PBL 3786/02 Voice-switched Speakerphone Circuit

Description

The PBL 3786/02 contains all the necessary circuitry, amplifiers, detectors, comparators and control functions to implement a high-performance, voice-switched, loudspeaking, "hands-free" telephone. The gain dynamics (attenuation between channels) is continuously adjustable (0 - 50 dB) via a separate pin. A background noise detector in the transmit channel reduces the influence of continuous noise signals.

The PBL 3786/02 is designed for telephone line powered applications. The circuit contains a transformerless power amplifier with patented current circuitry that eliminates the need for inductors. Automatic volume attenuation extends the operating range at low line voltages.

Key features

- Adjustable gain dynamics (0 - 50 dB).
- Direct telephone-line powered (patented).
- Low power consumption, 2.2 mA at 3.2 V (typical).
- Direct drive of 25 - 50 ohm loudspeaker.
- 22-pin dual in-line plastic encapsulation.
- Background noise compensation with hold.
- Low noise
- Fully accessible in- and out-puts of the channel input amplifiers.
- Minimum of external components.

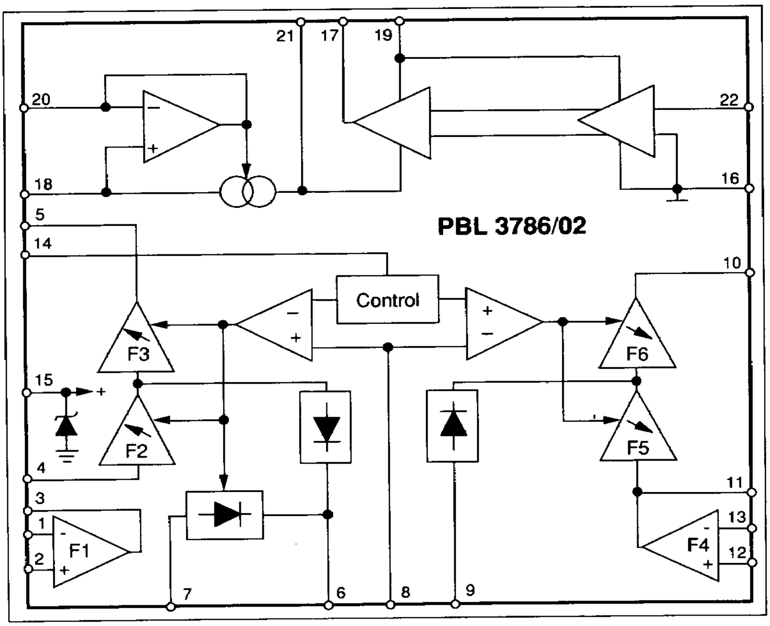
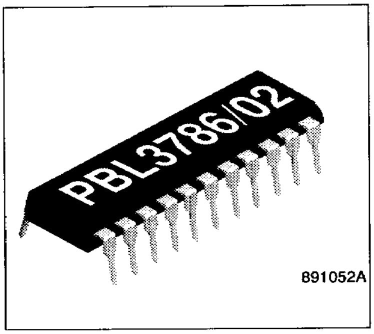


Figure 1. Block diagram.



Maximum ratings

Parameter	Symbol	Min	Max	Unit
Speech switch supply current	I_D		10	mA
Speaker amplifier supply current	I_{+L}		200	mA
Operating temperature		0	70	°C
Storage Temperature	T_{Stg}	-55	125	°C

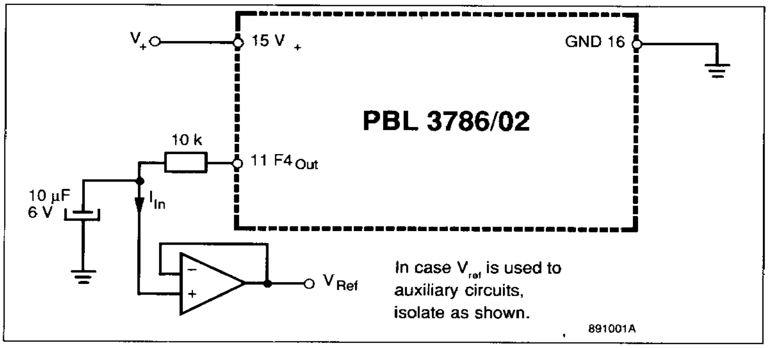


Figure 2.

