

# DATA SHEET

## **TEA1064A**

Low voltage versatile telephone  
transmission circuit with dialler  
interface and transmit level  
dynamic limiting

Product specification  
File under Integrated Circuits, IC03A

March 1994

## Low voltage versatile telephone transmission circuit with dialler interface and transmit level dynamic limiting

**TEA1064A**

### GENERAL DESCRIPTION

The TEA1064A is a bipolar integrated circuit that performs all the speech and line interface functions required in fully electronic telephone sets. It performs electronic switching between dialling and speech and has a powerful DC supply for peripheral circuits. The IC operates at line voltages down to 1.8 V DC (with reduced performance) to facilitate the use of more telephone sets connected in parallel. The transmit signal on the line is dynamically limited (speech-controlled) to prevent distortion at high transmit levels of both the sending signal and the sidetone.

### PACKAGE OUTLINES

TEA1064A :20-lead DIL; plastic (SOT146).<sup>(1)</sup>

TEA1064AT:20-lead mini-pack; plastic (SO20; SOT163A).<sup>(2)</sup>

### Notes

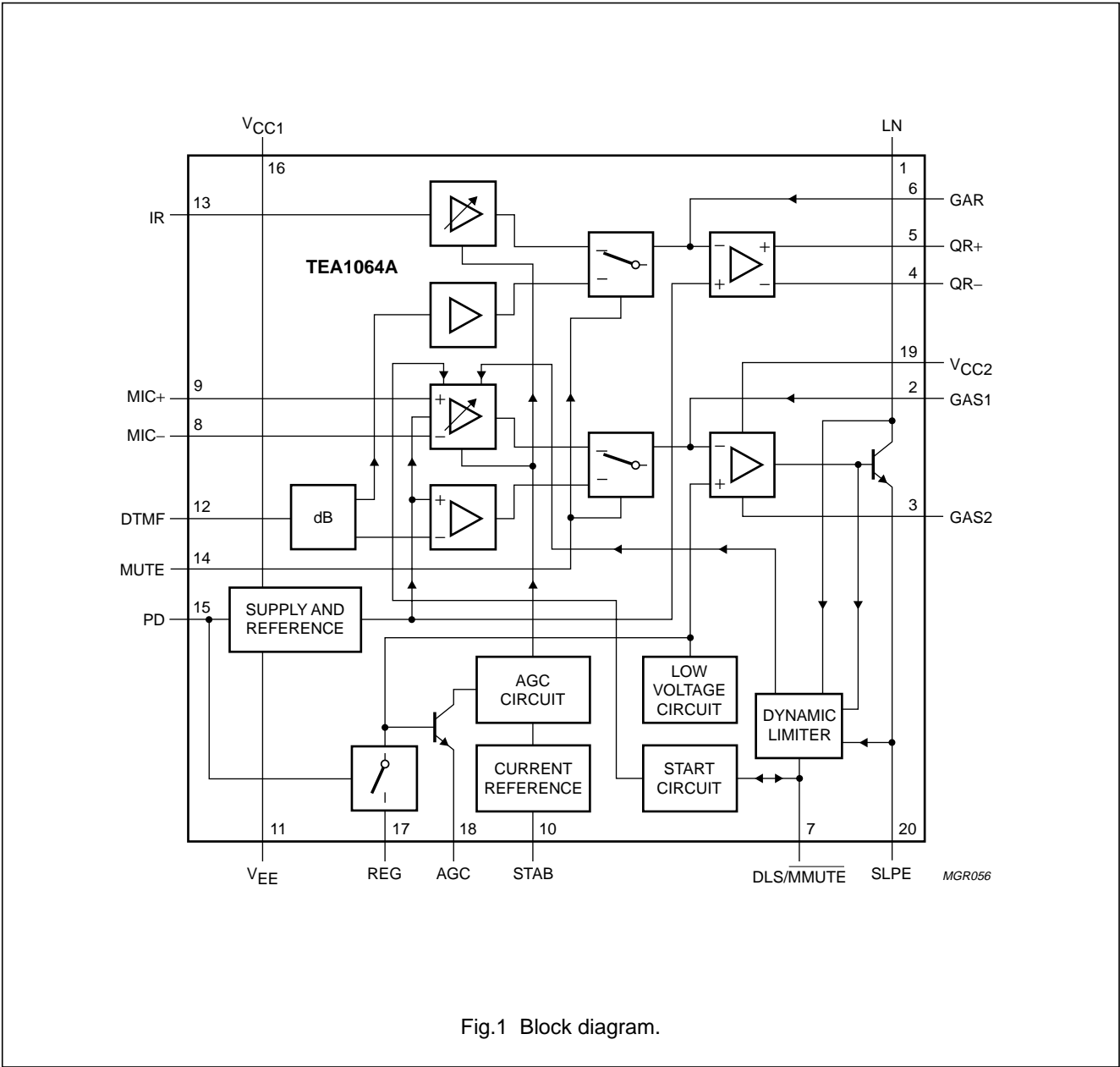
1. SOT146-1; 1998 Jun 18.
2. SOT163-1; 1998 Jun 18.

### FEATURES

- Low DC line voltage; operates down to 1.8 V (excluding polarity guard)
- Voltage regulator with low voltage drop and adjustable static resistance
- DC line voltage adjustment facility
- Provides a supply for external circuits in two options:
  - unregulated supply, regulated line voltage;
  - stabilized supply, line voltage varies with supply current
- Dynamic limiting (speech-controlled) in transmit direction prevents distortion of line signal and sidetone
- Symmetrical high-impedance inputs (64 k $\Omega$ ) for dynamic, magnetic or piezo-electric microphones
- Asymmetrical high-impedance input (32 k $\Omega$ ) for electret microphones
- DTMF signal input
- Confidence tone in the earpiece during DTMF dialling
- Mute input for disabling speech during pulse or DTMF dialling
- Power-down input for improved performance during pulse dial or register recall (flash)
- Receiving amplifier for magnetic, dynamic or piezo-electric earpieces
- Large amplification setting ranges on microphone and earpiece amplifiers
- Line loss compensation (line current dependent) for microphone and earpiece amplifiers (not used for DTMF amplifier)
- Gain control curve adaptable to exchange supply
- Automatic disabling of the DTMF amplifier in extremely-low voltage conditions
- Microphone MUTE function available with switch

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## QUICK REFERENCE DATA

PARAMETER	CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
Operating ambient temperature range		$T_{amb}$	-25	—	+ 75	°C
Line current operating range:						
normal operation		$I_{line}$	11	—	140 <sup>(1)</sup>	mA
with reduced performance		$I_{line}$	2	—	11	mA
Internal supply current:						
power-down input LOW	$V_{CC1} = 2.8\text{ V}$	$I_{CC1}$	—	1.3	1.6	mA
power-down input HIGH	$V_{CC1} = 2.8\text{ V}$	$I_{CC1}$	—	60	82	μA
Voltage gain range:						
microphone amplifier		$G_v$	44	—	52	dB
receiving amplifier		$G_v$	20	—	45	dB
Line loss compensation:						
gain control range		$G_v$	5.7	6.1	6.5	dB
exchange supply voltage range		$V_{exch}$	36	—	60	V
exchange feeding bridge resistance range		$R_{exch}$	400	—	1000	Ω
Maximum output voltage swing on LN (peak-to-peak value)	$R15 + R16 = 448\text{ Ω}$					
	$I_{line} = 15\text{ mA}$					
	$I_p = 2\text{ mA}$	$V_{LN(p-p)}$	3.7	3.95	4.2	V
	$I_p = 4\text{ mA}$	$V_{LN(p-p)}$	3.0	3.25	3.5	V
<b>Regulated line voltage application</b>						
Supply for peripherals	$R15 = 0\text{ Ω};$ $R16 = 392\text{ Ω}$ $I_{line} = 15\text{ mA}$ $I_p = 1.4\text{ mA}$	$V_p$	2.5	—	—	V
	$I_p = 2.7\text{ mA};$ $R_{REG-SLPE} = 20\text{ kΩ}$	$V_p$	2.9	—	—	V
	$I_{line} = 15\text{ mA}$ without $R_{REG-SLPE}$	$V_{LN}$	—	3.57	—	V
DC line voltage	$R_{REG-SLPE} = 20\text{ kΩ}$	$V_{LN}$	—	4.57	—	V

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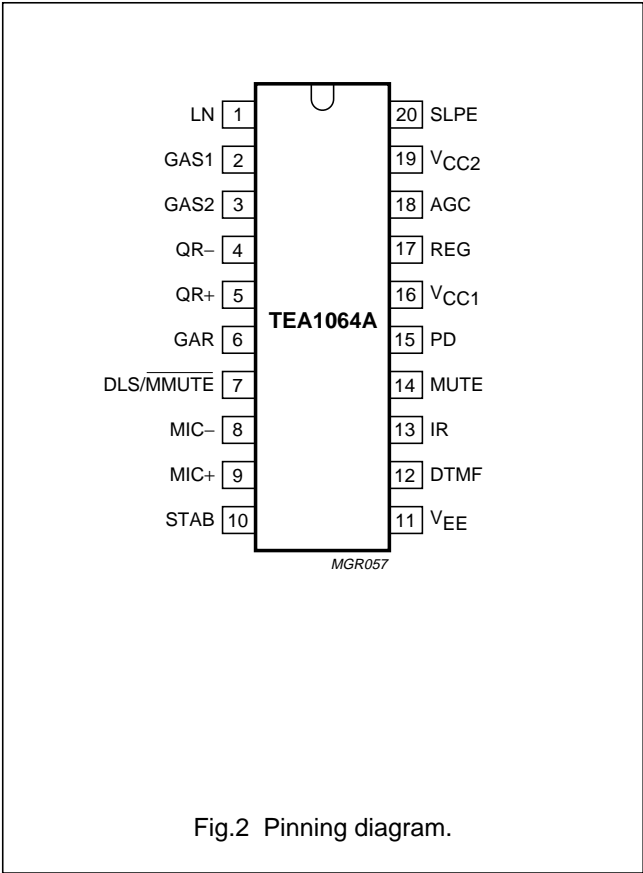
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PARAMETER	CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
Stabilized supply voltage application						
Supply for peripherals	R15 = 392 Ω; R16 = 56 Ω I <sub>line</sub> = 15 mA I <sub>p</sub> = 0 to 4 mA	V <sub>CC2-SLPE</sub>	3.05	3.3	3.55	V
DC line voltage	I <sub>line</sub> = 15 mA I <sub>p</sub> = 2 mA	V <sub>LN</sub>	4.2	4.4	4.8	V
	I <sub>p</sub> = 4 mA	V <sub>LN</sub>	4.9	5.1	5.5	V

Note

1. For TEA1064AT the maximum line current depends on the heat dissipating qualities of the mounted device.

PINNING



- |                     |  |
|---------------------|--|
| 1 LN                | positive line terminal   |
| 2 GAS1              | gain adjustment; transmitting amplifier                                |
| 3 GAS2              | gain adjustment; transmitting amplifier                                |
| 4 QR-               | inverting output, receiving amplifier                                  |
| 5 QR+               | non-inverting output, receiving amplifier                              |
| 6 GAR               | gain adjustment; receiving amplifier                                   |
| 7 DLS/<br>MMUTE     | decoupling for transmit amplifier<br>dynamic and microphone MUTE input |
| 8 MIC-              | inverting microphone input   |
| 9 MIC+              | non-inverting microphone input   |
| 10 STAB             | current stabilizer   |
| 11 V <sub>EE</sub>  | negative line terminal   |
| 12 DTMF             | dual-tone multi-frequency input  |
| 13 IR               | receiving amplifier input  |
| 14 MUTE             | mute input   |
| 15 PD               | power-down input   |
| 16 V <sub>CC1</sub> | internal supply decoupling   |
| 17 REG              | voltage regulator decoupling   |
| 18 AGC              | automatic gain control input   |
| 19 V <sub>CC2</sub> | reference voltage with respect to SLPE                                 |
| 20 SLPE             | slope adjustment for DC<br>curve/reference for peripheral circuits.    |

# Low voltage versatile telephone transmission circuit with dialler interface and transmit level dynamic limiting

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## FUNCTIONAL DESCRIPTION

### Supplies $V_{CC1}$ , $V_{CC2}$ , LN, SLPE, REG and STAB (Fig.3)

Power for the TEA1064A and its peripheral circuits is usually obtained from the telephone line. The IC develops its own supply voltage at  $V_{CC1}$  and regulates its voltage drop. The internal supply requires a decoupling capacitor between  $V_{CC1}$  and  $V_{EE}$ . The internal current stabilizer is set by a  $3.6\text{ k}\Omega$  resistor between STAB and  $V_{EE}$ .

The DC current flowing into the set is determined by the exchange supply voltage  $V_{exch}$ , the feeding bridge resistance  $R_{exch}$ , the subscriber line DC resistance  $R_{line}$  and the DC voltage (including polarity guard) on the subscriber set (see Fig.3).

The internal voltage regulator generates a temperature-compensated reference voltage that is available between  $V_{CC2}$  and SLPE [ $V_{ref} = V_{CC2-SLPE} = 3.3\text{ V (typ.)}$ ]. This internal voltage regulator requires decoupling by a capacitor between REG and  $V_{EE}$  (C3).

