TRANSMISSION INTERFACE WITH DTMF — TEA1046

This integrated circuit is a dual-tone multi-frequency (DTMF) generator and a speech transmission circuit on a single chip. It supplies frequency combinations in accordance with CCITT recommendations for use in push-button telephones. It can be operated with a single contact keyboard or via a direct interface with a microcomputer. I^2L technology allows digital and analogue functions to be implemented on the same chip.

The speech-transmission part incorporates microphone and telephone amplifiers, anti-sidetone and line adaption. The microphone inputs, suitable for different types of transducers, are symmetrical to allow long cable connections with good immunity against radio-frequency interferences.

The logic inputs contain an interface circuit to guarantee well defined states and on and off resistance of the keyboard contacts.

The circuit features:
- stabilized DTMF levels to be set externally
- wide operating range of line current and temperature
- no individual DTMF level adjustments required
- microcomputer compatible logic inputs
- gain setting for microphone and receiver amplifiers
- internally generated electronic muting
- low spreads on amplifier gains
- low number of external components

QUICK REFERENCE DATA

Line voltage	V_L	typ.	4.8	V
Line current	I_L		10 to 120	mA
Adjustable dynamic resistance	R_i		600 to 900	Ω
Microphone signal amplification	A_M	typ.	50	dB
Telephone signal amplification	A_T	typ.	20	dB
DTMF tone levels (adjustable)				
lower frequency	V_{LG}	max.	−6	dBm
higher frequency	V_{HG}	max.	−4	dBm
Operating temperature range	T_{amb}		−25 to + 85	°C

PACKAGE OUTLINES

TEA1046P : 24-lead DIL, plastic (SOT-101).
TEA1046D: 24-lead DIL, ceramic (SOT-149).

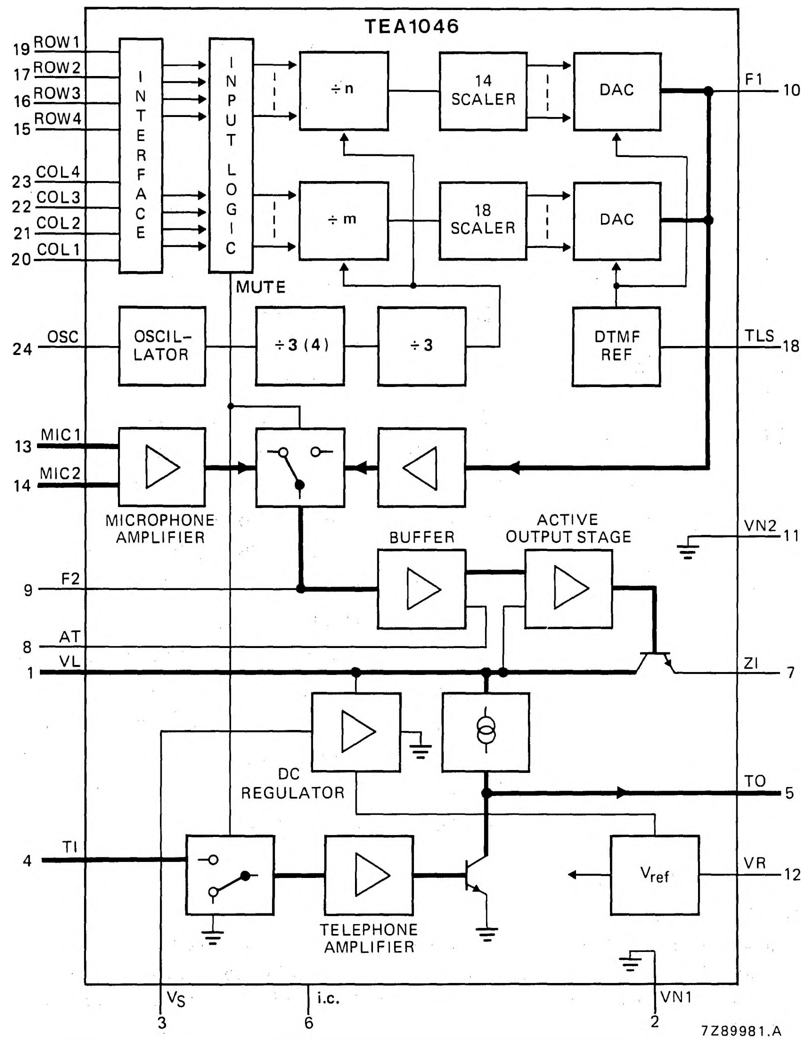


Fig. 1 Functional block diagram.