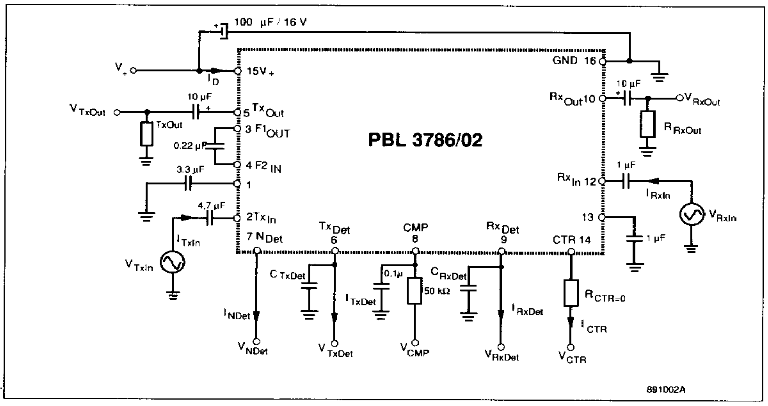


Figure 3.

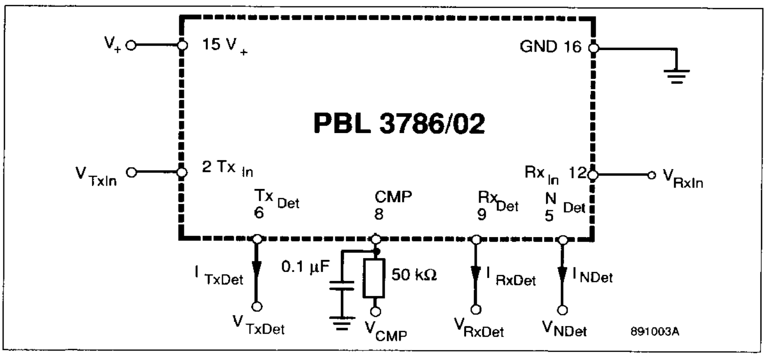


Figure 4.

Electrical characteristics

V_+ = 3.4 V, f = 1 kHz, T = 25°C, C_{TxDet} = 0, and C_{RxDet} = 0 unless otherwise noted.

Parameter	Ref fig	Conditions	Min	Typ	Max	Unit
Speech control section						
Terminal voltage, V_+	3		3.2			V
Regulator voltage, V_+	3			3.3		V
Internal reference voltage, V_{Ref}	2			1.90		V
Supply current I_d	3	V_+ = 3.2 V		1.15	1.70	mA
Supply current at power down, I_D	3	V_{CTR} < 0.8 V, V_+ = 3.2 V		0.65	1.30	mA
Frequency response for all amplifiers	3	200 - 3400 Hz, Relative 1 kHz	-1		1	dB
Transmit gain, $20^{\cdot 10} \cdot \log(V_{Txout}/V_{Txin})$	3	$V_{CMP} = V_{Ref} + 0.1$ V	41.5	44		dB
		$V_{CMP} = V_{Ref} - 0.1$ V		-6	-3.5	dB
Receive gain, $20^{\cdot 10} \cdot \log(V_{Rxout}/V_{Rxin})$	3	$V_{CMP} = V_{Ref} - 0.1$ V	26.5	29		dB
		$V_{CMP} = V_{Ref} + 0.1$ V		-21	-18.5	dB
Max transmit detector gain, $20^{\cdot 10} \cdot \log(V_{Txdet}/V_{Txin})$	3	$v_{TxDet} < 200\ mV_p$				
		$V_{CMP} = V_{Ref} + 0.1$ V		67.5		dB
		$V_{CMP} = V_{Ref} - 0.1$ V	37	42.5		dB
Max receive detector gain, $20^{\cdot 10} \cdot \log(V_{Rxdet}/V_{Rxin})$	3	$v_{TxDet} < 200\ mV_p$				
		$V_{CMP} = V_{Ref} - 0.1$ V		53		dB
		$V_{CMP} = V_{Ref} + 0.1$ V	22.5	28		dB
Noise rectifier gain, (note 1)	3	$V_{CMP} = V_{Ref} + 0.1$ V, C_{Txdet}=1µF		6.0		dB
		$V_{CMP} = V_{Ref} - 0.1$ V		Hold		dB
Tx_{In} impedance, V_{TxIn}/I_{TxIn}	3		80	100	120	Kohm
Rx_{In} impedance, V_{RxIn}/I_{RxIn}	3		80	100	120	Kohm
Tx_{Out} ac, Load impedance	3		25			Kohm
Rx_{Out} ac, Load impedance	3		25			Kohm
Dynamics		2% distortion, $R_{Txout}=R_{Rxout}$=25k				
Transmit output, v_{TxOut}	3	V_+ = 3.5 V		500		mV_p
		V_+ = 2.9 V		250		mV_p
Receive output, v_{RxOut}	3	V_+ = 3.5 V		500		mV_p
		V_+ = 2.9 V		250		mV_p
Noise, n						
Transmit output, v_{TxOut}	3	$V_{CMP} = V_{Ref} + 0.1$ V, v_{TxIn} = 0 V		-75		dBpsof
Receive output, v_{RxOut}	3	$V_{CMP} = V_{Ref} - 0.1$ V, v_{RxIn} = 0 V		-80		dBA
Tx_{In} input impedance, v_{TxIn} / i_{TxIn}	3		2.5	3.2	3.9	kohm
Rx_{In} input impedance, v_{RxIn} / i_{RxIn}	3		8	10	12	kohm
Tx_{Det} source current, I_{RxDet}	4	$V_{TxIn} = V_{Ref} - 0.1$ V, $V_{CMP} = V_{Ref} + 0.1$ V, $V_{TxDet} = V_{Ref}$		2.5	6.0	mA
Rx_{Det} sink current, I_{RxDet}	4	$V_{RxIn} = V_{Ref} + 0.1$ V, $V_{CMP} = V_{Ref} + 0.1$ V, $V_{RxDet} = V_{Ref}$		-6.0	-2.5	mA
Tx_{Det} sink current, I_{TxDet}	3	$V_{CMP} = V_{Ref} + 0.1$ V, V_{TxIn} = 0, $V_{TxDet} = V_{Ref}$ + 0.7 V	-30			µA
Rx_{Det} source current, I_{RxDet}	3	$V_{CMP} = V_{Ref} - 0.1$ V, V_{RxIn} = 0, $V_{RxDet} = V_{Ref}$ - 0.7 V			30	µA
Tx_{Det} swing relative to V_{Ref}, V_{TxDet}	4	$V_{CMP} = V_{Ref} + 0.1$ V, $V_{TxIN} = V_{Ref} - 0.1$ V	(note 2)	+0.7		V
Rx_{Det} swing relative to V_{Ref}, V_{RxDet}	4	$V_{CMP} = V_{Ref} - 0.1$ V, $V_{RxIN} = V_{Ref} + 0.1$ V	(note 2)	-0.7		V
N_{Det} source current (fast charge), I_{NDet}	4	V_+ = 2.7 V, $V_{CMP} = V_{Ref} + 0.1$ V, $V_{NDET} = V_{Ref} - 0.45$ V, V_{Txin}=0	1.5	4.5		mA
N_{Det} sink current, I_{NDet}	4	$V_{CMP} = V_{Ref} + 0.1$ V, $V_{NDet} = V_{Ref}$, $V_{TxIN} = V_{Ref} - 0.1$ V	-75	-35	-15	µA

