialler has to be high during dialling. Apply a series resistance in the MUTE wire from dialler to TEA1112 (ca. 50 kΩ) to prevent discharge of the VDD capacitor during break periods at pulse dialling (or flash) at MUTE = high.
$\overline{MUTE}$	TEA1112A	$\overline{MUTE}$ is active low. MUTE from the dialler has to be low during dialing.
LED		Current consumed by the LED is not available for an added HF application. The ILED-pin can be connected with SLPE when the LED function is not used.



***: EMC components**

Not placed: R3, R4, R13 and C1

R11 and C5 are mounted on the PCB to demonstrate the TEA1113

Fig.57 Circuit diagram of the OM4776 evaluation board with the basic application of the TEA1112/A

7. RF IMMUNITY OF THE TEA1112 /A

The TEA1112 and TEA1112A have been designed with on-chip measures to keep RF disturbances away from sensitive circuit parts at higher RF frequencies (> 80 MHz). For the lower frequency range (from 150kHz upwards) the coupling into the IC occurs mainly via the A/B-lines and the handset cord. Improvement of the immunity at those frequencies can be realised by filtering at the PCB connectors and IC pins and a PCB layout which is designed with respect to EMC.

An evaluation board OM4776 [9] has been made for the TEA1112/A with the basic application according Fig.57. The components side is shown in Fig.58 and the board layout in Fig.59. The dimensions of the board are 6.5 x 8 cm. It is provided with connection terminals at the PCB edge and jumpers (J3, J4) to define the state of the logic inputs of the TEA1112 as well as the TEA1112A. Jumpers J1 and J2 are for the LED and AGC function respectively. Some of the components are mounted on soldering pins to simplify modification of the application.

Components R3, R4, R13 and C1 are not placed while R11 and C5 are intended for use of the board with the TEA1113. The TEA1113 is not described in this report; refer to [10]. See Fig.57 for components values.

The OM4776 has a single-sided wiring with filled ground plane between the interconnections. The EMC measures on the PCB are:

- Filtering from A-B/B-A terminals to line input LN of the TEA1112/A by means of C12 and C13 at the line terminals, R12 and C14 from pin LN to VEE.
- Filtering from the PCB terminals MIC-/MIC+ to the MIC inputs of the IC by C20 and C21 at the PCB terminals, series resistors R16 and R17 and decoupling at the MIC pins by means of C16 and C17. The bandwidth of microphone amplifier is limited by C2.
- Filtering of the receiver channel at input IR by C18 and from output QR to the earpiece terminals by means of R14 and C19. Furthermore is the bandwidth of the receiver amplifier limited by C8 and stability guaranteed by means of the combination of C8 and C9.
- Decoupling at VCC pin by means of C15.

General recommendations of EMC measures to design the PCB are:

- Use a filled ground between the wires in case of a single-sided PCB or a ground plane when a double-sided PCB is applied.
- Place line and handset connectors close to each other on the same side of the PCB and decouple the connections by means of EMC capacitors.
- Place EMC capacitors as close as possible to the corresponding IC pins. Use small size ceramic capacitors.
- Make interconnection-wires as short as possible. Use wire-bridges instead of a clever design with long wires.
- Design a symmetrical microphone entry from connector to MIC inputs of the IC.

Test method and results

The RF immunity test is split up in two test methods. The conducting test [11], in the frequency range of 150 kHz to 150 MHz, is carried out with a RF disturbance signal coupled into the A-B/B-A cable via coupling/decoupling networks. The RF signal with an amplitude of 3 V for f < 30 MHz and 0.5 V for f > 30 MHZ is modulated with an AM signal of 1 kHz sinewave and 80% modulation depth.The results of the measurements are given in Fig.60 by means of detected levels at the A-B lines and receiver output with respect to 1 Vrms (0 dBV) reference level.