The reference voltage can be used to:

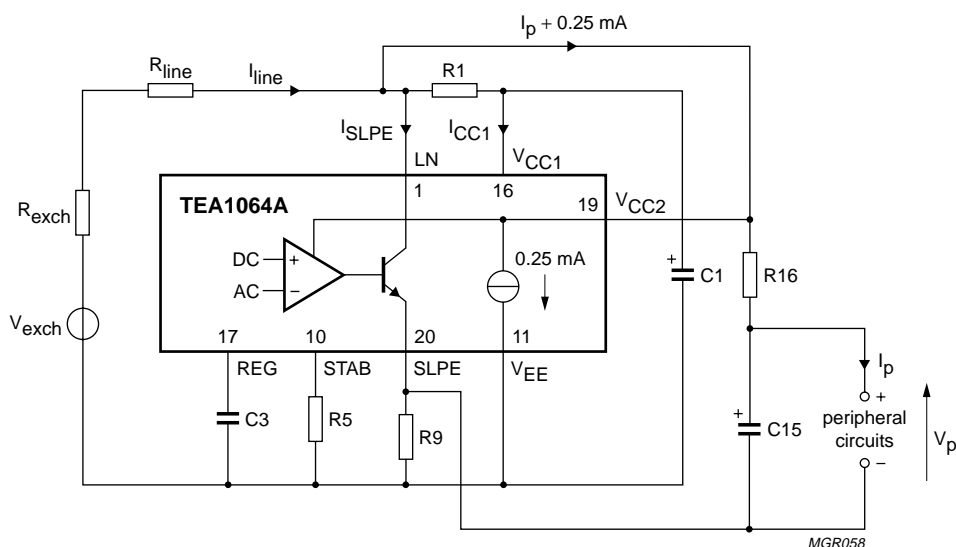
- regulate directly the line voltage (stabilized  $V_{LN-SLPE} = V_{CC2-SLPE}$ )<sup>(1)</sup>
- to stabilize the supply voltage for peripherals.

### Regulated line voltage

In this application the  $V_{CC2}$  pin is connected to the LN pin as shown in Fig.3. This configuration gives a stabilized voltage across pins LN and SLPE which, applied via the low-pass filter R16, C15, provides a supply to the peripherals that is independent of the line current and depends only on the peripheral supply current.

The value of R16 and the level of the DC voltage  $V_{LN-SLPE}$  determine the supply capabilities. In the basic application  $R16 = 392\ \Omega$  and  $C15 = 220\ \mu\text{F}$ . The worst-case peripheral supply current as a function of supply voltage is shown in Fig.4. To increase the supply capabilities, the DC voltage  $V_{LN-SLPE}$  can be increased by using  $R_{VA(REG-SLPE)}$  or by decreasing the value of R16.

(1) The TEA1064A application with regulated line voltage is the same as is used for TEA1060/TEA1061, TEA1067 and TEA1068 integrated circuits.

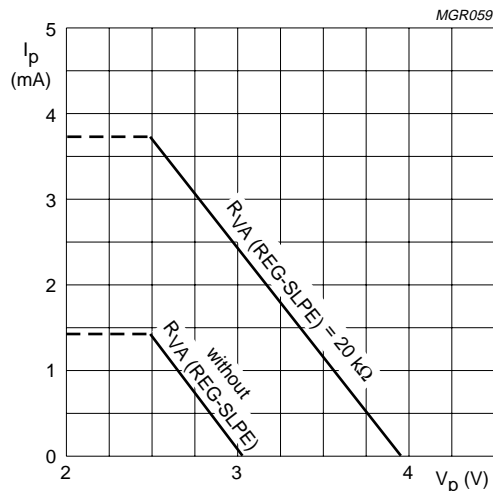


The voltage  $V_{LN-SLPE}$  is fixed to  $V_{ref} = 3.3 \pm 0.25\text{ V}$ . Resistor R16 together with the line current determine the supply capabilities and the maximum output swing on the line (no loop damping is necessary).  
The line voltage  $V_{LN} = V_{ref} + ([I_{line} - 1.55\text{ mA}] \times R9)$ .

Fig.3 Application with regulated line voltage (stabilized  $V_{LN-SLPE}$ ).

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$I_{line} = 15 \text{ mA}$ ;  $R16 = 392 \Omega$ ;  $R15 = 0 \Omega$ ; valid for MUTE = 0 and 1.  
Line current has very little influence

Fig.4 Minimum supply current for peripherals ( $I_p$ ) as a function of the peripheral supply voltage ( $V_p$ ).

The maximum AC output swing on the line at low line currents is influenced by R16 (limited by current) and the maximum output swing on the line at high line currents is influenced by the DC voltage  $V_{LN-SLPE}$  (limited by voltage). In both these situations, the internal dynamic limiter in the sending channel prevents distortion when the microphone input is overdriven. The maximum AC output swing on LN is shown in Fig.5; practical values for R16 are from 200 to 600  $\Omega$  and this influences both the maximum output swing at low line currents and the supply capabilities.

The SLPE pin is the ground reference for peripheral circuits, therefore inputs MUTE, PD and DTMF are also referenced to SLPE.

Active microphones can be supplied between  $V_{CC1}$  and  $V_{EE}$ . Low-power circuits that provide only MUTE and/or PD inputs to the TEA1064A also can be powered from  $V_{CC1}$ . However  $V_{CC1}$  cannot be used for circuits that provide DTMF signals to the TEA1064A because  $V_{CC1}$  is referred to ground.

If the line current  $I_{line}$  exceeds  $I_{CC1} + 0.25 \text{ mA}$ , the voltage converter shunts the excess current to SLPE via LN; where  $I_{CC1} \approx 1.3 \text{ mA}$ , the value required by the IC for normal operation.

The DC line voltage on LN is:

$$V_{LN} = V_{LN-SLPE} + (I_{SLPE} \times R_9)$$

$$V_{LN} = V_{ref} + [(I_{line} - I_{CC1} - 0.25 \times 10^{-3} \text{ A}) \times R_9]$$

in which

$V_{ref} = 3.3 \text{ V} \pm 0.25 \text{ V}$  is the internal reference voltage between  $V_{CC2}$  and SLPE; its value can be adjusted by external resistor  $R_{VA}$

$R_9$  = external resistor between SLPE and  $V_{EE}$  (20  $\Omega$  in basic application).

With  $R_9 = 20 \Omega$ , this results in:

$$V_{LN} = 3.57 \pm 0.25 \text{ V at } I_{line} = 15 \text{ mA}$$

$$V_{LN} = 4.17 \pm 0.3 \text{ V at } I_{line} = 15 \text{ mA},$$

$$R_{VA(REG-SLPE)} = 33 \text{ k}\Omega$$

$$V_{LN} = 4.57 \pm 0.35 \text{ V at } I_{line} = 15 \text{ mA},$$

$$R_{VA(REG-SLPE)} = 20 \text{ k}\Omega$$

The preferred value for  $R_9$  is 20  $\Omega$ . Changing  $R_9$  influences microphone gain, DTMF gain, the gain control characteristics, sidetone, and the DC characteristics (especially the low voltage characteristics).

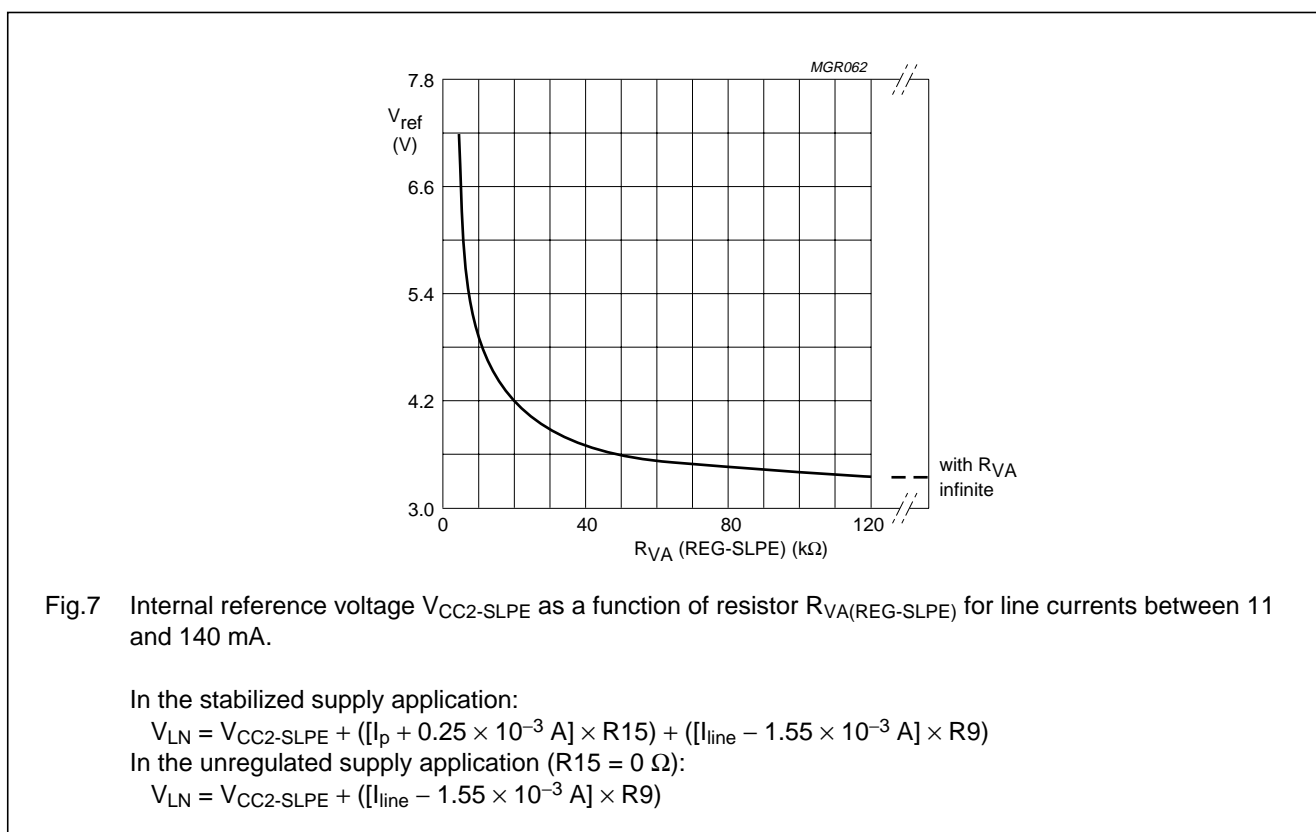
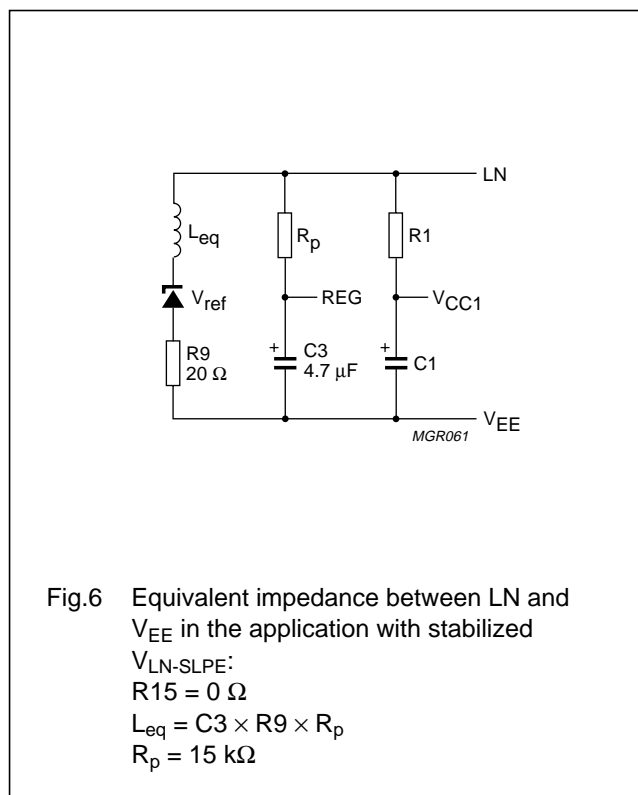
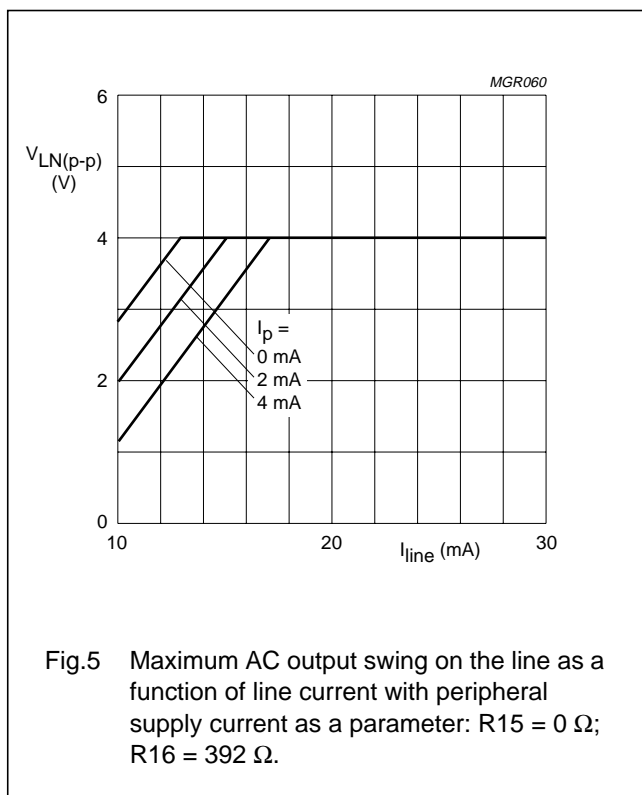
In normal conditions,  $I_{SLPE} \gg (I_{CC1} + 0.25 \text{ mA})$  and the static behaviour is equivalent to a voltage regulator diode with an internal resistance of  $R_9$ . In the audio frequency range the dynamic impedance is determined mainly by R1. The equivalent impedance of the circuit in the audio frequency range is shown in Fig.6.