Parameter	Ref fig	Conditions	Min	Typ	Max	Unit
N_{Det} leakage current (hold), I_{NDet}	3	$V_{CMP} = V_{Ref}$ - 0.1 V, $V_{NDet} = V_{Ref}, V_{Txin}$=0		-100		nA
N_{Det} swing relative to V_{Ref}, V_{NDet}	4	$V_{CMP} = V_{Ref}$ + 0.1 V, $V_{TxIN} = V_{Ref}$ - 0.1 V		-0.45		V
CMP (comparator) sensitivity, transmit (Tx) mode to receive (Rx) mode or vice versa	3 13	Tx mode = max Tx gain, Rx mode = max Rx gain		100		mV
CTR voltage for full duplex, V_{CTR}	3	$V_{CMP} = V_{Ref} \pm 0.35$ V		V_+		V
CTR sink current for mute, I_{CTR}	3	$V_{CMP} = V_{Ref} \pm 0.35$ V, R_{CTR}=1k	50		60	µA
CTR voltage for cutoff, V_{CTR}	3			0.8		V
Loudspeaker amplifier						
Operating voltage, V_{+L}	5		2.5		12	V
Current consumption (no signal), I_{+L}	5	V_{+L} = 3.0 V		1	2	mA
	5	V_{+L} = 5.0 V		1.5		mA
	5	V_{+L} = 12.0 V		8	12	mA
	20	R_E = 1.5 K, + Line = 3.0 V, V_{RDC} = 0.35 V		1.5		mA
	20	R_E = 1.5 K, + Line = 12.0 V, V_{RDC} = 5.0 V		8		mA
Current consumption (output swing at 5% dist.)	5	V_{+L} = 3.0 V		7		mA
	5	V_{+L} = 5.0 V		13		mA
	5	V_{+L} = 12.0 V		30		mA
Swing at 5% dist., V_{Out}	5	V_{+L} = 3.0 V	0.6	0.85		V_p
	5	V_{+L} = 5.0 V	1.5	1.7		V_p
	5	V_{+L} =12.0 V	3.6	4.5		V_p
Gain,	5	V_{+L} =5.0 V	34.5	36.5	38.5	dB

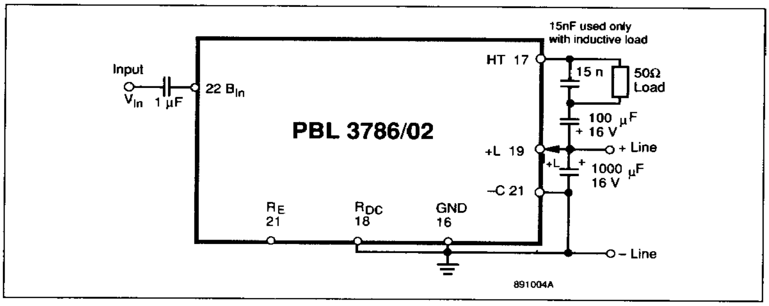


Figure 5.