TRANSMISSION INTERFACE WITH DTMF — TEA1046

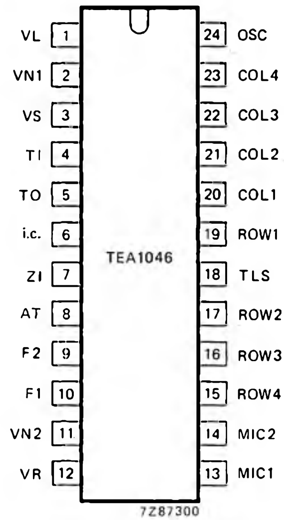


Fig. 2 Pinning diagram.

PINNING

1	VL	positive line-voltage
2	VN1	negative line-voltage
3	VS	voltage stabilizer filter
4	TI	telephone amplifier input
5	TO	telephone amplifier output
6	i.c.	internally connected
7	ZI	impedance setting input
8	AT	anti-sidetone output
9	F2	second filter
10	F1	first filter
11	VN2	negative line voltage
12	VR	reference voltage output
13	MIC1	microphone input (pos.)
14	MIC2	microphone input (neg.)
15	ROW4	row input 941 Hz/BCD input
16	ROW3	row input 852 Hz/BCD input
17	ROW2	row input 770 Hz/BCD input
18	TLS	DTMF level setting
19	ROW1	row input 697 Hz/BCD input
20	COL1	column input 1209 Hz/mute input
21	COL2	column input 1336 Hz/mute input
22	COL3	column input 1477 Hz/enable input
23	COL4	column input 1633 Hz/mute input
24	OSC	oscillator input

FUNCTIONAL DESCRIPTION

Voltage regulator (Fig. 3)

Different line lengths and feeding bridge resistances of the exchange cause a large line current range to supply this circuit. As all functions on this chip are working within a total current of 10 mA, the rest of the line current is shunted by the voltage regulator circuit. It regulates the voltage drop over the circuit on a nominal level of 4.8 V.

The capacitor connected to input VS provides a low-pass filter function to avoid influence of the audio signals on the line.

The static behaviour of the voltage regulator is expressed by:

$$V_L = V_o + (I_L - I_i)\, R13$$

where V_o = 4.8 V at T_a = 25 °C and R13 = 5 Ω, I_i = 10 mA.

The dynamic impedance of the regulator is equivalent to a resistor in series with a simulated inductor:

$$Zr(\omega) = R_{eq} + j\omega L_{eq}$$

where R_{eq} = R13 = 5 Ω
$L_{eq} \approx$ 5 H (C_{VS} = 68 μF).

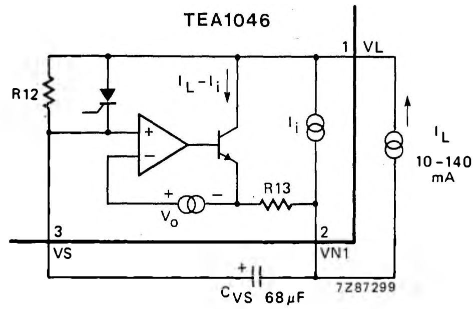


Fig. 3 Voltage regulator principle.

By connecting a resistor parallel to R12 the d.c. level (V_L) can be decreased. A resistor parallel C_{VS} increases the level (see Fig. 3). All this with respect to limited values. The shunt regulator contains a thyristor which short-circuits R12 for a short period during the switch-on time. This reduces the over-shoot voltage to only 1 V above the level set by the regulator.