The internal reference voltage  $V_{CC2-SLPE}$  can be increased by external resistor  $R_{VA(REG-SLPE)}$  connected between REG and SLPE. The supply voltage  $V_{CC2-SLPE}$  is shown as a function of  $R_{VA(REG-SLPE)}$  in Fig.7. Changing the reference voltage influences the output swing of both sending and receiving amplifiers.

At line currents below 8 mA (typ.), the DC voltage dropped across the circuit is adjusted to a lower level automatically (approximately 1.8 V at 2 mA). This gives the possibility of operating more telephone sets in parallel with DC line voltages (excluding polarity guard) down to an absolute minimum of 1.8 V. At line currents below 8 mA (typ.), the circuit has limited sending and receiving levels.

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### Stabilized peripheral supply voltage

The configuration shown in Fig.8 provides a stabilized voltage across pins  $V_{CC2}$  and SLPE for peripheral circuits (such as dialling and control circuits); the DC voltage  $V_{LN}$  now varies with the peripheral supply current.

The  $V_{CC2}$ -SLPE supply must be decoupled by capacitor C15. For stable loop operation, resistor R16 ( $\approx 50 \Omega$ ) is connected between  $V_{CC2}$  and SLPE in series with C15. The voltage regulator control loop is completed by resistor R15 between LN and  $V_{CC2}$ .

For sets with an impedance of  $600 \Omega$ , practical values are:  $R15 = 200$  to  $600 \Omega$ ;  $C15 = 220 \mu F$ ;  $C3 = 470 \text{ nF}$ . The ratio  $R15/R16 \leq 8$  is for stable loop operation with sufficient phase margin, and  $R15/R16 \geq 6$  is for satisfactory set impedance in the audio frequency range.

For sets with complex impedance, the value of C3 and the ratio  $R15/R16$  are different (further information is given in the TEA1064A Application Report<sup>(1)</sup>).

The peripheral supply capability depends mainly on the available line current, the required AC output swing on the line, the maximum permitted DC voltage on the line and

the values of external components (especially R15). With  $R15 = 392 \Omega$  and  $R16 = 56 \Omega$  (basic application) the maximum possible AC output swing on the line as a function of line current is as shown in Fig.9, the curve parameter is the peripheral supply current ( $I_p$ ). Different values for R15 (from 200 to  $600 \Omega$ ) maintaining  $6 < R15/R16 < 8$  give different results (these are described in the TEA1064A Application Report<sup>(1)</sup>).

(1) Supplied on request.

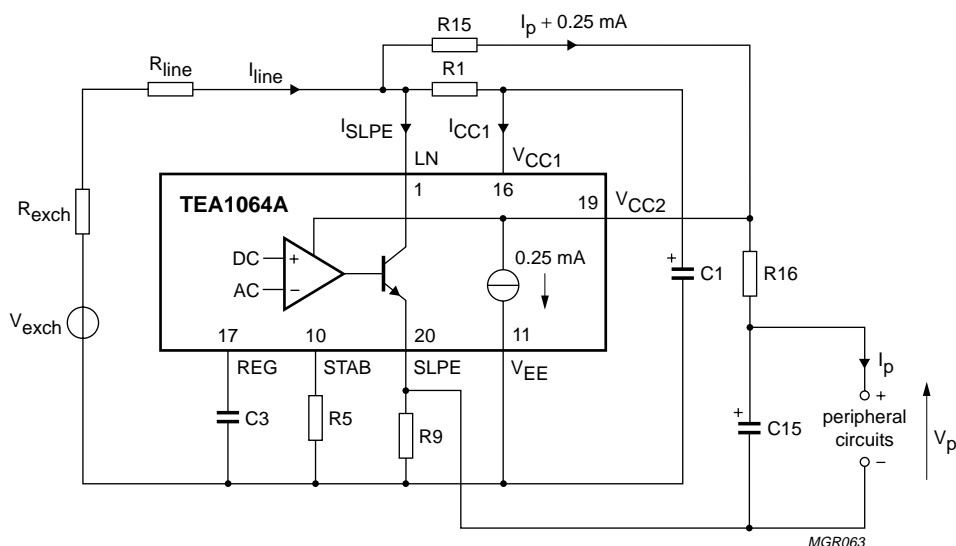


Fig.8 Application with stabilized supply voltage for peripheral circuits:  $R15 = 392 \Omega$ ;  $R16 = 56 \Omega$ .

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The DC line voltage on LN is

$$V_{LN} = V_{LN-SLPE} + (I_{SLPE} \times R_9).$$

Therefore

$$V_{LN} = V_{ref} + ([I_p + 0.25 \times 10^{-3} \text{ A}] \times R_{15}) + ([I_{line} - I_{CC1} - 0.25 \times 10^{-3} \text{ A}] \times R_9)$$

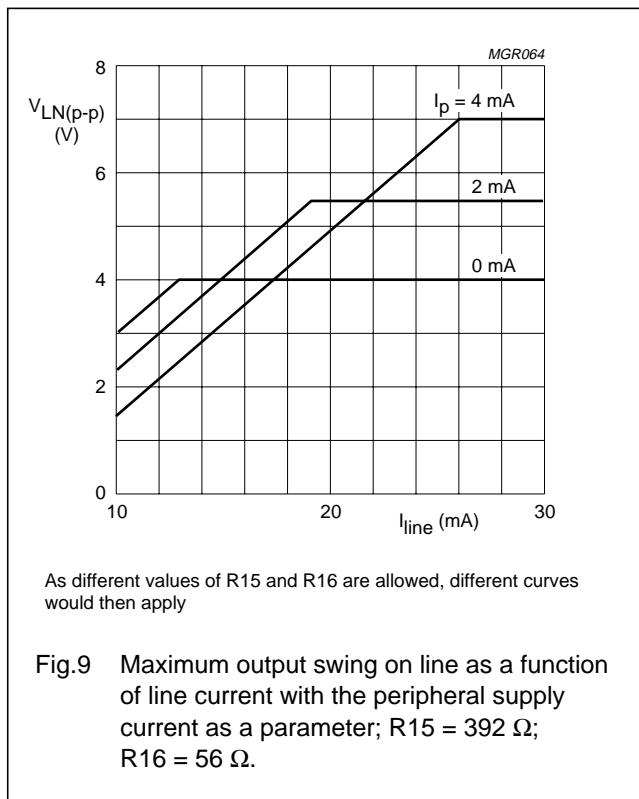
in which:

$V_{ref}$  is the internal reference voltage between  $V_{CC2}$  and SLPE (the value of  $V_{ref}$  can be adjusted by an external resistor,  $R_{VA}$ ).  $V_{ref} = 3.3 \text{ V}$  (typ.) without  $R_{VA}$

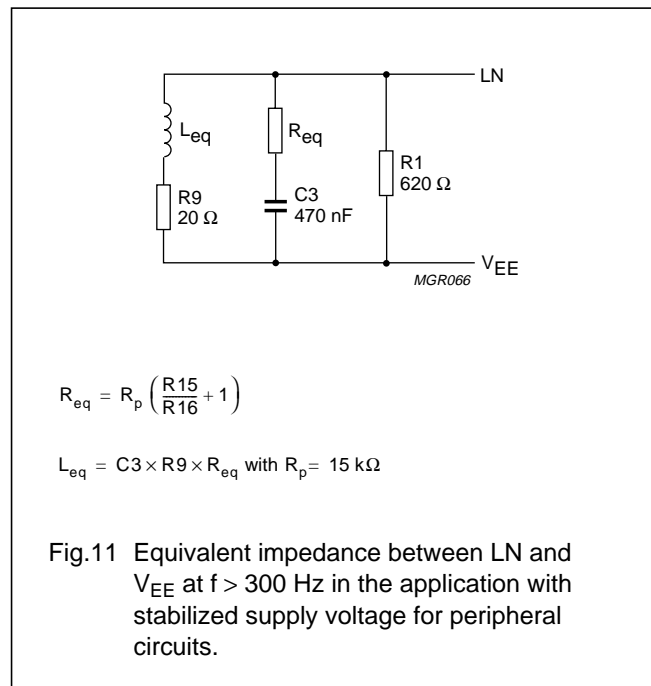
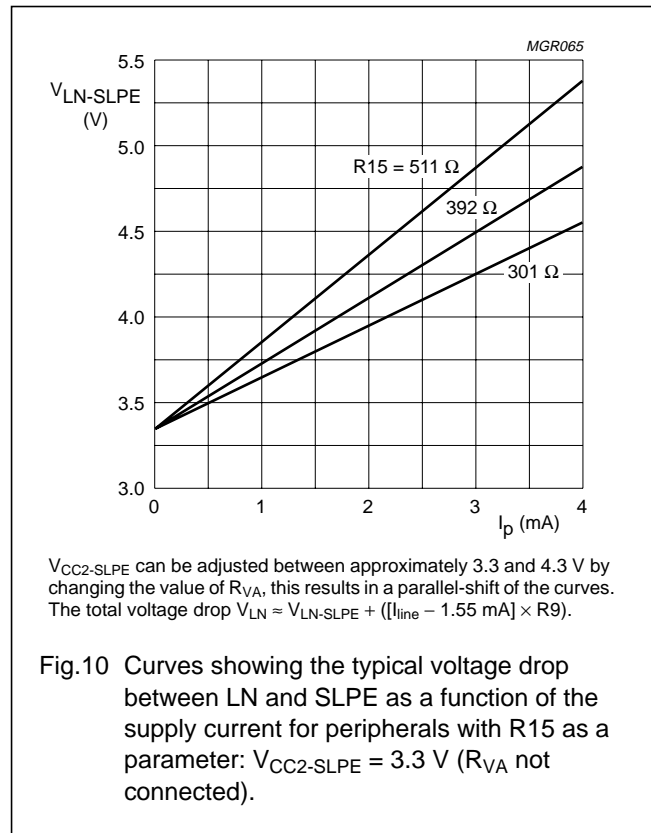
$I_p$  is the supply current used by peripheral circuits

$R_{15}$  is an external resistor between LN and  $V_{CC2}$  (392  $\Omega$  in the basic application)

$R_9$  is an external resistor between SLPE and  $V_{EE}$  (20  $\Omega$  in the basic application)



The DC voltage  $V_{LN-SLPE}$  as a function of  $I_p$  with  $R_{15}$  as a parameter is shown in Fig.10. In the audio frequency range, the dynamic impedance is determined mainly by  $R_1$ . The equivalent impedance in the audio range of the circuit (Fig.8) is shown in Fig.11.



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### Microphone inputs MIC+ and MIC– and gain pins GAS1 and GAS2

The TEA1064A has symmetrical microphone inputs, its input impedance is  $64\text{ k}\Omega$  ( $2 \times 32\text{ k}\Omega$ ) and its voltage amplification is typ. 52 dB with  $R7 = 68\text{ k}\Omega$ . Either dynamic, magnetic or piezo-electric microphones can be used, or an electret microphone with a built-in FET buffer. Arrangements for the microphone types are shown in Fig.12.

The gain of the microphone amplifier is proportional to external resistor R7 connected between GAS1 and GAS2 and with this it can be adjusted between 44 dB and 52 dB to suit the sensitivity of the transducer.

An external 100 pF capacitor (C6) is required between GAS1 and SLPE to ensure stability. A larger value of C6 may be chosen to obtain a first-order low-pass filter with a cut-off frequency corresponding to the time constant  $R7 \times C6$ .

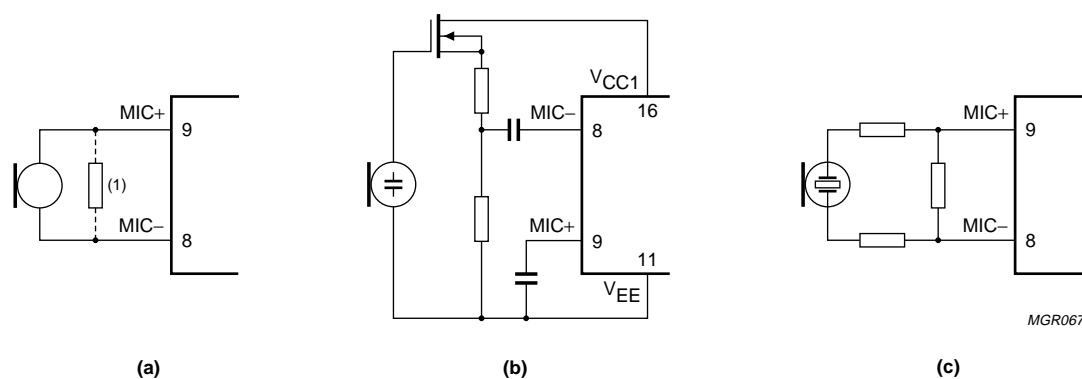


Fig.12 Microphone arrangements: a) magnetic or dynamic microphone, the resistor (1) may be connected to reduce the terminating impedance, or for sensitive types a resistive attenuator can be used to prevent overloading the microphone inputs; b) electret microphone; c) piezo-electric microphone.