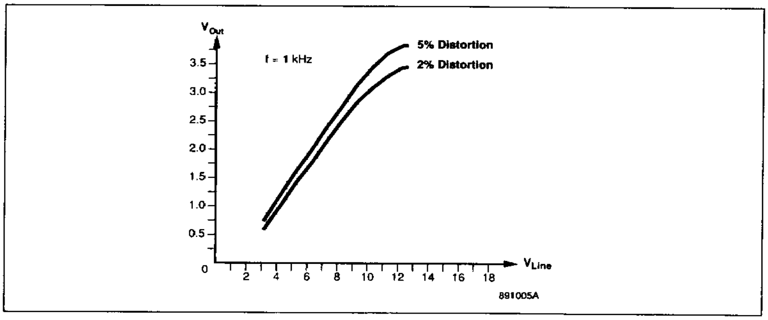


Figure 6. Power amplifier output distorsion. Line voltage versus output swing

Parameter	Ref fig	Conditions	Min	Typ	Max	Unit
Frequency response	5	200 to 3400 Hz, relative 1kHz, V_{+L} = 5.0 V	-1		1	dB
Amplifier power efficiency (5% dist), n	5	V_{+L} = 3.0 to 12.0 V, n = 100 • P_{Load}/P_{Supply}		40		%
Input impedance pin 1	5		24	30	36	kohm

Notes

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

   V_{NDet} = voltage at noise detector output
   V_{Ref} = reference voltage (about 1.9 V)
   V_{TxDet} = voltage a transmit detector output
   V_{TxDet} = voltage at transmit detector output at the point when the voltage at the noise detector starts moving when a signal at transmit channel input is gradually increased (threshold, typical value 50 mV)

2. Depends on V_+. Channels are tracking.

Pin Descriptions

Refer to figure 9. (22-pin dual-in-line package)

Pin	Name	Function
1	$-Tx_{In}$	Transmit channel negative input.Input impedance 3.16 kohm.
2	$+Tx_{In}$	Transmit channel positive input. Input impedance 100 kohm.
3	$F1_{Out}$	Output of the first amplifier in the transmit channel.
4	$F2_{In}$	Output of the second amplifier in the transmit channel.
5	Tx_{OUT}	Transmit channel output. Min. ac.load impedance 25 kohm.
6	Tx_{Det}	Transmit signal detector output. Goes positive in reference to the internal reference voltage, approximately 1.9 V, when signal is present at Tx_{In}.
7	N_{Det}	Background noise detector output.Goes negative when a noise of a longer duration appears at Tx_{In}.
8	CMP	Comparator input. External resistance to this input should be 50 kohm. Summing point to the different detector outputs.
9	Rx_{Det}	Receive signal detector output. Goes negative in reference to the internal reference voltage, approximately 1.9 V, when signal is present at Rx_{In}.
10	Rx_{OUT}	Receive channel output. Min. ac.load impedance 25 kohm.
11	$F1_{Out}$	Output of the first and input of the second amplifiers in the receive channel.Sense point for the internal reference voltage.
12	$+Rx_{In}$	Receive channel positive input. Input impedance 10 kohm.
13	$-Tx_{In}$	Transmit channel negative input.Input impedance 3.16 kohm.
14	CTR	Control input for gain dynamics, mute, and power down.
15	V_+	Supply for the speech-switching circuitry. A shunt regulator sets the voltage to approximately 3.2 V at 1 mA.
16	GND	Ground for the whole system (-line).
17	HT	Loudspeaker power amplifier output.
18 20 21	R_{DC} R_E -C	These inputs allow the supply to the loudspeaker amplifier to be used in two different ways, described in the text.
19	+L	Positive supply for the loudspeaker amplifier.
22	B_{In}	Signal input for the loudspeaker amplifier.Input impedance 30 kohm.

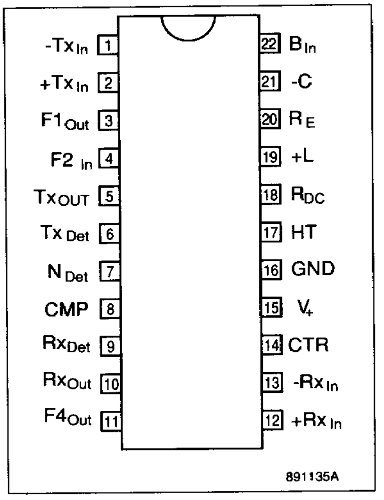


Figure 7. Pin configuration.