Active output stage

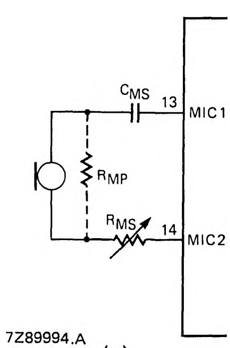
The amplifier consists of a voltage to current converter with a class-A output stage. Because of the feedback from the line to the input the circuit acts as a dynamic resistance (R_a). This resistance can be adjusted by the external resistor R_{ZI} and the value can be found by:

$$R_a = 8.93 \times R_{ZI} \ (\Omega)$$

The total dynamic resistance R_i equals R_a parallel with the resistance R_P of all other circuits parts, which value is approximately 7 kΩ.
With $R_{ZI} = 75\ \Omega$, $R_a = 670\ \Omega$ and $R_i = 610\ \Omega$.
For $R_{ZI} = 120\ \Omega$, $R_a = 1070\ \Omega$ and $R_i = 900\ \Omega$.

Microphone amplifier

Pins 13 and 14 respectively are the non-inverting and inverting inputs for the microphone. The purely symmetrical inputs are suitable for low ohmic dynamic or magnetic capsules. The input impedance equals 4 kΩ. The voltage amplification from microphone input to pin 1 (VL) is 50 dB and if a lower gain is required the attenuation for a series resistor R_{MS} will be:



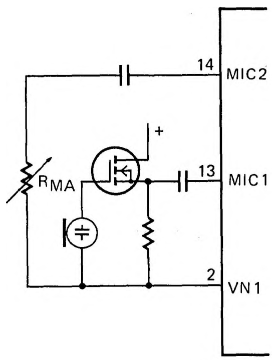
(a)

$$\frac{A_M(R_{MS} \neq 0)}{A_M(R_{MS} = 0)} = \frac{4}{4 + R_{MS}} \qquad (R_{MS} \text{ in k}\Omega)$$

$$A_M = \left| \frac{V_L}{V_M} \right|$$

Fig. 4 Symmetrical microphone connection. Resistor R_{MP} may be used to lower the microphone termination resistance.

The microphone amplifier also has an excellent behaviour for connection of an electret microphone with built in FET-source follower. In this condition pin 14 is decoupled for a.c. and the amplifier is driven at pin 13. The input impedance in this asymmetrical mode is 22 kΩ. If attenuation of the amplification is required the value of R_{MA} is given by:



(b)

$$\frac{A_M(R_{MA} \neq 0)}{A_M(R_{MA} = 0)} = \frac{22 + R_{MA}}{22 + 11R_{MA}} \quad (R_{MA} \text{ in k}\Omega)$$

$$A_M = \left| \frac{V_L}{V_{MIC1}} \right|$$

Fig. 5 Electret microphone circuit.

Telephone amplifier and anti-sidetone network

This amplifier is a non-inverting fixed feedback amplifier with a class-A output stage. The gain is fixed and measures 20 dB from pin 4 (TI) to pin 5 (TO). The output is intended to drive capsules Z_T of nom. 350 Ω. For Z_T smaller than 350 Ω the maximum output voltage swing is determined by the bias current of 3.5 mA and Z_T. For Z_T greater than 350 Ω the maximum voltage swing is determined internally. The received line signal is attenuated by the anti-sidetone network and can be adjusted by R_{AT}. The amplification from the line to the telephone output is given by:

$$A_T = 10 \frac{R_{AT}}{R_{AT} + Z_S} \times \frac{Z_T}{Z_T + R_O} \quad \text{(see Fig. 14)}$$

Z_S is the impedance of the anti-sidetone network
Z_T is the capsule impedance
R_O is the amplifier output resistance

Optimum side-tone suppression is obtained as Z_S (R_{A1}, R_{A2} and C_A) equals

$$Z_S = K \frac{Z_L \times R_i}{Z_L + R_i}$$

Z_L = line terminating impedance
R_i = output stage impedance // passive circuit impedance
K = 237

In the application of Fig. 14 the network is optimized for 5 km of twisted copper wire (ϕ0.5 mm) cable with a d.c. resistance of 176 Ω/km. The side-tone suppression in the range from 0 — 10 km is at least 10 dB compared with the case when no compensation is applied.