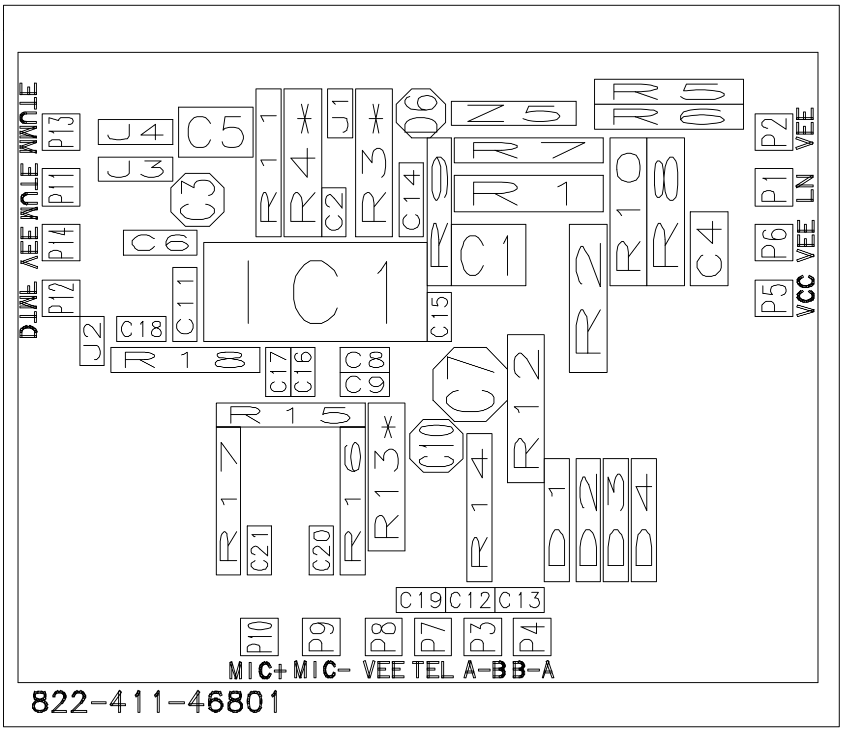


Fig.58 Components side of the OM4776 evaluation board

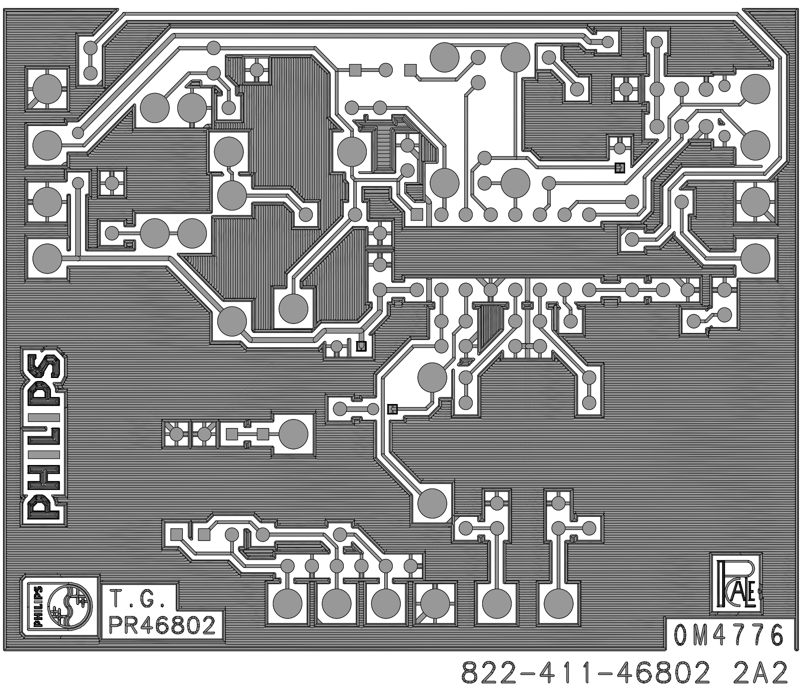


Fig.59 Layout of the wiring of the OM4776

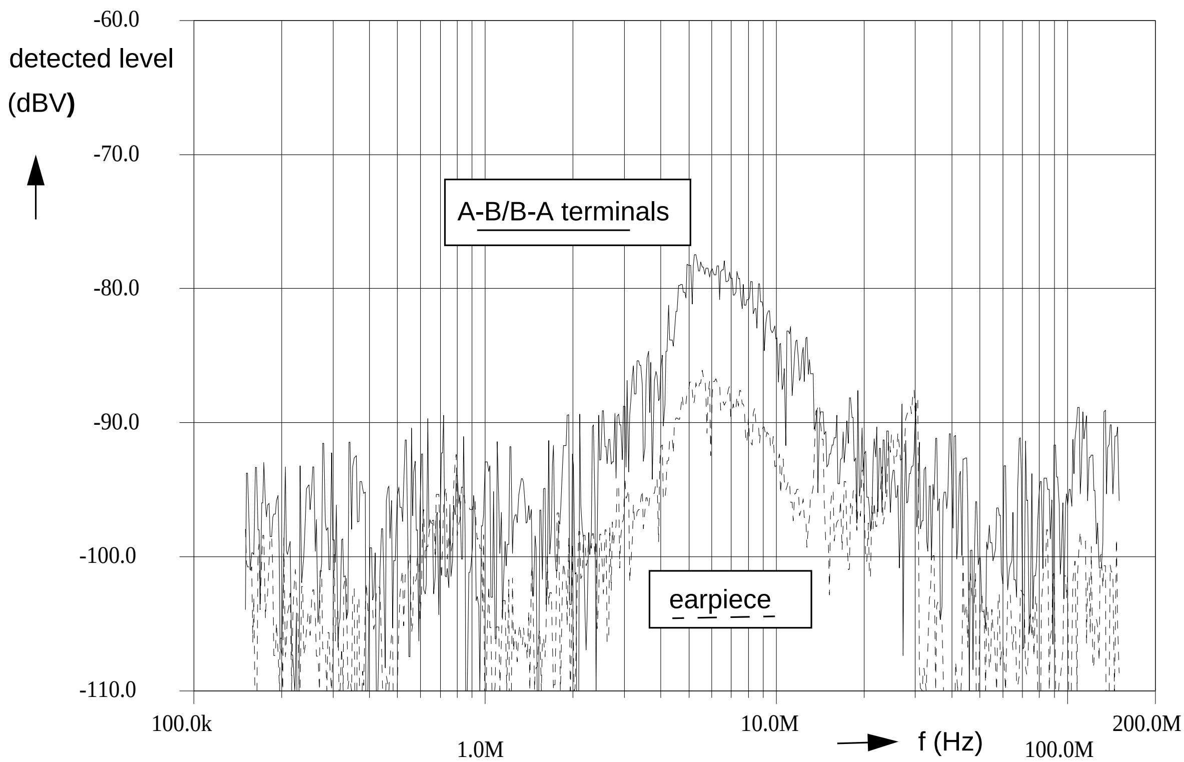


Fig.60 EMC behaviour of the OM4776; conducting test

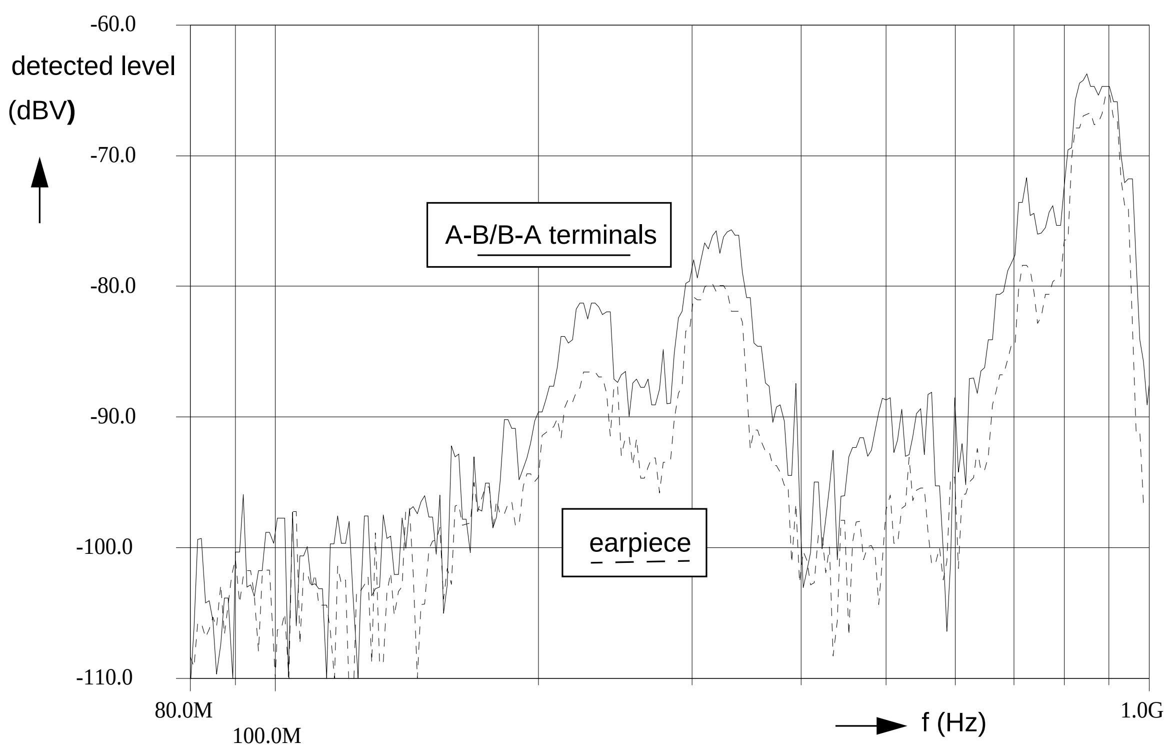


Fig.61 EMC behaviour of the OM4776; radiation test

The second test [12] of the OM4776 is carried out in an electro-magnetic field. The field strength is 3 V/m over the frequency range 80 MHz to 1 GHz while the signal is modulated with an AM signal of 1 kHz and 80% modulation depth. The results of the measurements are shown in Fig.61 by means of detected levels at the A-B lines and receiver output with respect to 1 Vrms (0 dBV) reference level.

The OM4776 evaluation board meets the requirements according [11] and [12]. The detected signal levels, as a result of the measurements, are in both cases less than the -60 dBV demands.