### Dynamic limiter (microphone) pin DLS/MMUTE

A low level at the DLS/MMUTE pin inhibits the microphone inputs MIC+ and MIC– but has no influence on the receiving and DTMF amplifiers.

Removing the low level at the DLS/MMUTE pin provides the normal function of the microphone amplifier after a short time determined by the capacitor connected to DLS/MMUTE pin. The microphone mute function can be realised by a simple switch as shown in Fig.13.

To prevent distortion of the transmitted signal, the gain of the sending amplifier is reduced rapidly when peaks of the signal on the line exceed an internally-determined threshold. The time in which gain reduction is effected (attack time) is very short. The circuit stays in the gain-reduced condition until the peaks of the sending signal remain below the threshold level. The sending gain then returns to normal after a time determined by the capacitor connected to DLS/MMUTE (release time).

The internal threshold adapts automatically to the DC voltage setting of the circuit (voltage  $V_{LN-SLPE}$ ). This

means that the maximum output swing on the line will be higher if the DC voltage dropped across the circuit is increased.

Fig.14 shows the maximum possible output swing on the line as a function of the DC voltage drop ( $V_{LN-SLPE}$ ) with  $I_{line} - I_p$  as a parameter.

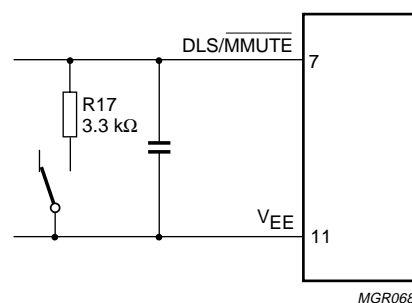


Fig.13 Microphone-mute function.

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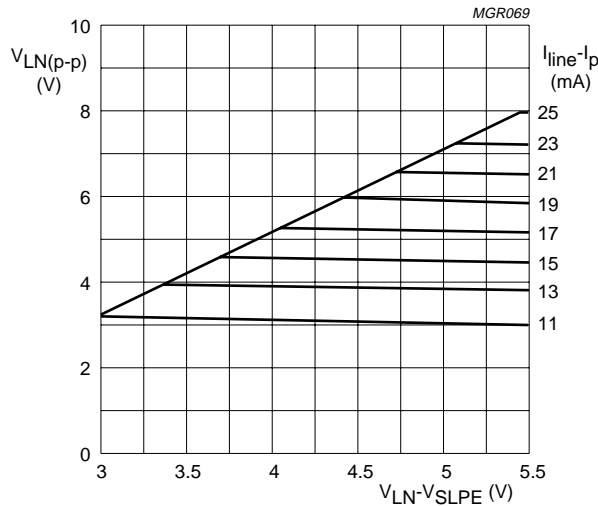


Fig.14 Maximum output swing on line as a function of the DC voltage drop  $V_{LN-SLPE}$  with  $I_{line} - I_p$  as a parameter:  $R_{15} = 392 \Omega$ ;  $R_{16} = 56 \Omega$ ; or  $R_{15} = 0 \Omega$  and  $R_{16} = 392 + 56 = 448 \Omega$ .

The internal threshold level is lowered automatically if the DC current in the transmit output stage is insufficient. This prevents distortion of the sending signal in applications using parallel-connected telephones or telephones operating over long lines, for example.

Dynamic limiting also considerably improves sidetone performance in over-drive conditions (less distortion; limited sidetone level).

## Receiving amplifier IR, QR+, QR- and GAR

The receiving amplifier has one input IR and two complementary outputs, QR+ (non-inverting) and QR- (inverting). These outputs may be used for single-ended or differential drive, depending on the type and sensitivity of the earpiece used (see Fig.15). Gain from IR to QR+ is typically 31 dB with  $R_4 = 100 \text{ k}\Omega$ , sufficient for low-impedance magnetic or dynamic earpieces which are suitable for single-ended drive. By using both outputs (differential drive) the gain is increased by 6 dB. Differential drive can be used when the earpiece impedance exceeds  $450 \Omega$  as with high-impedance dynamic, magnetic or piezo-electric earpieces.

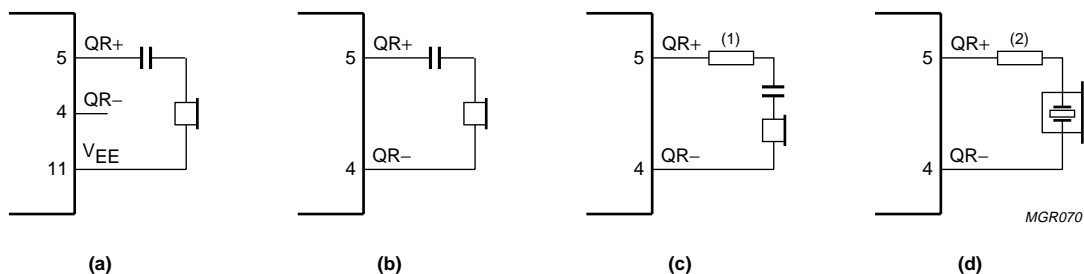


Fig.15 Alternative receiver arrangements: a) dynamic earpiece with an impedance less than  $450 \Omega$ ; b) dynamic earpiece with an impedance more than  $450 \Omega$ ; c) magnetic earpiece with an impedance more than  $450 \Omega$ , resistor (1) may be connected to prevent distortion (inductive load); d) piezo-electric earpiece, resistor (2) is required to increase the phase margin (stability with capacitive load).

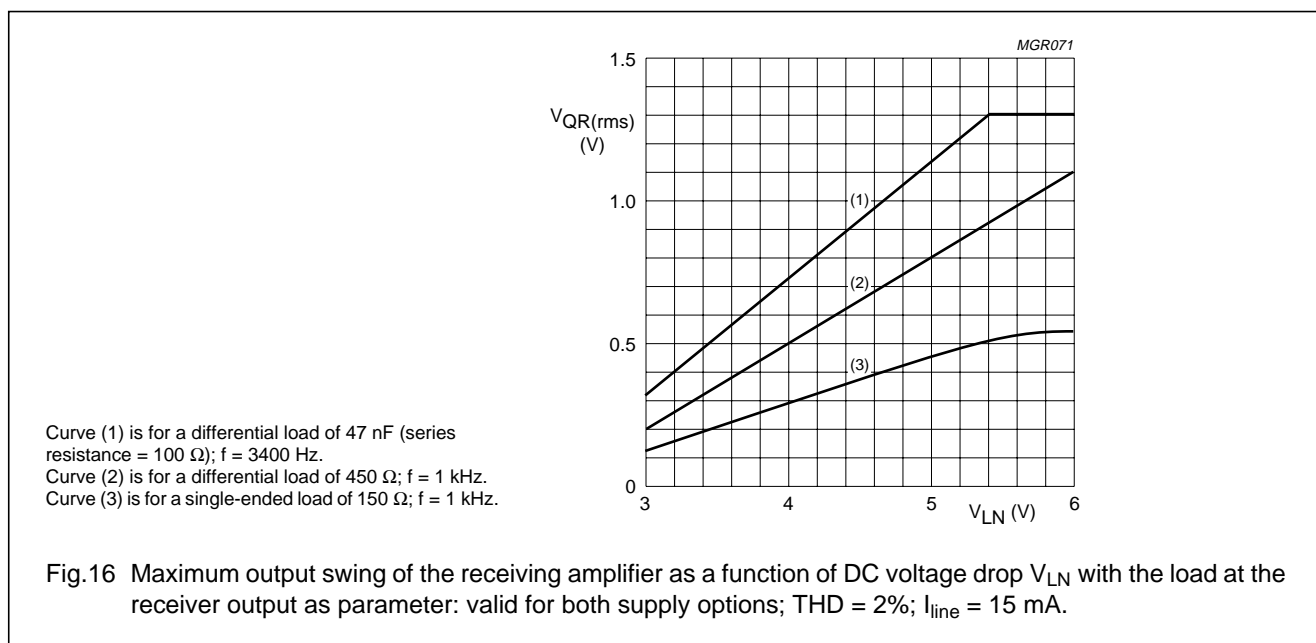
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The output voltage of the receiving amplifier is specified for continuous-wave drive. Fig.16 shows the maximum output swing of the receiving amplifier as a function of the DC voltage drop ( $V_{LN}$ ). The maximum output voltage will be higher under speech conditions, where the ratio of the peak to the RMS value is higher.

The gain of the receiving amplifier can be adjusted to suit the sensitivity of the transducer used. The adjustment range is between 20 dB and 39 dB with single-ended drive and between 26 dB and 45 dB with differential drive. The gain is proportional to the external resistor R4 connected between GAR and QR+. The overall gain between LN and QR+ can be found by subtracting the attenuation of the anti-sidetone network (32 dB) from the amplifier gain.

Two external capacitors ( $C4 = 100$  pF and  $C7 = 10 \times C4 = 1$  nF) ensure stability. A larger value may be chosen to obtain a first-order low-pass filter. The cut-off frequency corresponds with the time constant  $R4 \times C4$ . The relationship  $C7 = 10 \times C4$  must be maintained.



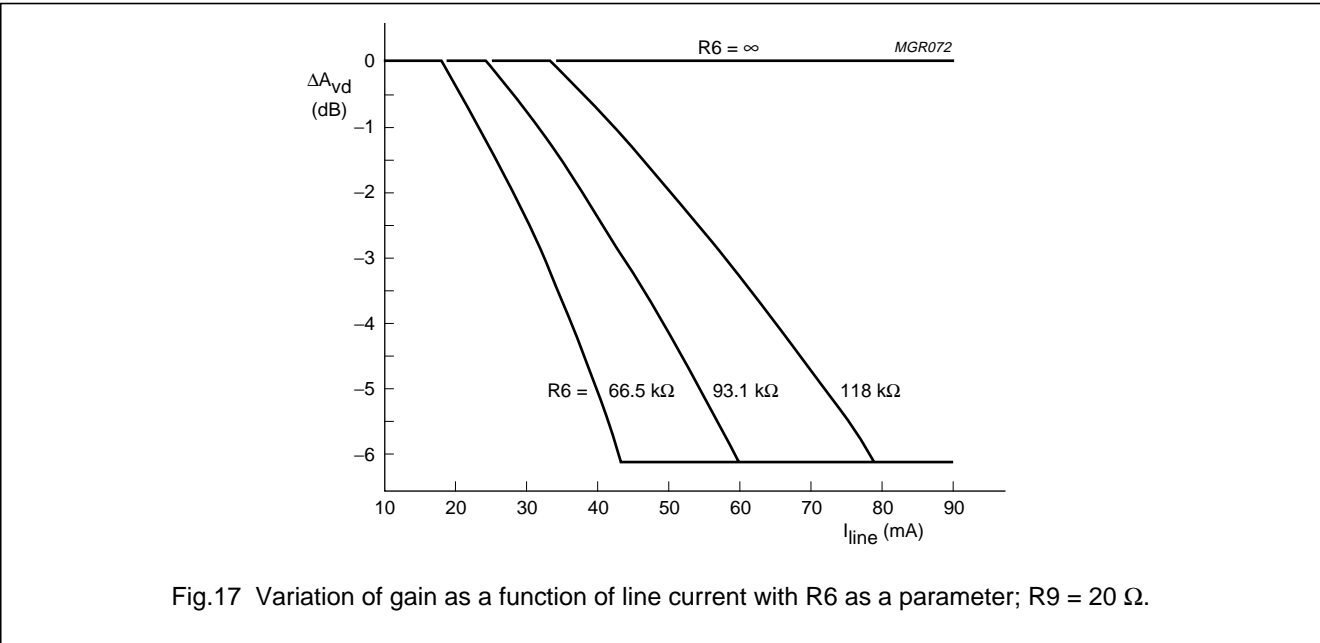
### Automatic gain control input AGC

Automatic compensation of line loss is obtained by connecting a resistor (R6) between AGC and  $V_{EE}$ . This automatic gain control varies the gain of the microphone amplifier and receiving amplifier in accordance with the DC line current. The control range is 6.1 dB; this corresponds to a 5 km line of 0.5 mm diameter copper twisted-pair cable (DC resistance = 176  $\Omega$ /km, average attenuation = 1.2 dB/km). The DTMF gain is not affected by this feature.

The value of R6 must be chosen with reference to the exchange supply voltage and its feeding bridge resistance (see Fig.17 and Table 1). Different values of R6 give the same line current ratios at the start and the end of the control range. If automatic line-loss compensation is not required the AGC pin can be left open, the amplifiers then give their maximum gain.

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**Table 1** Values of R6 giving optimum line-loss compensation at various values of exchange supply voltage ( $V_{exch}$ ) and exchange feeding bridge resistance ( $R_{exch}$ ); R9 = 20  $\Omega$ .

		$R_{exch}$ ( $\Omega$ )			
		400	600	800	1000
		$R6$ (k $\Omega$ )			
$V_{exch}$ (V)	36	84.5	66.5	X	X
	48	118	93.1	77.8	66.5
	60	X	X	97.6	84.5

**MUTE input** (see notes 1. and 2.)

MUTE = HIGH enables the DTMF input and inhibits the microphone and receiving amplifier inputs.

MUTE = LOW or open-circuit disables the DTMF input and enables the microphone and receiving amplifier inputs.

Switching MUTE gives negligible clicks at the telephone outputs and on the line.