Keyboard inputs

Inputs for the logic control are compatible with different types of keyboard. Using a keyboard, tone combinations are generated:

- by connecting one of row inputs to one of the column inputs by means of a single switch of the matrix.
- or by applying a dual contact keyboard having its common row contact tied to ground and the common column contact tied to VR.

An anti-bounce circuit eliminates the switch bounce for up to 2 ms. Two key roll-over is provided by blocking other inputs as soon as one key is pressed. Single tones can be generated if the column input is connected to VR or the row input to ground. The inputs for the keyboard connections can be used for direct connection to a microcomputer. If the column inputs are interconnected and made HIGH (= VR) the row inputs are changed to another mode, allowing the circuit to be driven by 4-bit data plus an enable signal. In this mode, it is also possible to connect a separate mute enable signal on inputs COL1, 2 and 4 and a tone enable input on COL3.

Truth table microcomputer mode

row				column		tones Hz	symbol	mute
1	2	3	4	1, 2, 4	3			
H	H	H	H	L	L	–	–	off
X	X	X	X	H	L	–	–	on
H	H	H	H	H	H	697/1209	1	on
H	H	H	L	H	H	697/1336	2	on
H	H	L	H	H	H	697/1477	3	on
H	H	L	L	H	H	697/1633	A	on
H	L	H	H	H	H	770/1209	4	on
H	L	H	L	H	H	770/1336	5	on
H	L	L	H	H	H	770/1477	6	on
H	L	L	L	H	H	770/1633	B	on
L	H	H	H	H	H	852/1209	7	on
L	H	H	L	H	H	852/1336	8	on
L	H	L	H	H	H	852/1477	9	on
L	H	L	L	H	H	852/1633	C	on
L	L	H	H	H	H	941/1209	*	on
L	L	H	L	H	H	941/1336	0	on
L	L	L	H	H	H	941/1477	#	on
L	L	L	L	H	H	941/1633	D	on

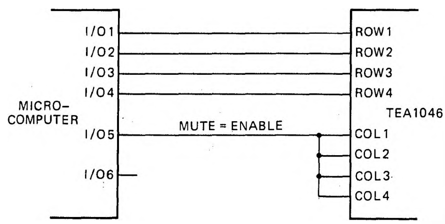
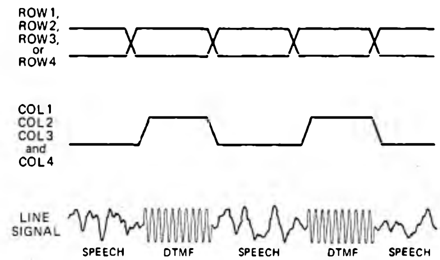


Fig. 6 Microcomputer mode.
All column inputs interconnected.



(a)

Fig. 7 Tone/speech waveform in circuit diagram Fig. 6.

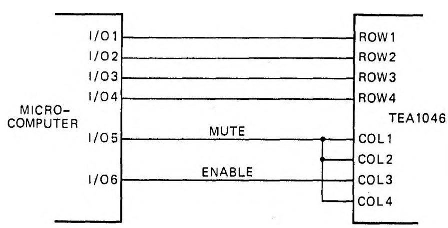
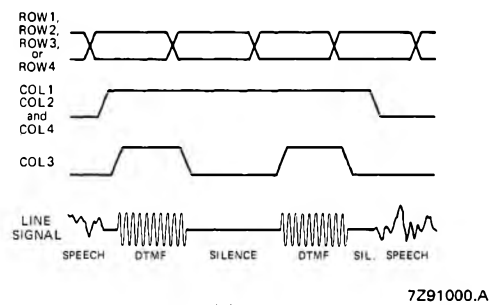


Fig. 8 Microcomputer mode.
Column inputs COL1, 2 and 3 interconnected.