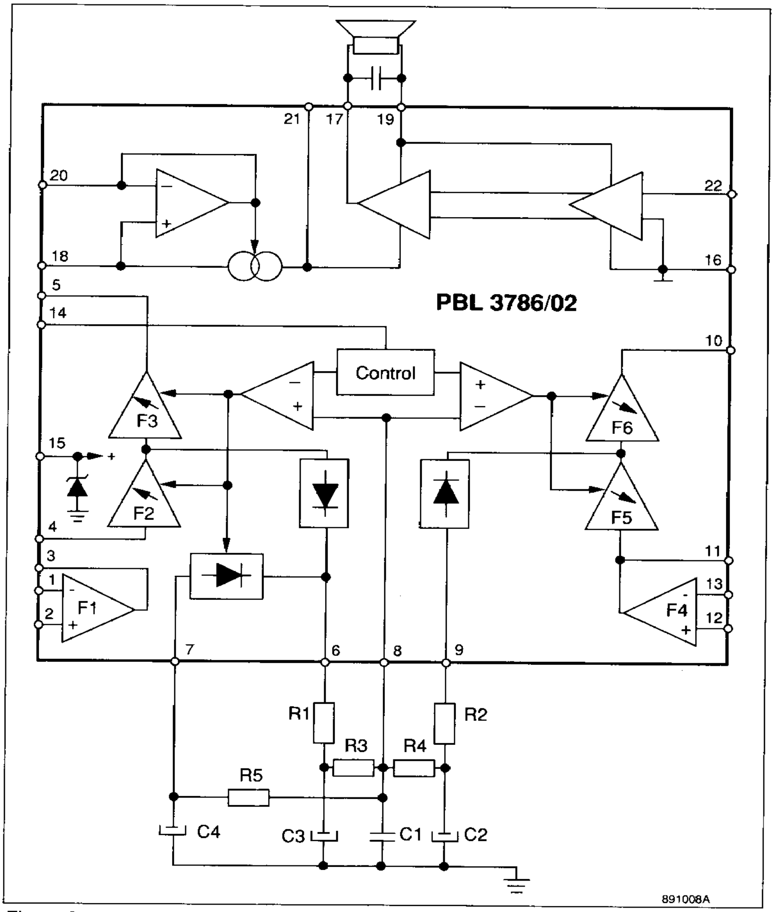


Figure 8.

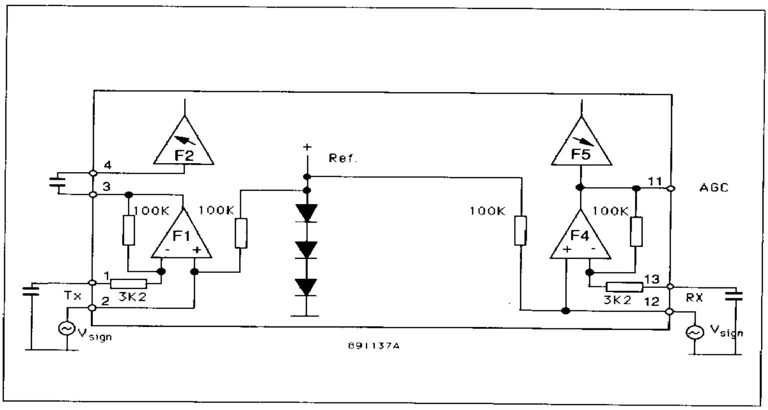


Figure 9.Receive and transmitt channel input arrangement.

Functional description

Speech control section

Transmit and receive channels

The transmit and receive channels consist of three amplifying stages each, F1, F2, F3 and F4, F5, F6. The inputs and outputs of the amplifiers must be AC-coupled.

F1 and F4 are fixed-gain amplifiers of 30 dB respectively 20 dB, while the rest are of controlled-gain type.

The gain of F2 and F3, as well as F5 and F6, is controlled by comparators. The comparators receive their information partly from the summing point of the transmit, receive, and noise detectors; the CMP input; and partly through the control input, CTR, which controls the gain dynamics. Amplifiers F2 and F3 have the maximum gain when the transmit channel is fully open, consequently F5 and F6 will have minimum gain. When F5 and F6 have maximum gain, the receive channel is fully open and the amplifiers F2 and F3 are at minimum gain. See figure 8.

The positive input on each channel has a high input impedance. It gives a good gain precission and noise performance with low signal source impedance. The negative input should be connected to ground with a capacitor. The differential input on the Tx channel can be used to suppress unwanted signals in the supply (See figure 9). Also see appliction 1.

The output of the send channel input amplifier, F_1, is accessible in order to apply filtering in the send channel.

The output of the receive channel input amplifier, F_4, is accessible to give a signal for possible AGC system. See figure 11.

Signal detectors and comparators

The signal detectors sense and rectify the signals to opposite polarities, referenced to the internal reference voltage of approximately 1.9 V. The voltage at Rx_{Det} will go negative and at Tx_{Det} positive, in the presence of signal at the respective channel input.