**Dual-tone multi-frequency input DTMF** (see note 1.)

When the DTMF input is enabled, dialling tones may be sent on to the line. The voltage gain between DTMF-SLPE and LN- $V_{EE}$  is typ. 26 dB less than the gain of the microphone amplifier and varies with R7 in the same way as the gain of the microphone amplifier. This means that the tone level at the DTMF input has to be adjusted after

setting the gain of the microphone amplifier. With R7 = 68 k $\Omega$  the gain is typically 26 dB.

The signalling tones can be heard in the earpiece at a low level (confidence tone).

**Power-down input PD** (see notes 1. and 2.)

During pulse dialling or register recall (timed loop break) the telephone line is interrupted; as a consequence it provides no supply for the transmission circuit connected to  $V_{CC1}$  or for the peripherals between  $V_{CC2}$  and SLPE. These supply gaps are bridged by the charges in the capacitors C1 and C15. The requirements on these capacitors are eased by applying a HIGH level to the PD input during the time of the loop break. This reduces the internal supply current  $I_{CC1}$  from (typ.) 1.3 mA to (typ.) 60  $\mu$ A and switches off the voltage regulator to prevent discharge via LN and  $V_{CC2}$ .

A HIGH level at PD also internally disconnects the capacitor at REG so that the voltage stabilizer has no switch-on delay after line interruptions. This minimizes the contribution of the IC to the current waveform during pulse dialling or register recall.

When the power-down facility is not required, the PD pin can be left open-circuit or connected to SLPE.

**Side-tone suppression**

Suppression of the transmitted signal in the earpiece is obtained by the anti-sidetone network comprising R1// $Z_{line}$ ,

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R2, R3, R8, R9 and  $Z_{bal}$  (see Fig.18). Maximum compensation is obtained when the following conditions are fulfilled:

- a)  $R9 \times R2 = R1 \times (R3 + [R8/Z_{bal}])$
- b)  $(Z_{bal}/[Z_{bal} + R8]) = (Z_{line}/[Z_{line} + R1])$

If fixed values are chosen for R1, R2, R3 and R9, then condition a) is always fulfilled provided  $|R8/Z_{bal}| \ll R3$ .

To obtain optimum sidetone suppression, condition b) has to be fulfilled, resulting in:

$$Z_{bal} = (R8/R1) \times Z_{line} = k \times Z_{line}$$

where k is a scale factor;  $k = (R8/R1)$ .

The scale factor k (value of R8) is chosen to meet the following criteria:

- compatibility with a standard capacitor from the E6 or E12 range for  $Z_{bal}$ ;
- $|Z_{bal}/R8| \ll R3$  to fulfil condition a) and thus ensure correct anti-sidetone bridge operation;
- $|Z_{bal} + R8| \gg R9$  to avoid influencing the transmit gain.

In practice  $Z_{line}$  varies considerably with the line length and line type. Therefore the value chosen for  $Z_{bal}$  should be for an average line length giving satisfactory sidetone suppression with short and long lines. The suppression also depends on the accuracy of the match between  $Z_{bal}$  and the impedance of the average line.

### Example

The line impedance for which optimum suppression is to be obtained can be represented by  $210 \Omega + (1265 \Omega // 140 \text{ nF})$ . This represents a 5 km line of 0.5 mm diameter copper twisted-pair cable matched with  $600 \Omega$  ( $176 \Omega/\text{km}$ ;  $38 \text{ nF/km}$ ).

With  $k = 0.64$  this results in:  $R8 = 390 \Omega$ ;  
 $Z_{bal} = 130 \Omega + (820 \Omega // 220 \text{ nF})$ .

The anti-sidetone network for the TEA1060 family shown in Fig.18 attenuates the signal received from the line by 32 dB before it enters the receiving amplifier. The attenuation is almost constant over the whole audio-frequency range.

Alternatively a conventional Wheatstone bridge can be used as an anti-sidetone circuit (Fig.19). Both bridge types can be used with either resistive or complex set impedances. (More information on the balancing of anti-sidetone bridges can be obtained in our publication "Versatile speech transmission ICs for electronic telephone sets", order number 9398 341 10011).

### Notes

1. The reference used for the MUTE, DTMF and PD inputs is SLPE.
2. A LOW level for any of these pins is defined by connection to SLPE, a HIGH level is defined as a voltage greater than  $V_{SLPE} + 1.5 \text{ V}$  and smaller than  $V_{CC1} + 0.4 \text{ V}$ .

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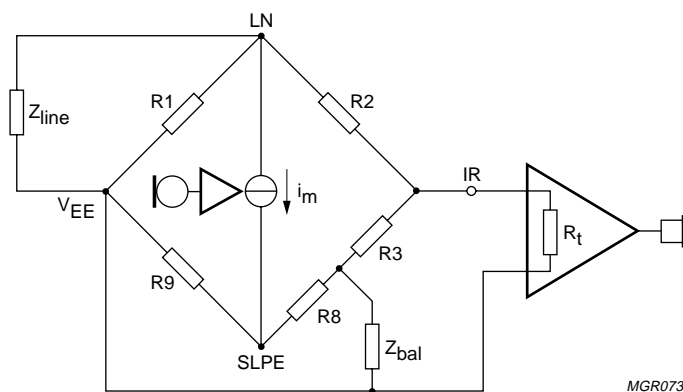


Fig.18 Equivalent circuit of TEA1060 family anti-side-tone bridge.

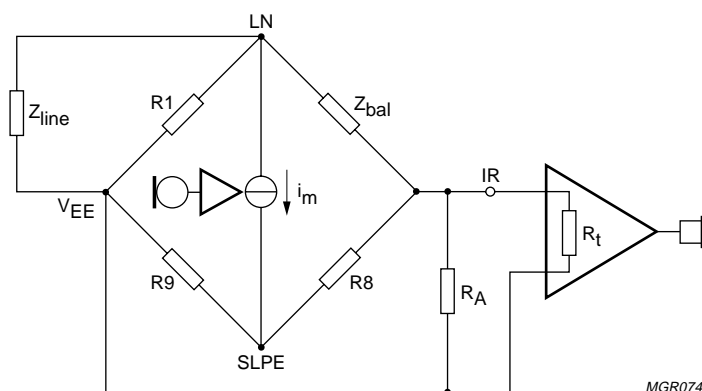


Fig.19 Equivalent circuit of an anti-sidetone network in the Wheatstone bridge configuration.



# Low voltage versatile telephone transmission circuit with dialler interface and transmit level dynamic limiting

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## RATINGS

Limiting values in accordance with the Absolute Maximum System (IEC 134)

PARAMETER	CONDITIONS	SYMBOL	MIN.	MAX.	UNIT
Positive line voltage continuous		$V_{LN}$	—	12	V
Repetitive line voltage during switch-on line interruption		$V_{LN}$	—	13.2	V
Repetitive peak line voltage one 1 ms pulse per 5 s	$R9 = 20\ \Omega$ ; $R10 = 13\ \Omega$ (Fig.24)	$V_{LN}$	—	28	V
Line current TEA1064A (note 1)	$R9 = 20\ \Omega$	$I_{LN}$	—	140	mA
Line current TEA1064AT (note 1)	$R9 = 20\ \Omega$	$I_{LN}$	—	140	mA
Input voltage on pins other than LN and $V_{CC2}$		$V_i$	$V_{EE}-0.7$	$V_{CC1} + 0.7$	V
Total power dissipation (note 2)	$R9 = 20\ \Omega$				
TEA1064A		$P_{tot}$	—	714	mW
TEA1064AT		$P_{tot}$	—	555	mW
Storage temperature range		$T_{stg}$	-40	+ 125	°C
Operating ambient temperature range		$T_{amb}$	-25	+ 75	°C
Junction temperature		$T_j$	—	+ 125	°C

## Notes

1. Mostly dependent on the maximum required  $T_{amb}$  and on the voltage between LN and SLPE. See Figs 20 and 21 to determine the current as a function of the required voltage and the temperature.
2. Calculated for the maximum ambient temperature specified  $T_{amb} = 75\ ^\circ\text{C}$  and a maximum junction temperature of  $125\ ^\circ\text{C}$ .

## THERMAL RESISTANCE

From junction to ambient in free air

TEA1064A	$R_{th\ j-a}$	=	70 K/W
TEA1064AT mounted on glass epoxy board $41 \times 19 \times 1.5\ \text{mm}$	$R_{th\ j-a}$	=	90 K/W

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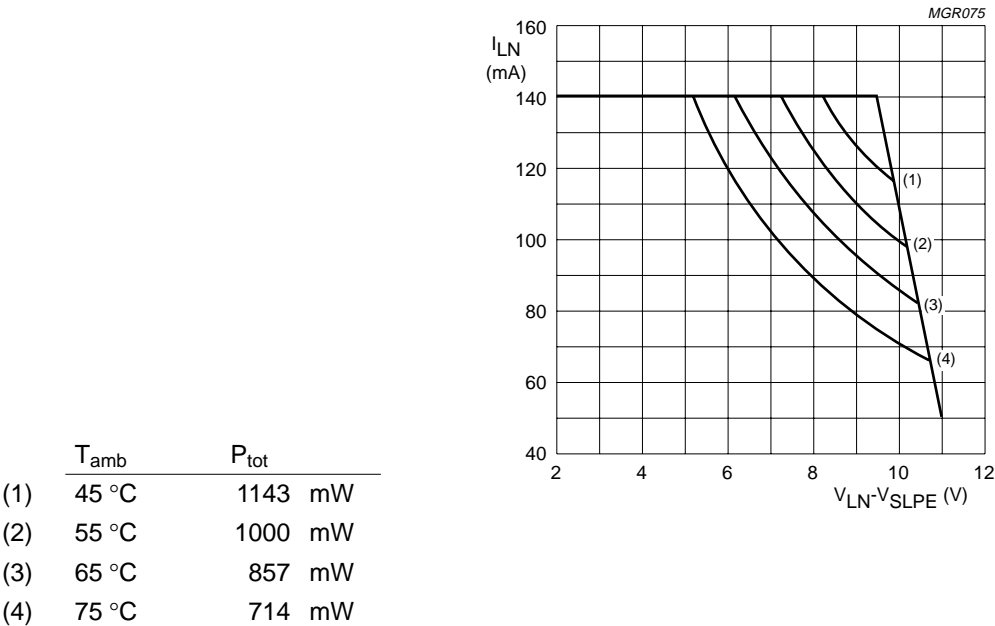


Fig.20 TEA1064A safe operating area.

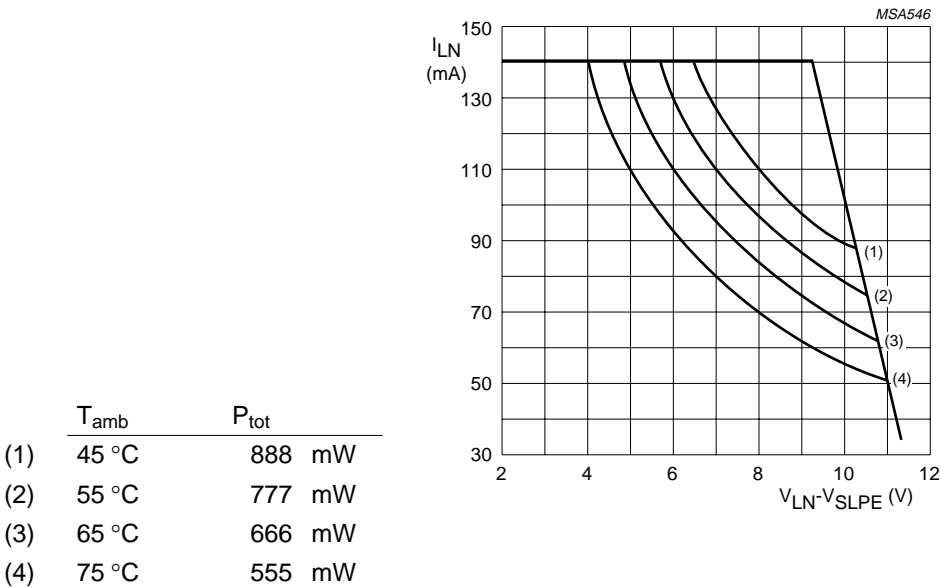


Fig.21 TEA1064AT safe operating area.