(b)

Fig. 9 Tone/speech waveform in circuit diagram Fig. 8.

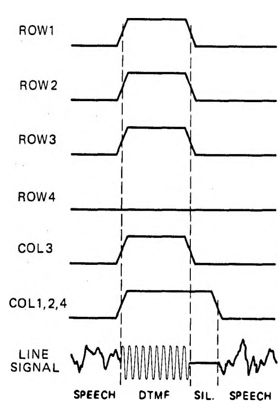


Fig. 10 Waveform tones 697/1336 Hz (dialling number 2).

Dial tone generator

The crystal oscillator frequency is twelve or nine times the clock frequency i.e. 4.782720 MHz or 3.579 545MHz (mask option). The CCITT recommends that the tones should be within 1.5% of the specified frequencies. Many authorities however require a closer tolerance. The application using a crystal of 4.78 MHz gives a maximum dividing error of 0.11% whilst for an application with a 3.58 MHz crystal the error is 0.25% maximum.

The output from the dividers for the higher and the lower frequency tones are symmetrical square-wave pulses which contain considerable odd-numbered harmonics. The lower order odd numbered harmonics (11th and less) are eliminated by synthesising the tone frequencies as crude stepped sinewave approximations. Each half cycle of the tone waveform comprises seven discrete amplitudes for the higher frequency tone. Each amplitude increment is generated by switching on and off an individual current source for the duration of each step of the sinewave. The frequency of the tones is varied by changing the duration of each step. This circuit allows the connecting of two low-pass first order filters to pins 9 and 10 if CEPT 203 recommendations have to be achieved.

The second filter is also used for filtering the microphone signal. If lower requirements for the distortion can be applied the filter at pin 10 can be deleted. In that case the filter at pin 9 must have a lower cut-off frequency (1800 Hz) to achieve a correct pre-emphasis since the roll-off of the filters is compensated internally.

RATINGS

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

Supply current	I_P	max.	150 mA
Surge current ($t_p < 250\ \mu s$)	I_S	max.	850 mA
Operating ambient temperature range	T_{amb}	−25 to +85	°C
Storage temperature range	T_{stg}	−55 to +125	°C
Junction temperature	T_j	max.	150 °C

CHARACTERISTICS

T_{amb} = 25 °C; I_L = 15 mA, unless otherwise specified. See also Fig. 11.

description	symbol	min.	typ.	max.	unit
Supply					
Line voltage d.c.					
I_L = 15 mA	V_L	4.5	4.8	5.1	V
I_L = 50 mA	V_L	4.7	5.0	5.3	V
I_L = 100 mA	V_L	5.0	5.4	6.5	V
Temperature coefficient	TC	–	−8	–	mV/K
Line current range	I_L	10	–	120	mA
Stabilized voltage (pin 3)					
I_L = 15 mA	V_S	–	3.3	–	V
I_L = 100 mA	V_S	–	3.8	–	V
Reference voltage (pin 12)	V_R	–	1.0	–	V