In the idle (no signal) position, the voltage at Rx_{Det}, Tx_{Det}, and consequently CMP is equal to the internal reference voltage (approximately 1.9 V).

Signal at Tx_{In} will result in an increased level at Tx_{Det} and hence also at CMP. The comparators will now increase the gain in the transmit channel and

Figure 10. Transmitt chznnel input amplifier used to suppress ripple in the mic. supply.
R1 = R2 ≈ 3k2
R3 = R4 ≈ 100k
R5 = R6

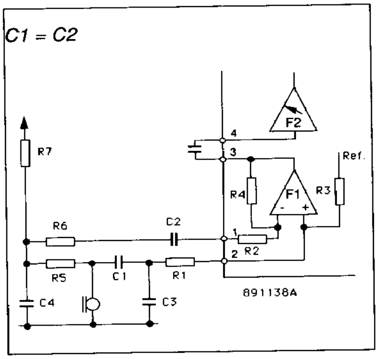


Figure 10.

Figure 11.Receive channel with AGC signal arrangement.

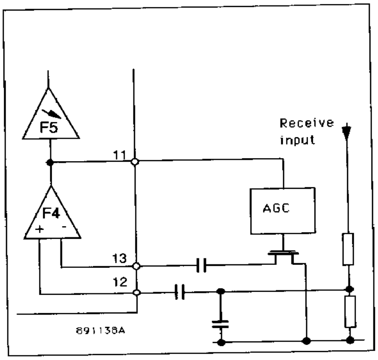


Figure 11.

Figure 12. Transmit- and receive-channel rectifier characteristics.

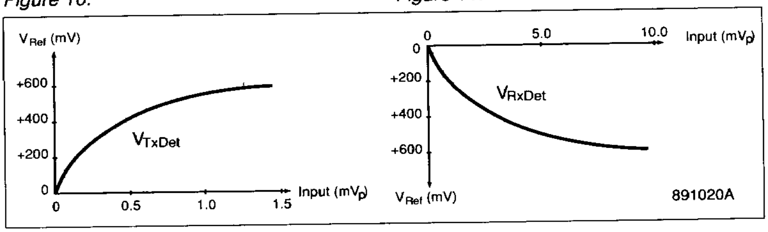


Figure 13. Transmit and receive output dynamics.

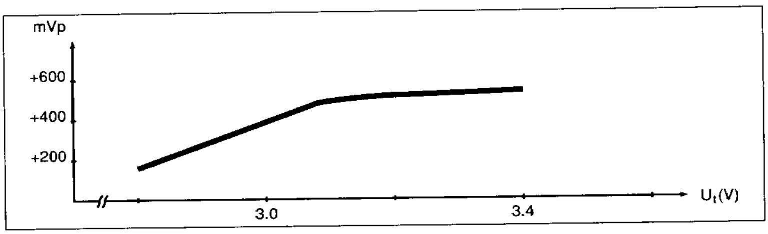


Figure 14. Relationship between the voltage levels at Tx_{In}, Tx_{Det} and NDET.

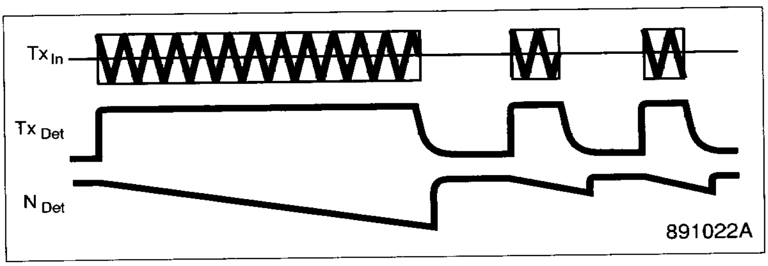
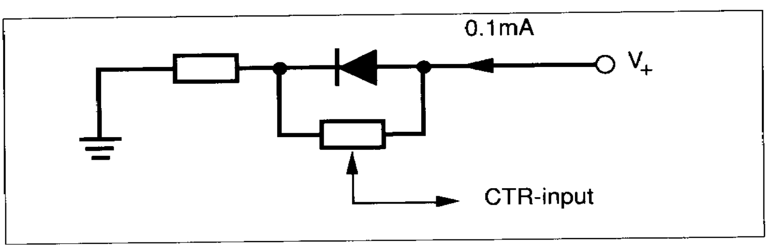


Figure 15. The control input voltage,from full duplex to full speech control.