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## CHARACTERISTICS

$I_{line} = 11$  to  $140$  mA;  $V_{EE} = 0$  V;  $f = 800$  Hz;  $T_{amb} = 25$  °C;  $R_L = 600$   $\Omega$ ; tested in the circuit of Fig.22 or 23); unless otherwise specified

PARAMETER	CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
<b>Supplies LN, V<sub>CC1</sub>, V<sub>CC2</sub></b> (pins 1, 16, 19)						
Reference DC voltage between V <sub>CC2</sub> and SLPE	$I_{line} = 15$ mA $I_p = 0$ ; 4 mA					
R <sub>VA</sub> not connected		V <sub>CC2-SLPE</sub>	3.05	3.3	3.55	V
Variation with temperature	$I_{line} = 15$ mA	V <sub>CC2-SLPE</sub> /ΔT	−3.0	−1.0	1.0	mV/K
Variation with line current referred to 15 mA	$I_{line} = 100$ mA	ΔV <sub>CC2-SLPE</sub>	−	60	−	mV
With R <sub>VA</sub> connected between REG and SLPE	R <sub>VA</sub> = 33 kΩ	V <sub>CC2-SLPE</sub>	3.6	3.8	4.2	V
	R <sub>VA</sub> = 20 kΩ	V <sub>CC2-SLPE</sub>	3.95	4.2	4.65	V
DC line voltage: voltage drop between LN and V <sub>EE</sub>	MIC−, MIC+ inputs open; R15 = 392 $\Omega$ ; without R <sub>VA</sub>					
at $I_{line} = 15$ mA	$I_p = 0$ mA	V <sub>LN</sub>	3.4	3.6	4.0	V
	$I_p = 2$ mA	V <sub>LN</sub>	4.2	4.4	4.8	V
	$I_p = 4$ mA	V <sub>LN</sub>	4.9	5.1	5.5	V
at $I_{line} = 100$ mA	$I_p = 2$ mA	V <sub>LN</sub>	−	6.1	7.0	V
at $I_{line} = 140$ mA	$I_p = 2$ mA	V <sub>LN</sub>	−	7.0	7.8	V
Voltage drop under low current conditions	$I_p = 0$ mA					
	$I_{line} = 2$ mA	V <sub>LN</sub>	−	1.8	−	V
	$I_{line} = 4$ mA	V <sub>LN</sub>	−	2.2	−	V
	$I_{line} = 7$ mA	V <sub>LN</sub>	−	3.2	−	V
	$I_{line} = 11$ mA	V <sub>LN</sub>	−	3.5	−	V
Internal supply current I <sub>CC1</sub> : current into pin V <sub>CC1</sub>	V <sub>CC1</sub> = 2.8 V PD = LOW	I <sub>CC1</sub>	−	1.3	1.6	mA
	PD = HIGH	I <sub>CC1</sub>	−	60	82	μA
<b>Microphone inputs MIC−, MIC+</b> (pins 8, 9)						
Input impedance: differential		Z <sub>i</sub>	51	64	77	kΩ
single-ended		Z <sub>i</sub>	25.5	32.0	38.5	kΩ
Common mode rejection ratio		CMRR	−	82	−	dB

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PARAMETER	CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
Voltage gain (see Fig.22)	$I_{line} = 15 \text{ mA};$ $R7 = 68 \text{ k}\Omega$	$G_v$	51	52	53	dB
Variation of $G_v$ with frequency, referred to 0.8 kHz	$f = 300 \text{ and } 3400 \text{ Hz}$	$\Delta G_v f$	-0.5	$\pm 0.1$	+ 0.5	dB
Variation of $G_v$ with temperature, referred to 25 °C	without R6; $I_{line} = 50 \text{ mA};$ $T_{amb} = -25 \text{ to } + 75 \text{ }^\circ\text{C}$	$\Delta G_v T$	—	$\pm 0.2$	—	dB
<b>DTMF input</b> (pin 12)						
Input impedance		$Z_i$	16.8	20.7	24.6	k $\Omega$
Voltage gain (see Fig.22)	$I_{line} = 15 \text{ mA};$ $R7 = 68 \text{ k}\Omega$	$G_v$	25	26	27	dB
Variation of $G_v$ with frequency, referred to 0.8 kHz	$f = 300 \text{ and } 3400 \text{ Hz}$	$\Delta G_v f$	-0.5	$\pm 0.1$	+ 0.5	dB
	$f = 697 \text{ and } 1633 \text{ Hz}$	$\Delta G_v f$	-0.2	$\pm 0.05$	+ 0.2	dB
Variation of $G_v$ with temperature, referred to 25 °C	$I_{line} = 50 \text{ mA};$ $T_{amb} = -25 \text{ to } + 75^\circ\text{C}$	$\Delta G_v T$	—	$\pm 0.2$	0.5	dB
<b>Gain adjustment inputs GAS1, GAS2</b> (pins 2, 3)						
Transmitting amplifier, gain adjustment range		$\Delta G_v$	-8	—	+ 0	dB
<b>Sending amplifier output LN</b> (pin 1)						
<i>Dynamic limiter</i>						
Output voltage swing (peak-to-peak value)	$I_{line} = 15 \text{ mA};$ $R7 = 68 \text{ k}\Omega;$ $I_p = 0 \text{ mA};$ $V_{i(rms)} = 3.6 \text{ mV}$	$V_{LN(p-p)}$	3.6	4.0	4.5	V
Total harmonic distortion	$V_i = 3.6 \text{ mV} + 10 \text{ dB}$	THD	—	1.5	2.0	%
	$V_i = 3.6 \text{ mV} + 15 \text{ dB}$	THD	—	2.8	10.0	%
Output voltage swing (peak-to-peak value)	$V_i = 3.6 \text{ mV} + 10 \text{ dB}$					
	$I_p = 2 \text{ mA}$	$V_{LN(p-p)}$	3.7	3.95	4.2	V
	$I_p = 4 \text{ mA}$	$V_{LN(p-p)}$	3.0	3.25	3.5	V
	$I_p = 0 \text{ mA};$ $I_{line} = 7 \text{ mA}$	$V_{LN(p-p)}$	—	2	—	V
	$I_p = 0 \text{ mA};$ $I_{line} = 4 \text{ mA}$	$V_{LN(p-p)}$	—	1	—	V

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PARAMETER	CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
Dynamic behaviour of limiter	C16 = 470 nF					
attack time, $V_{mic}$ jumps from 2 mV to 40 mV		$t_{att}$	–	1.5	5.0	ms
release time, $V_{mic}$ jumps from 40 mV to 2 mV		$t_{rel}$	50	150	–	ms
Noise output voltage (RMS value)	$I_{line} = 15$ mA; R7 = 68 k $\Omega$ ; 200 $\Omega$ between MIC– and MIC+; psophometrically weighted (P53 curve)	$V_{no(rms)}$	–	–72	–	dBmp
<b>Receiving amplifier input IR</b> (pin 13)						
Input impedance		$Z_i$	17	21	25	k $\Omega$
<b>Receiving amplifier outputs QR– QR+</b> (pins 4, 5)						
Output impedance	single-ended	$Z_o$	–	4	–	$\Omega$
Voltage gain	Fig.23; $I_{line} = 15$ mA; R4 = 100 k $\Omega$					
single-ended; $R_T = 300$ $\Omega$		$G_v$	30	31	32	dB
differential; $R_T = 600$ $\Omega$		$G_v$	36	37	38	dB
Variation with frequency, referred to 0.8 kHz	f = 300 and 3400 Hz	$\Delta G_v f$	–0.5	–0.2	0	dB
Variation with temperature, referred to 25 °C	without R6; $I_{line} = 50$ mA; $T_{amb} = -25$ to +75 °C	$\Delta G_v T$	–	$\pm 0.2$	–	dB
Output voltage (RMS value)	THD = 2%; sinewave drive; R4 = 100 k $\Omega$ ; $I_{line} = 15$ mA					
single-ended; $R_T = 150$ $\Omega$	$I_p = 0$ mA	$V_{o(rms)}$	–	0.22	–	V
	$I_p = 2$ mA	$V_{o(rms)}$	–	0.35	–	V
differential; $R_T = 450$ $\Omega$	$I_p = 0$ mA	$V_{o(rms)}$	–	0.39	–	V
	$I_p = 2$ mA	$V_{o(rms)}$	–	0.64	–	V
differential; $C_T = 47$ nF; (100 $\Omega$ series resistor); f = 3400 Hz	$I_p = 0$ mA	$V_{o(rms)}$	–	0.57	–	V
	$I_p = 2$ mA	$V_{o(rms)}$	–	0.9	–	V

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PARAMETER	CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
Output voltage (RMS value)	$I_p = 0 \text{ mA}$ ; THD = 10%; sinewave drive; $R_4 = 100 \text{ k}\Omega$ ; single-ended; $R_T = 150 \text{ }\Omega$ ; $I_{line} = 4 \text{ mA}$	$V_{o(rms)}$	—	25	—	mV
Noise output voltage (RMS value)	$I_{line} = 7 \text{ mA}$ ; $I_{line} = 15 \text{ mA}$ ; $R_4 = 100 \text{ k}\Omega$ ; psophometrically weighted (P53 curve); pin IR open single-ended; $R_T = 300 \text{ }\Omega$ ; differential; $R_T = 600 \text{ }\Omega$	$V_{o(rms)}$	—	160	—	mV
Noise output voltage (RMS value)	in circuit of Fig.23; S1 in position 2; 200 $\Omega$ between MIC+ and MIC-; single-ended; $R_T = 300 \text{ }\Omega$	$V_{no(rms)}$	—	45	—	$\mu\text{V}$
	$R_7 = 68 \text{ k}\Omega$ $R_7 = 24.9 \text{ k}\Omega$	$V_{no(rms)}$	—	90	—	$\mu\text{V}$
<b>Gain adjustment input GAR</b> (pin 6)						
Receiving amplifier, gain adjustment range		$\Delta G_v$	-11	—	+8	dB
<b>MUTE INPUT</b> (pin 14)						
Input voltage HIGH		$V_{IH}$	$1.5 + V_{SLPE}$	—	$V_{CC1} + 0.4$	V
Input voltage LOW		$V_{IL}$	0	—	$0.3 + V_{SLPE}$	V
Input current		$I_{mute}$	—	11	20	$\mu\text{A}$
Change of microphone amplifier gain at mute-ON	MUTE = HIGH	$-\Delta G_v$	—	100	—	dB

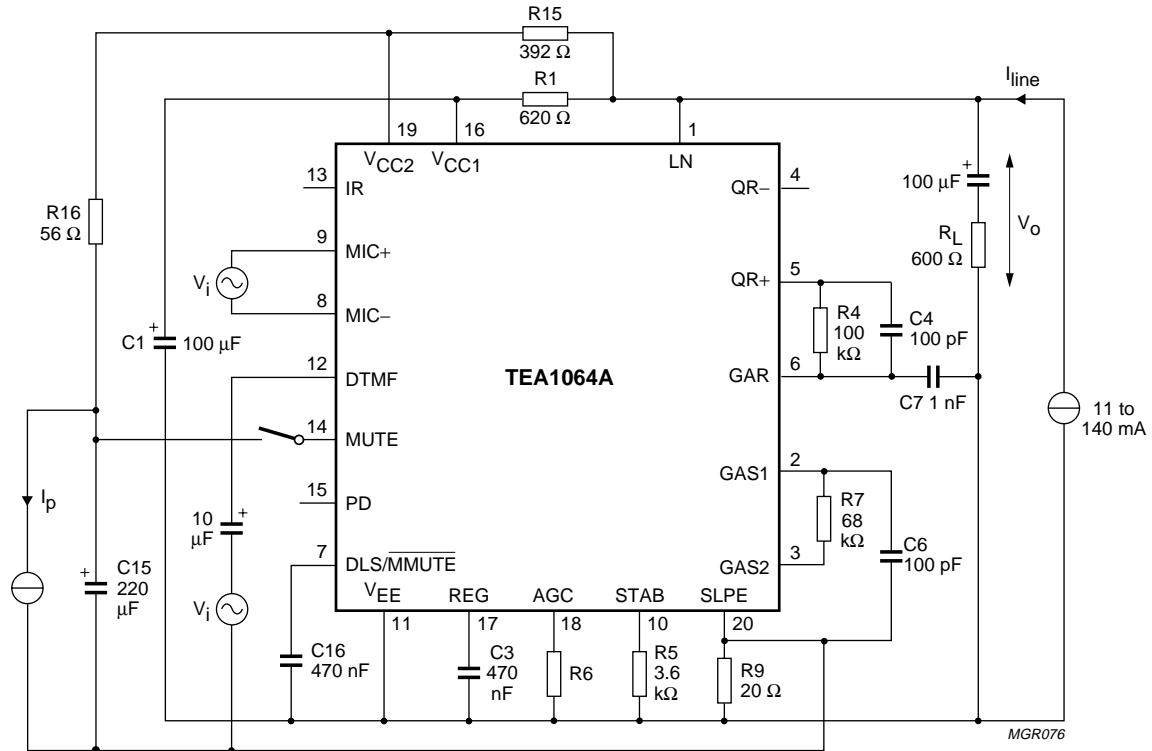
# Low voltage versatile telephone transmission circuit with dialler interface and transmit level dynamic limiting

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PARAMETER	CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
Voltage gain from input DTMF-SLPE to QR+ output with mute-ON	MUTE = HIGH; single-ended load; $R_L = 300\ \Omega$	$G_V$	–	–18	–	dB
<b>Power-down input PD</b> (pin 15)						
Input voltage HIGH		$V_{IH}$	$1.5 + V_{SLPE}$	–	$V_{CC1} + 0.4$	V
Input voltage LOW		$V_{IL}$	0	–	$0.3 + V_{SLPE}$	V
Input current		$I_{PD}$	–	5	10	$\mu A$
<b>Automatic gain control input AGC</b> (pin 18)						
Controlling the gain from IR (pin 13) to QR+, QR– (pins 4, 5) and the gain from MIC+, MIC– (pins 8, 9) to LN (pin 1)	$R6 = 93.1\ k\Omega$ (between pins 18 and 11)					
gain control range with respect to $I_{line} = 15\ mA$	$I_{line} = 75\ mA$	$-G_V$	5.7	6.1	6.5	dB
Highest line current for maximum gain		$I_{line}$	–	24	–	mA
Lowest line current for minimum gain		$I_{line}$	–	61	–	mA
Change of gain between $I_{line} = 15$ and $35\ mA$		$-\Delta G_V$	0.9	1.4	1.9	dB
<b>Microphone mute input DLS/MMUTE</b> (pin 7)						
Input voltage low		$V_{IL}$	$V_{EE}$	–	$V_{EE} + 0.3$	V
Input current at low input voltage		$I_{IL}$	–85	–60	–35	$\mu A$
Release time after a low level on pin 7	$C16 = 470\ nF$	$t_{rel}$	–	30	–	ms
Change of microphone amplifier gain at low input voltage on pin 7		$-\Delta G_V$	–	100	–	dB