description	symbol	min.	typ.	max.	unit
Microphone					
Input resistance (symmetrical)	R_i 13-14	–	4	–	kΩ
Input resistance (asymmetrical)	R_i 13	–	22	–	kΩ
Voltage amplification f = 800 Hz; R_L = 600 Ω	A_M	48	50	52	dB
Temperature coefficient I_L = 50 mA; T_{amb} = –5 to +45 °C	TC		t.b.f.		dB
Common mode rejection ratio	CMRR	60	–	–	dB
Distortion at V_L = 3 dBm	dt	–	2	–	%
Noise output voltage Z_L = 600 Ω; psophometrically weighted (P53 curve)	V_{NO}	–	–70	–	dBmp
Amplification reduction during dialling	ΔA_M	–	70	–	dB
Anti-sidetone					
Voltage amplification, microphone to anti-sidetone output (R_{AT} = 3.9 kΩ)	A_{AT}	–	25.8	–	dB
Transmitter output stage					
Dynamic resistance setting range	R_i	600	–	900	Ω
Variation over line current R_i = 600 Ω	ΔZ_o	–	100	–	Ω
Balance return loss from 300 up to 3400 Hz at 600 Ω (R_{Zl} = 75 Ω, C_L = 10 nF)	BRL	20	–	–	dB
at 900 Ω (R_{Zl} = 120 Ω, C_L = 30 nF)	BRL	20	–	–	dB
Telephone amplifier					
Voltage amplification R_T = 350 Ω	A_T	18	20	22	dB
Amplification variation f = 300 to 3400 Hz	$\Delta A_T/f$	–	0	–	dB
Amplification variation T = –5 to +45 °C	$\Delta A_T/T$	–	0	–	dB
Output voltage swing (d_t = 10%)	$V_{o(p-p)}$	–	1300	–	mV
Output impedance	Z_o	–	5	10	Ω
Input impedance	Z_i	–	100	–	kΩ
Output distortion level < –7 dBV	d_o	–	2	–	%
Output noise voltage psophometrically weighted (P53 curve)	$V_{no\ (rms)}$	–	–	500	μV
Bias current	I_M	3	3.5	4	mA

CHARACTERISTICS (continued)

description	symbol	min.	typ.	max.	unit
DTMF generator					
Tone frequencies					
low tones (row inputs)		697,	770,	852, 941	Hz
high tones (column inputs)		1209,	1336,	1477, 1633	Hz
Dividing error					
crystal frequency = 4.78 MHz	Δf_d	−0.04	–	+0.11	%
crystal frequency = 3.58 MHz	Δf_d	−0.25	–	−0.05	%
Tone output level					
$I_L > 10$ mA					
lower tones	V_{LG}	–	−11	–	dBm
higher tones	V_{HG}	–	−9	–	dBm
Tone output level					
$I_L > 12$ mA					
lower tones	V_{LG}	−11	–	−6	dBm
higher tones	V_{HG}	−9	–	−4	dBm
Tolerance on output level					
over temp. and current range	ΔV_o	−2	–	2	dB
Pre-emphasis higher tones					
over temp. and current range	ΔV_{HG}	1.3	2	2.7	dB
Tone delay					
after key actuation	t_d	–	10	–	μs
Switch delay time speech/mute					
after key release	t_d	–	10	–	μs
Switch bounce elimination	t_{sb}	–	2	–	ms
Keyboard inputs					
Contact off resistance	R_{Koff}	250	–	–	kΩ
Contact on resistance	R_{Kon}	–	–	10	kΩ
Lower frequency inputs (ROW1, 2, 3, 4)					
voltage LOW	V_{IL}	–	0.7	t.b.f.	V
voltage HIGH	V_{IH}	t.b.f.	1.7	–	V
current (d.c.) at V_{IL}	I_{IL}	–	20	1000	μA
current (d.c.) at V_{IH}	I_{IH}	–	–	–	μA
Higher frequency inputs (COL1, 2, 3, 4)					
voltage LOW	V_{IL}	–	0.3	t.b.f.	V
voltage HIGH	V_{IH}	t.b.f.	1.0	–	V
current (d.c.) at V_{IL}	I_{IL}	–	–	–	μA
current (d.c.) at V_{IH}	I_{IH}	–	20	1000	μA