Note: The logic inputs MUTE, MMUTE (TEA1112) and $\overline{\text{MUTE}}$, $\overline{\text{MMUTE}}$ (TEA1112A) are sensitive because of the rather low internal pull-down currents. When they are not used connect them to VEE, in case of the TEA1112, or to VCC, in case of the TEA1112A.

8. REFERENCES

[1] Philips Semiconductors DATA DHEET PCD3332-3 Multi-standard pulse/tone repertory dialler/ringer.

[2] Philips Semiconductors Tentative Device Specification TEA1112 / TEA1112A. Low voltage versatile telephone transmission circuits with dialler interface.

[3] Philips Semiconductors Application Note ETT/AN93015. ‘Application of the TEA1093 handsfree circuit’, by C.H.Voorwinden & K.Wortel.

[4] Philips Semiconductors Application Note ETT/AN94001. ‘User Manual for OM4750: Demonstration board TEA1093 and TEA1094’, by R.v.Leeuwen & C.Voorwinden.

[5] DATA HANDBOOK IC03 ‘Semiconductors For Telecom Systems’.

[6] Philips Semiconductors Application Note ETT/AN94002. ‘Design considerations for a high_end telephone set with PCA1070, TEA1093 and PCD335X’, by K.Wortel.

[7] Philips Semiconductors Application Note ETT95007. ‘OM4757 Demonstration Board PCD3332-3/ TEA1064B-1062/TEA1093-1094’, by F.v.Dongen.

[8] Philips Components Laboratory Report ETT89009. ‘Application of the versatile speech/transmission circuit TEA1064 in full electronic telephone sets’, by F.v.Dongen & P.J.M.Sijbers.

[9] Philips Semiconductors User Manual ETT/UM95011. ‘Evaluation board for the TEA1112/A and TEA1113’, by E.Bosma.

[10] Philips Semiconductors Tentative Device Specification TEA1113. Low voltage versatile telephone transmission circuit with dialler interface.

[11] IEC Publication DIS 1000-4-6 (formerly 801-6). Electromagnetic compatibility for electrical and electronic equipment. Part6: Immunity to conducted disturbances, induced by radio frequency fields above 9 kHz.

[12] IEC 1000-4-3 Draft International Standard (Annex B). Immunity to radiated, radio frequency, electromagnetic fields (formerly IEC 801-3).