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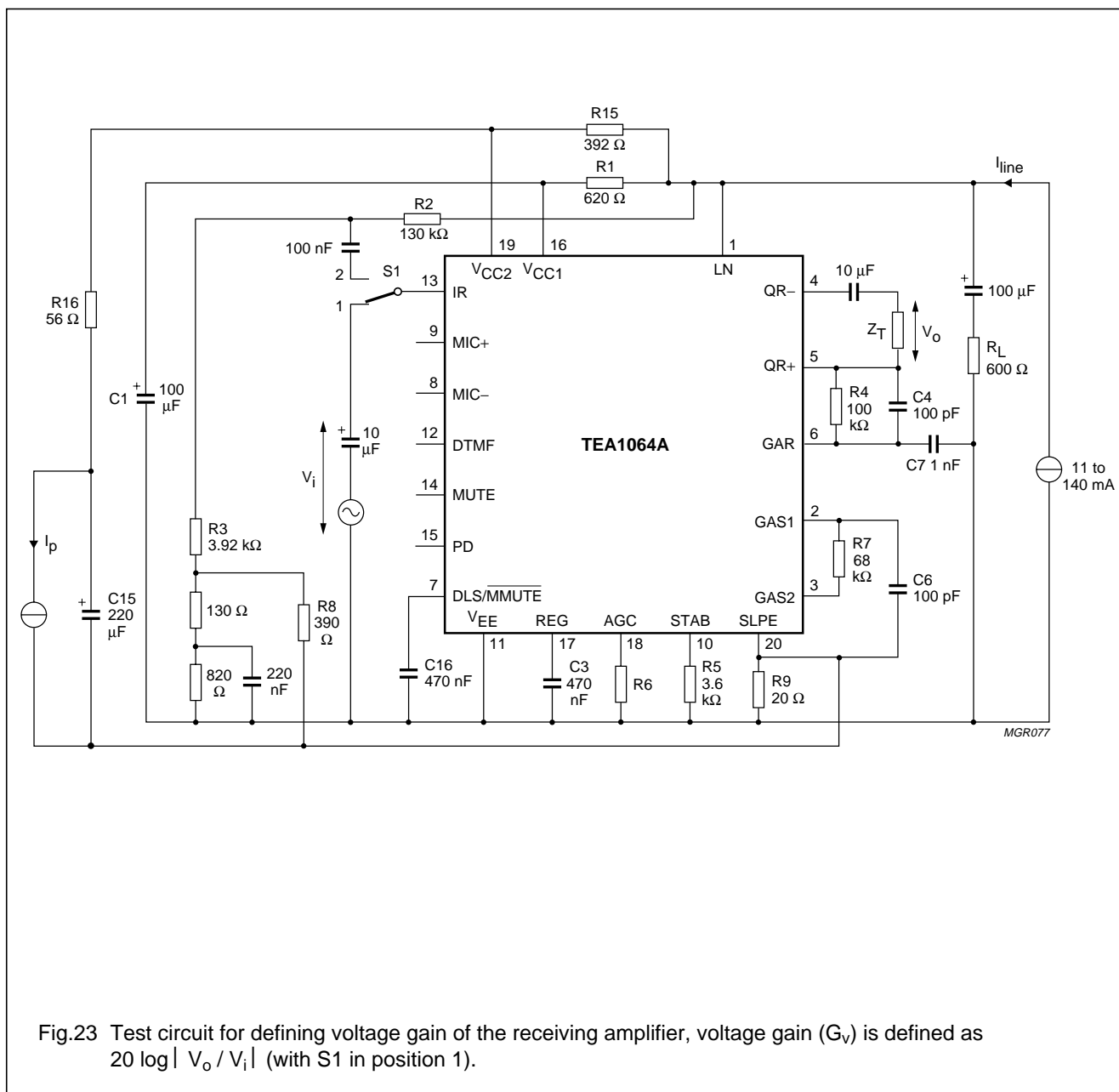
For measuring the gain from MIC+ and MIC- the MUTE input should be LOW or open-circuit; for measuring the DTMF input, the MUTE input should be HIGH. Inputs not being tested should be open-circuit.

Fig.22 Test circuit for defining voltage gain of MIC-, MIC+ and DTMF inputs; voltage gain ( $G_v$ ) is defined as  $20 \log |V_o / V_i|$ .



## Low voltage versatile telephone transmission circuit with dialler interface and transmit level dynamic limiting

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## APPLICATION INFORMATION

The basic application circuit is shown in Fig.24 and some typical applications are shown in Figs 25, 26 and 27.

In the basic application, the circuit provides two possibilities for supplies to peripheral circuits:

- regulated line voltage  $V_{LN}$  (stabilized  $V_{LN-SLPE}$ ) and unregulated supply voltage for peripheral circuits, the supply voltage is dependent only on the peripheral supply current. This application is the same as that used for TEA1060/TEA1061, TEA1067 and TEA1068;
- stabilized supply voltage for peripherals ( $V_{CC2-SLPE}$ ), the DC line voltage depends on the current flowing to the peripheral circuits.

# Low voltage versatile telephone transmission circuit with dialler interface and transmit level dynamic limiting

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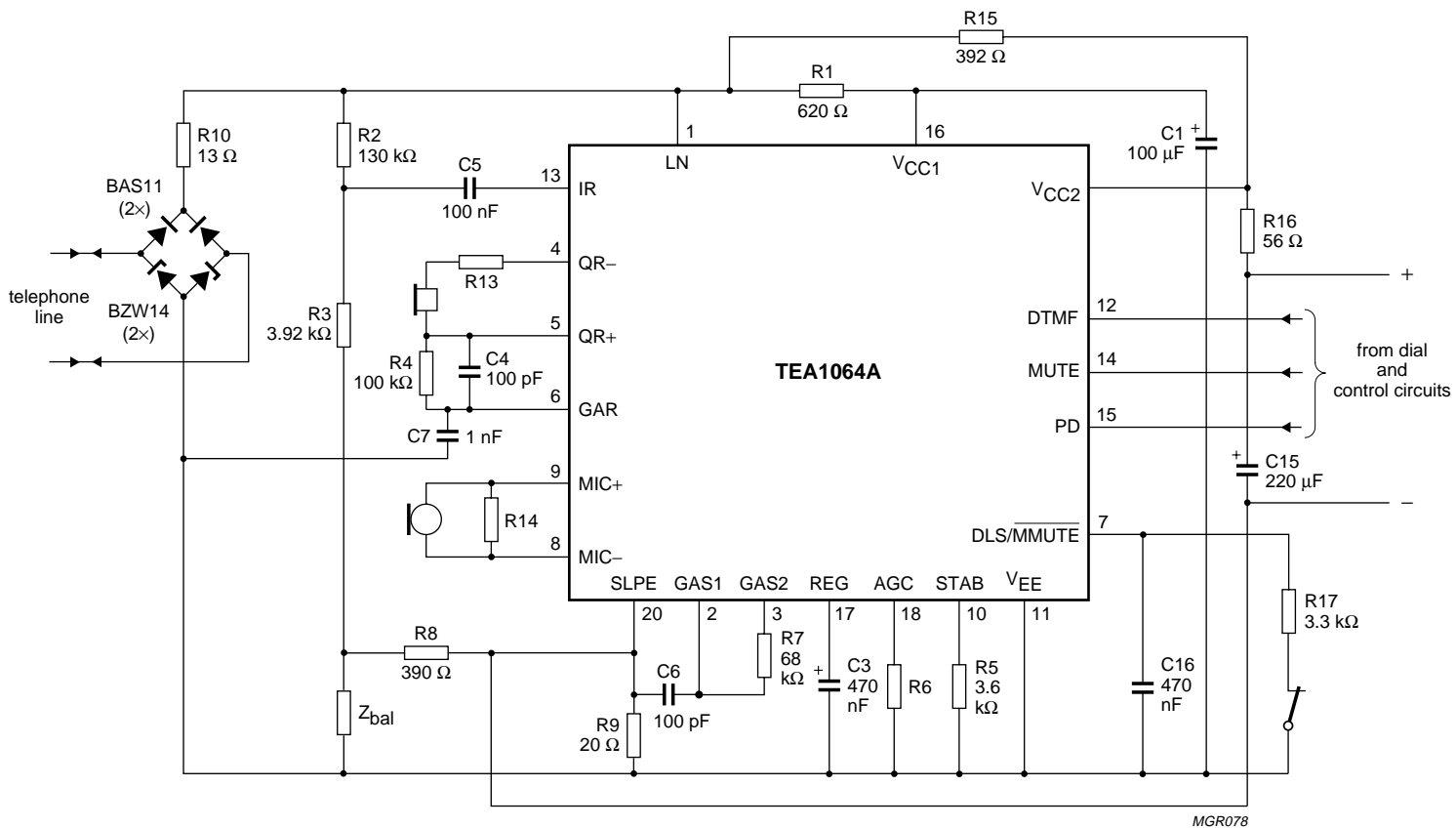


Fig.24 Basic application of the TEA1064A with stabilized supply for peripherals, shown here with a piezo-electric earpiece and DTMF dialling. The diode bridge and R10 limit the current into, and the voltage across, the circuit during line transients. A different protection arrangement is required for pulse dialling or register recall.

## Low voltage versatile telephone transmission circuit with dialler interface and transmit level dynamic limiting

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For the basic application giving regulated line voltage the above circuit is changed as follows:

- R15 must be short-circuited;
- the value of R16 is changed to 392  $\Omega$ ;
- the value of C3 is changed to 4.7  $\mu\text{F}$ .

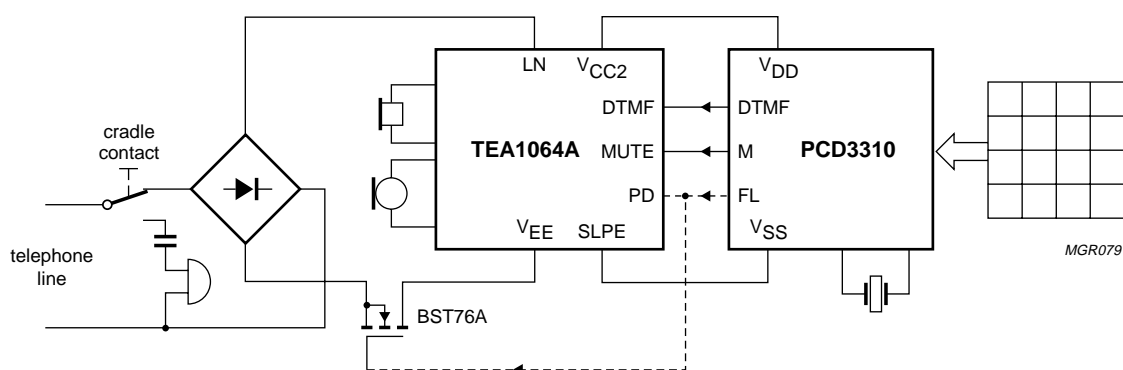


Fig.25 Typical DTMF-pulse set application circuit (simplified) showing the TEA1064A with the CMOS bilingual dialling circuit PCD3310; the broken line indicates optional flash (register recall by timed loop break).

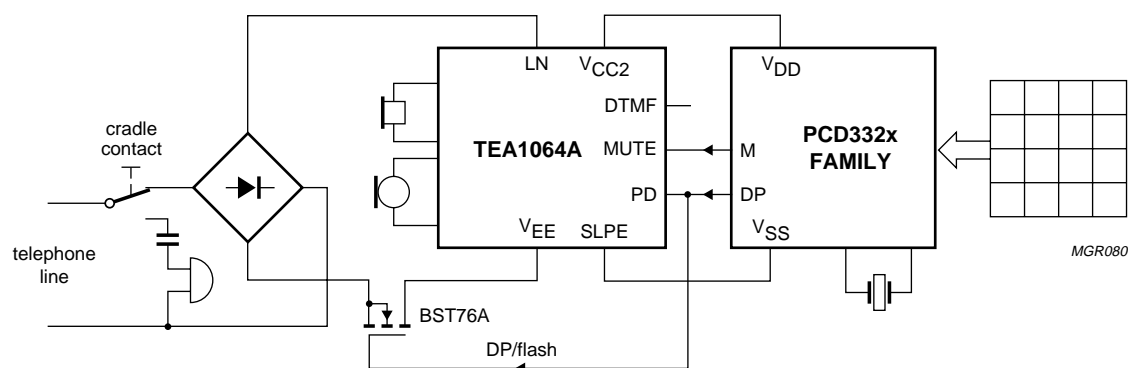


Fig.26 Typical pulse dial set application circuit (simplified) showing the TEA1064A with one of the PCD332X family of CMOS interrupted current-loop dialling circuits.