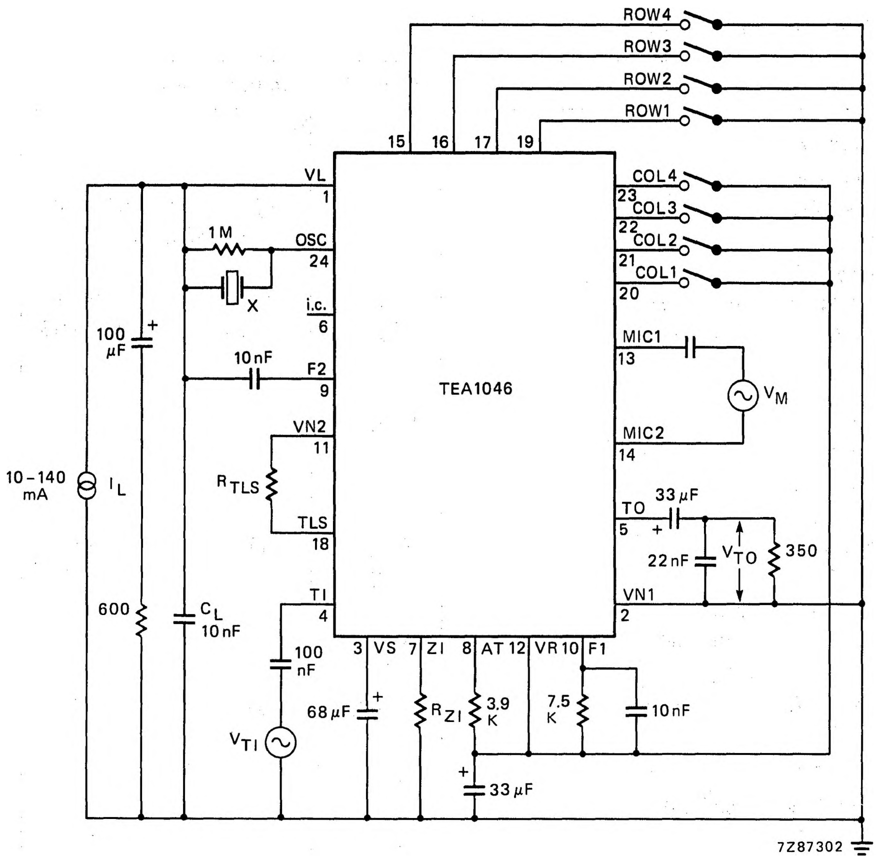


Fig. 11 Test circuit for measuring amplifier voltage gains and frequencies and levels of DTMF generator. X = 3.58 or 4.78 MHz.

$$A_M = \left| \frac{V_L}{V_M} \right| \quad (V_{TI} = 0) \qquad A_T = \left| \frac{V_{TO}}{V_{TI}} \right| \quad (V_M = 0) \qquad A_{AT} = \left| \frac{V_{AT}}{V_M} \right| \quad (V_{TI} = 0)$$

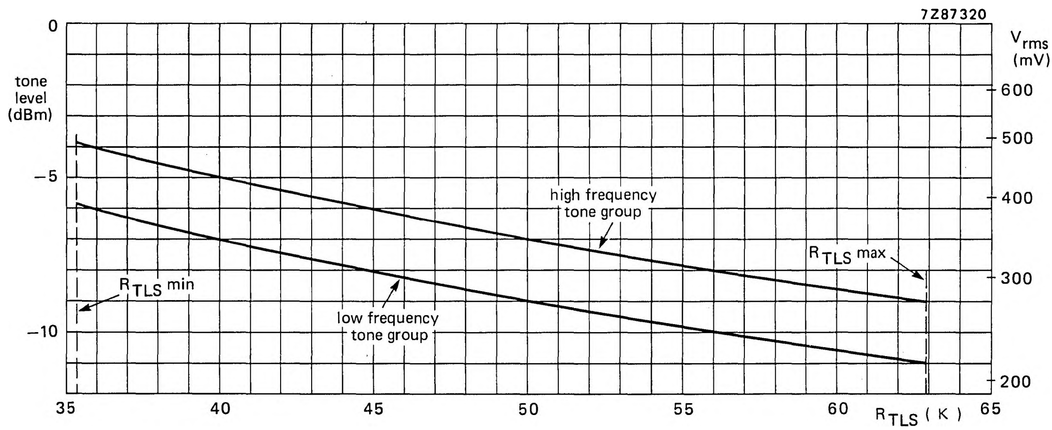
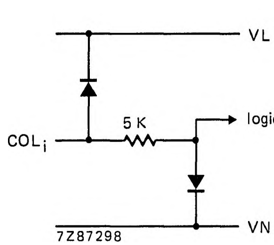