APPENDIX 1 List of abbreviations and definitions

A-B/B-A	Line terminals of application examples
AGC	Automatic Gain Control; line loss compensation facility
APT	Access Pause Time selection PCD3332-3
BRL	Balance Return Loss
CE/FDI	Chip Enable / Frequency Discriminator Input PCD3332-3
COL	Column keyboard input PCD3332-3
CSI	Cradle switch input PCD3332-3
DIODE	Diode option input PCD3332-3
DOO	DTMF output selection PCD3332-3
DPN/FLN	(Inverted) Dial Pulse / FLash output PCD3332-3
DTMF	Dual Tone Multi Frequency
EMC	Electro Magnetic Compatibility
Electret	Electret microphone with amplifier
F/E	Flash Earth selection PCD3332-3
GND	Ground reference TEA1093
GNDMIC	Ground reference microphone amplifier TEA1093
Gvrx	Gain factor of receive stage TEA1112/A
Gvtx	Gain factor of transmit stage TEA1112/A
HC4053	Philips IC with 3, 2-channel analogue switches
HF	Handsfree
HF-mic	Handsfree microphone
HF/RTE	Handsfree / Ringer Tone Enable output PCD3332-3
HOOK	HOOK-key PCD3332-3
HP	High Pass
HS-mic	Handset microphone
ICC, Icc	Current consumption of the TEA1112/A (from VCC)
Iled	Current through the LED connected between LN and ILED
Iline	Line current
Ip	Current consumption of the peripheral devices connected to VCC
Irec	Internal current consumption (from VCC) of the receiver amplifier of the TEA1112/A
Ish	Excess of line current from LN to SLPE
Istart, Istop	Start and stop currents of the AGC function
Ith	Threshold current of low voltage function
Itr	Current in transmission circuit of HF application
k	Scale factor of balance network
LED	Light Emitting Diode
LFE	Enable output PCD3332-3
LI	Listening-in
Leq	Artificial inductor of voltage stabilizer TEA1112/A; Leq = R9. C3. Rp
M/S	Mark Space ratio selection PCD3332-3

M0-M9	Memory location keys PCD3332-3
MIC	Microphone input TEA1093
MLA	Memory Location Access selection PCD3332-3
MOUT	Microphone amplifier output TEA1093
MRC	Memory Recall-key PCD3332-3
MUTE	MUTE output PCD3332-3 / MUTE input TEA1112
MUTER	Receive channel MUTE input TEA1093
MUTET	Transmit channel MUTE input TEA1093
OM4776	Evaluation board for the TEA1112/A
PCB	Printed Circuit Board
PCD3332-3	Multi standard pulse/tone repertory dialler/ringer IC
PTS	Pulse Tone Selection PCD3332-3
PXE	Piezo Ceramic Buzzer Element
Power Down/PD	Reduced current consumption mode during pulse dialling or flash
Ra	Resistor to adjust the sidetone bridge attenuation
Rast	Anti sidetone resistor
RESET	Reset input PCD3332-3
RF	Radio Frequency
RFS	Ringer Frequency Selection PCD3332-3
RINn	Receiver amplifier inputs TEA1093
ROW	Row keyboard input PCD3332-3
Rexch	Bridge resistance of exchange
Rgarint	Internal resistance (100 kΩ) to define receive gain TEA1112/A
Rgar	External resistance to reduce receive gain TEA1112/A
Rgasint	Internal resistance (69 kΩ) to define microphone gain TEA1112/A
Rgas	External resistance to reduce microphone gain TEA1112/A
Rp	Internal resistance of TEA1112/A between LN and REG
SREF	Supply reference input TEA1093
STORE	Store-key programming mode PCD3332-3
SUP	Supply input TEA1093
TEA1093	Handsfree IC
TEA1112	Transmission IC, MUTE and MMUTE active high
TEA1112A	Transmission IC, $\overline{\text{MUTE}}$ and $\overline{\text{MMUTE}}$ active low
TEA1112/A	General notation of the TEA1112 as well as the TEA1112A
TEA1113	Transmission IC of the TEA111X-family with dynamic limiter
THD	Total Harmonic Distortion (%)
TONE	Tone generator output PCD3332-3
VA-B	Voltage across the A-B/B-A line terminals
VBB	Supply output TEA1093
VCC	Supply pin / supply voltage of TEA1112/A
VDD	Positive supply PCD3332-3
VEE	Ground reference TEA1112/A

VLN	DC level at LN of the TEA1112/A (with respect to VEE)
VOL	Receiver volume adjustment TEA1093
VOLn	Volume control outputs PCD3332-3
VREF	Stabilized reference voltage between LN and SLPE of the TEA1112/A
VSLPE	DC level at SLPE TEA1112/A, DC level at GND TEA1093 of HF application
VSS	Negative Supply PCD3332-3
Vexch	Exchange voltage
XTALn	Oscillator inputs PCD3332-3
Zir	Input impedance of receive amplifier TEA1112/A
Zmic	Symmetrical Input impedance of microphone amplifier TEA1112/A
Z1	Complex network between LN and VCC TEA1112/A
Zbal	Balance network to reduce side tone
Zset	Set impedance between A-B/B-A terminals
α	Gain control factor of AGC function; $0.5 < \alpha <= 1$
[x]	Reference to REFERENCE chapter
(x)	Reference to equation (x)