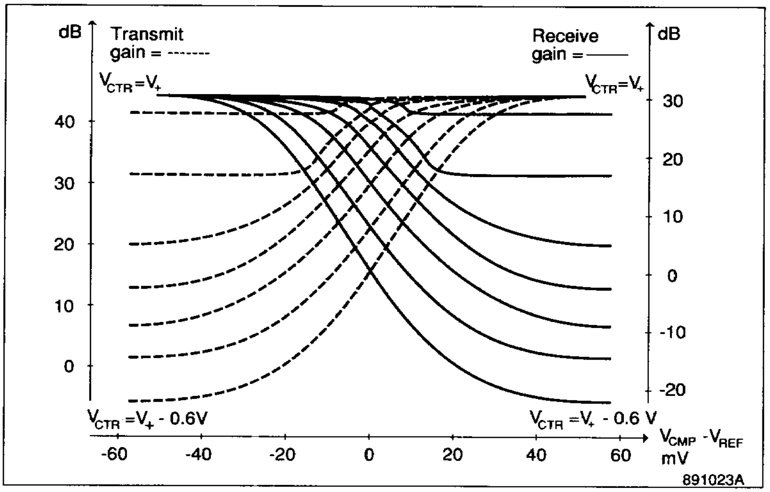


Figure 16. Transmit and receive gain as a function of V_{CMP} and V_{Ref}

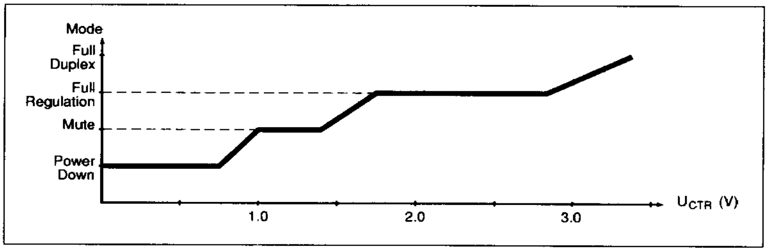


Figure 17. Gain dynamics control at V_+ = 3.4 V.

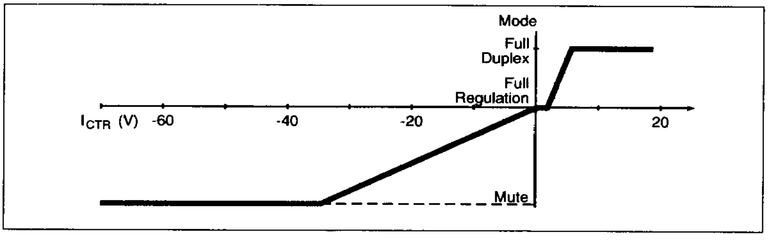


Figure 18. CONTROL input nodes.

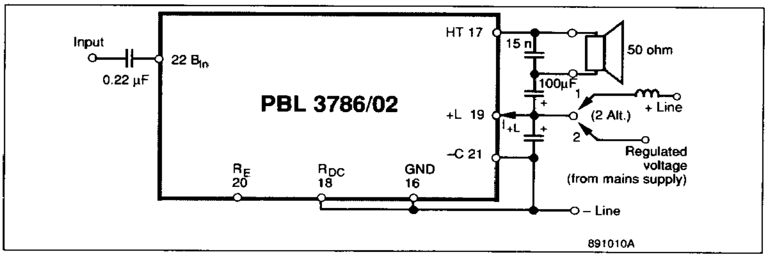


Figure 19. Power supply option with inductor or external power source.

decrease it in the receiving channel. Signal at Rx_{In} will affect the levels and gain setting in the opposite way. Maximum input current to CMP is 1 µA.

The voltages Rx_{Det} and Tx_{Det} are used to control the gain setting in the respective channel through comparators, where the CMP input is the summing point. The attack and decay times for signals at Rx_{Det} and Tx_{Det} are controlled by individual external RC networks. The attack time in the R_x channel is set by the capacitor, C2, and either by the maximum current capability of the detector output, or by the external resistor, R2, in series with the detector output.The RC network in the T_x channel R1,C3. See figure 8.

The decay time transmit and receive channels are set by C3 and C2 respectively, and by an internal resistor of 100 kohm, in parallel with the external resistors R1,R3 and R2,R4, respectively, connected to the CMP input.

C2 and C3 should be dimensioned for a charge time of 0.5 to 10 ms and for 150 to 300 ms discharge time. The total external resistance to the CMP input should be 50 kohm, therefore the resistors, R3,R4 are to be 100 kohm.

A hysteresis effect is achieved in the switching, since the level detectors sense the signals after F2 and F5 respectively (F2 and F5 are affected by the gain setting). For example, if the transmit channel is open (maximum gain), a smaller signal at Tx_{In} is needed to keep the channel open than would be needed to open it when the receive channel was open.

The output swing of the level detectors is matched for variations in the supply voltage. The detectors have a logarithmic rectifier characteristic, the gain, and thereby the sensitivity, is high at low signals. There is a break point, at about 200 mV from the reference, where the sensitivity for increasing input signals decreases 10 times. This gives increased dynamics for the detectors. See figure 12.