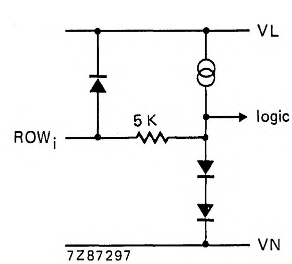
Fig. 12 DTMF level selection. The curve is valid for a dynamic impedance of 600 Ω (R_{ZI} = 75 Ω).

Some values:

LOW dBm	HIGH dBm	R_{TLS} kΩ
−6	−4	35.2
−8	−6	44.8
−11	−9	62.6



(a)



(b)

Fig. 13 Configuration inputs. (a) ROW1, 2, 3 and 4. (b) COL1, 2, 3 and 4.

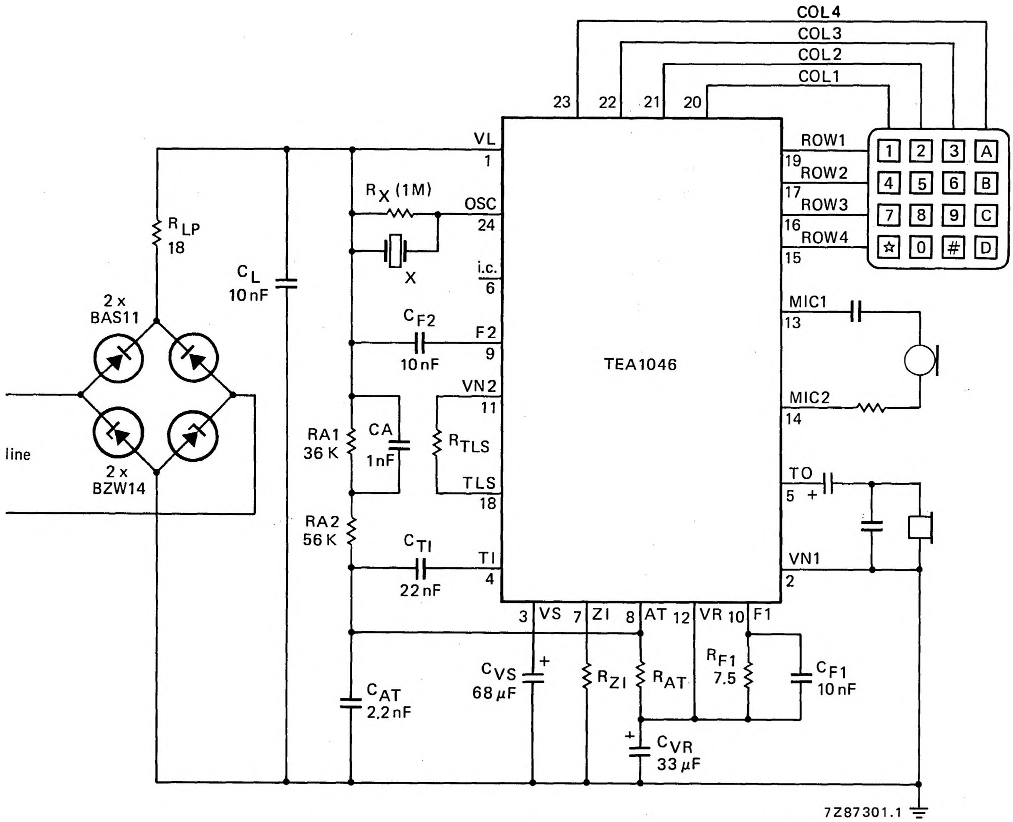


Fig. 14 Application diagram TEA1046 using dynamic transducers, R_{MS}, R_{AT}, R_{ZI} and R_{TLS} determined by transducers and system requirements.