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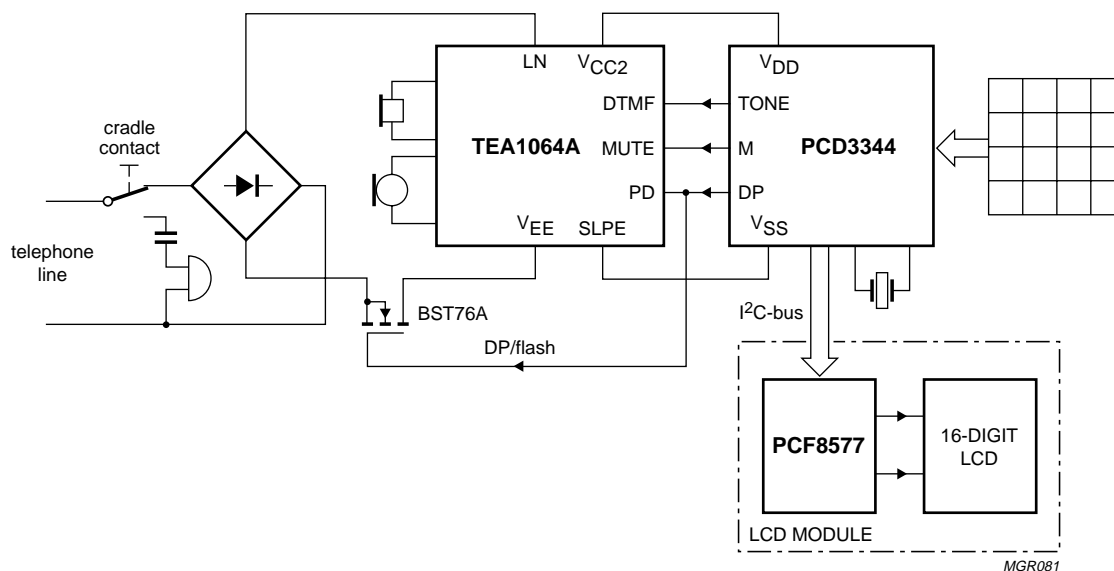


Fig.27 Typical dual-standard (pulse and DTMF) feature phone application circuit (simplified) showing the TEA1064A and the PCD3344 CMOS telephone microcontroller with on-chip DTMF generator plus I<sup>2</sup>C-bus.

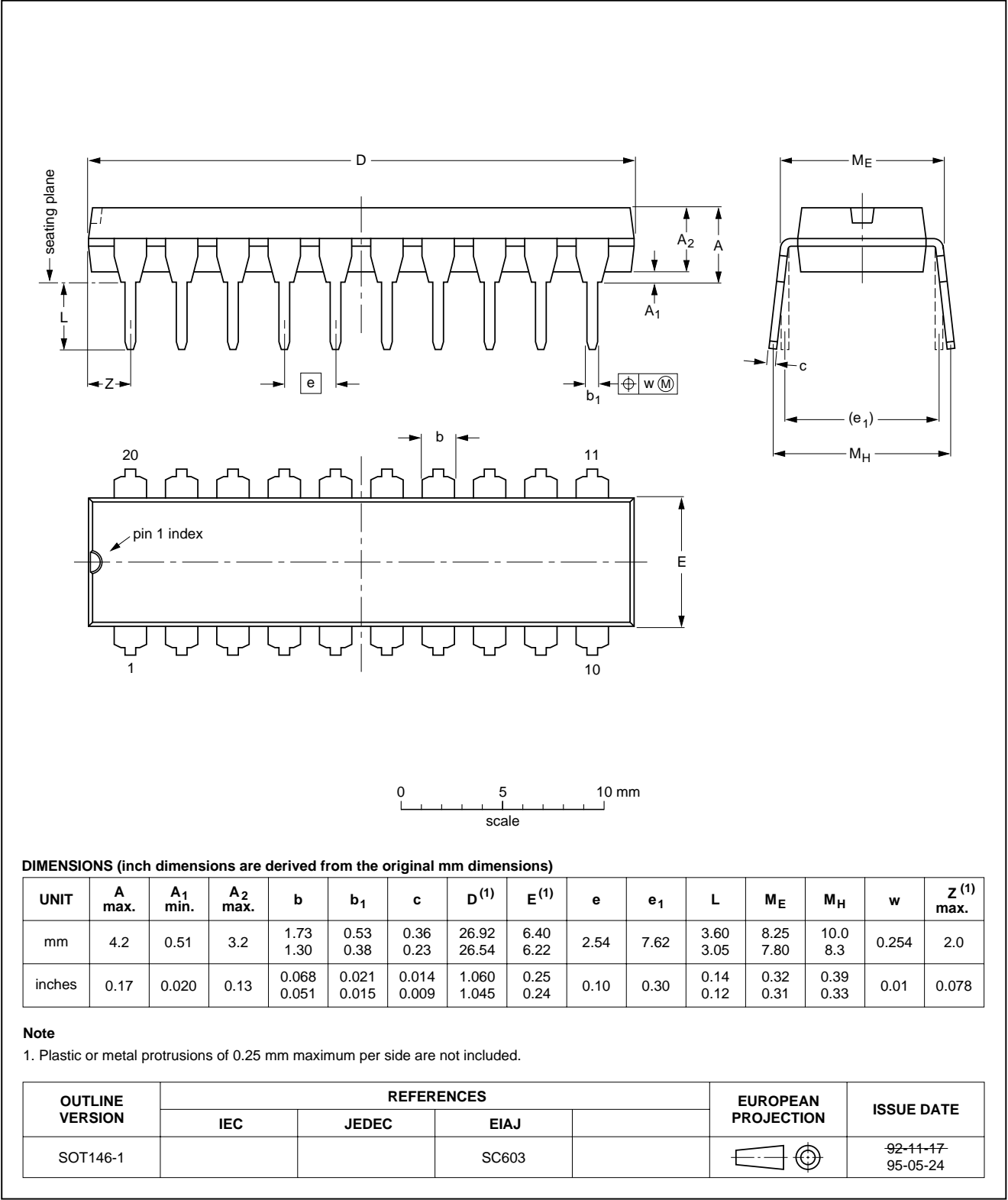
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PACKAGE OUTLINES

DIP20: plastic dual in-line package; 20 leads (300 mil)

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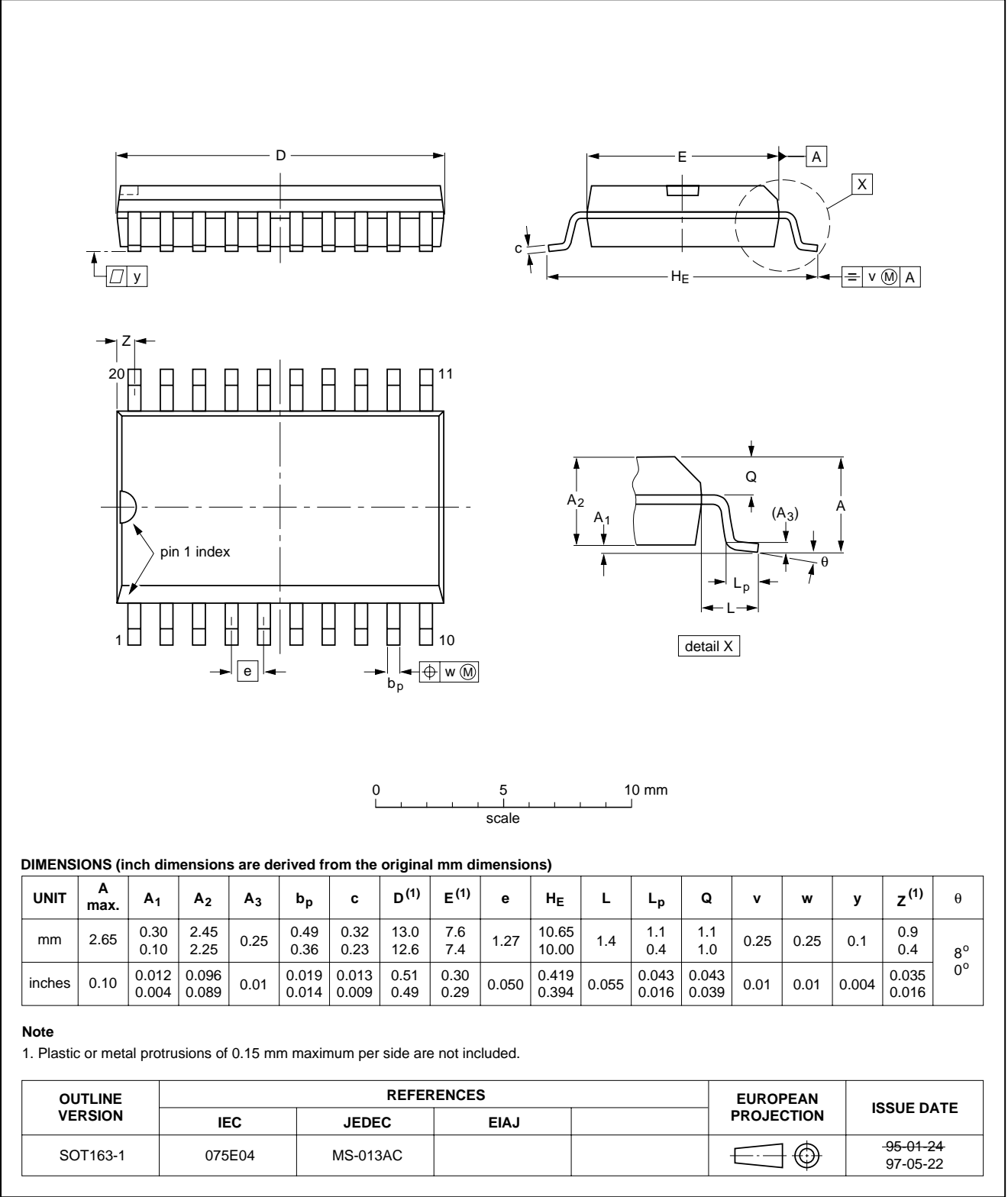


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SO20: plastic small outline package; 20 leads; body width 7.5 mm

SOT163-1



## Low voltage versatile telephone transmission circuit with dialler interface and transmit level dynamic limiting

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### SOLDERING

#### Introduction

There is no soldering method that is ideal for all IC packages. Wave soldering is often preferred when through-hole and surface mounted components are mixed on one printed-circuit board. However, wave soldering is not always suitable for surface mounted ICs, or for printed-circuits with high population densities. In these situations reflow soldering is often used.

This text gives a very brief insight to a complex technology. A more in-depth account of soldering ICs can be found in our *"Data Handbook IC26; Integrated Circuit Packages"* (order code 9398 652 90011).

#### DIP

##### SOLDERING BY DIPPING OR BY WAVE

The maximum permissible temperature of the solder is 260 °C; solder at this temperature must not be in contact with the joint for more than 5 seconds. The total contact time of successive solder waves must not exceed 5 seconds.

The device may be mounted up to the seating plane, but the temperature of the plastic body must not exceed the specified maximum storage temperature ( $T_{stg\ max}$ ). If the printed-circuit board has been pre-heated, forced cooling may be necessary immediately after soldering to keep the temperature within the permissible limit.

##### REPAIRING SOLDERED JOINTS

Apply a low voltage soldering iron (less than 24 V) to the lead(s) of the package, below the seating plane or not more than 2 mm above it. If the temperature of the soldering iron bit is less than 300 °C it may remain in contact for up to 10 seconds. If the bit temperature is between 300 and 400 °C, contact may be up to 5 seconds.

#### SO

##### REFLOW SOLDERING

Reflow soldering techniques are suitable for all SO packages.

Reflow soldering requires solder paste (a suspension of fine solder particles, flux and binding agent) to be applied to the printed-circuit board by screen printing, stencilling or pressure-syringe dispensing before package placement.

Several techniques exist for reflowing; for example, thermal conduction by heated belt. Dwell times vary between 50 and 300 seconds depending on heating method. Typical reflow temperatures range from 215 to 250 °C.

Preheating is necessary to dry the paste and evaporate the binding agent. Preheating duration: 45 minutes at 45 °C.

##### WAVE SOLDERING

Wave soldering techniques can be used for all SO packages if the following conditions are observed:

- A double-wave (a turbulent wave with high upward pressure followed by a smooth laminar wave) soldering technique should be used.
- The longitudinal axis of the package footprint must be parallel to the solder flow.
- The package footprint must incorporate solder thieves at the downstream end.

During placement and before soldering, the package must be fixed with a droplet of adhesive. The adhesive can be applied by screen printing, pin transfer or syringe dispensing. The package can be soldered after the adhesive is cured.

Maximum permissible solder temperature is 260 °C, and maximum duration of package immersion in solder is 10 seconds, if cooled to less than 150 °C within 6 seconds. Typical dwell time is 4 seconds at 250 °C.

A mildly-activated flux will eliminate the need for removal of corrosive residues in most applications.

##### REPAIRING SOLDERED JOINTS

Fix the component by first soldering two diagonally-opposite end leads. Use only a low voltage soldering iron (less than 24 V) applied to the flat part of the lead. Contact time must be limited to 10 seconds at up to 300 °C. When using a dedicated tool, all other leads can be soldered in one operation within 2 to 5 seconds between 270 and 320 °C.

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**Low voltage versatile telephone transmission circuit  
with dialler interface and transmit level dynamic limiting**

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**TEA1064A****DEFINITIONS**

<b>Data sheet status</b>	
Objective specification	This data sheet contains target or goal specifications for product development.
Preliminary specification	This data sheet contains preliminary data; supplementary data may be published later.
Product specification	This data sheet contains final product specifications.
<b>Limiting values</b>	
Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.	
<b>Application information</b>	
Where application information is given, it is advisory and does not form part of the specification.	

**LIFE SUPPORT APPLICATIONS**

These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Philips customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Philips for any damages resulting from such improper use or sale.



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Low voltage versatile telephone transmission circuit  
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**NOTES**

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**NOTES**

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