Background noise detector

The general function of the background noise detector is to create a negative signal (in respect to the reference) that, when coupled to the summing point at the CMP input, will counteract the signal from the transmit level detector to an extent representing the actual noise level. This prevents the noise from influencing the switching comparators.

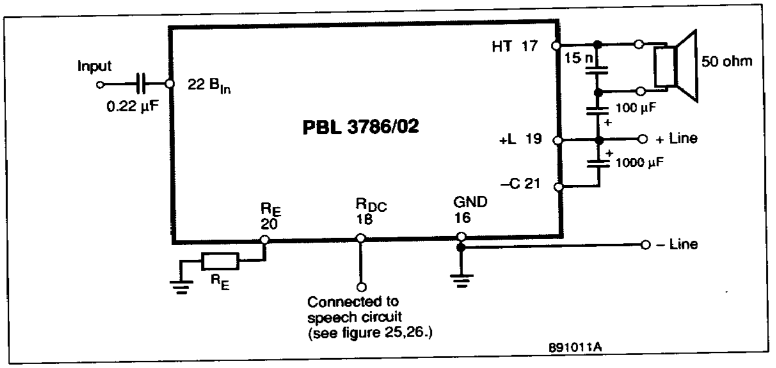


Figure 20. Power supply in parallel with speech circuit.

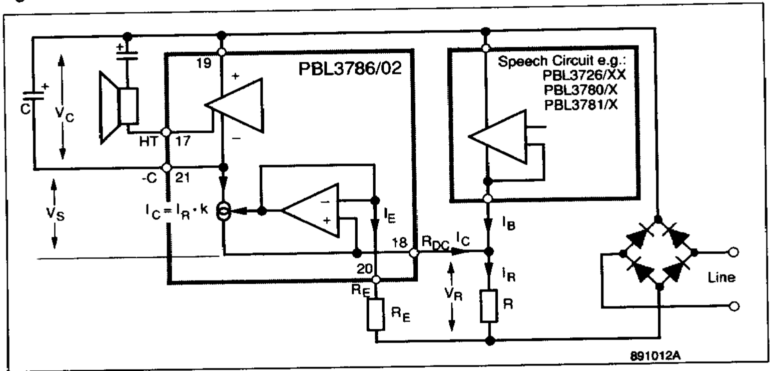


Figure 21. Current baising regulated by the speech circuit working in parallel with PBL 3786/02.

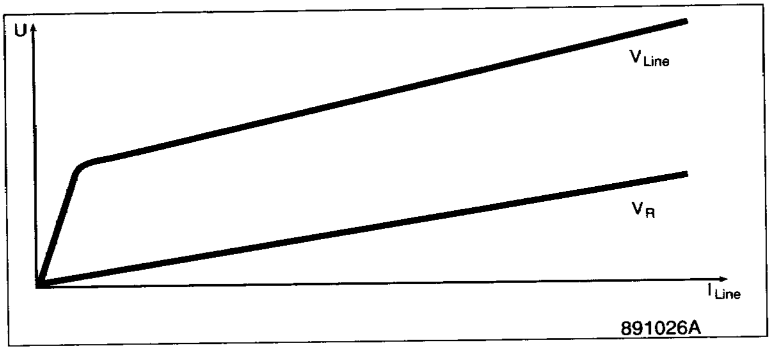


Figure 22. Speech circuit DC characteristics.

The input signal to the background noise level detector is taken from the output of the transmit detector, a signal representing the envelope of the amplified microphone signal, except for the part of it that decreases faster than C3, on the output of Tx_{Det} discharges. The detector amplifies the inversion of this signal about 2 times (transmit mode) and drives an RC-net consisting of an internal resistor of 100 kohms and an external capacitor, C4. The voltage over C4 is coupled to the CMP input via resistor R5. The extent to which the N_{Det} output will influence the potential at the CMP input is set by the gain of the detector, the maximum swing, and R5.

If a constant-input signal, a signal with no longer breaks, is received from the microphone, the voltage over C4 is pulled in the negative direction (relative to the reference) with a time constant set by C4 to e.g. 4 - 5 s. A continuous input signal is thereby treated as noise. Since the output of the noise detector is going negative, it thereby counteracts the voltage from Tx_{Det} in the summing point at CMP.

If the input signal contains breaks like breath pauses, the voltage at Tx_{Det} output decreases. If the voltage over C3 becomes less than the voltage over C4 divided by the gain of the detector (absolute values), the detector starts a rapid charge of C4, up toward the reference voltage. If the breaks are frequent enough (typical speech), the background noise detector will not influence the switching of the comparators. See figure 14.

There is a threshold (approximately 50 mV) at Tx_{Det} to prevent the activation of noise detection in noiseless surroundings.

In the receive mode, some of the loudspeaker output signal will be sensed by the microphone. In order not to treat this transmit input signal as noise, the noise detector goes to a "hold" state in this mode, and "remembers" the level of the former transmit or standby mode.

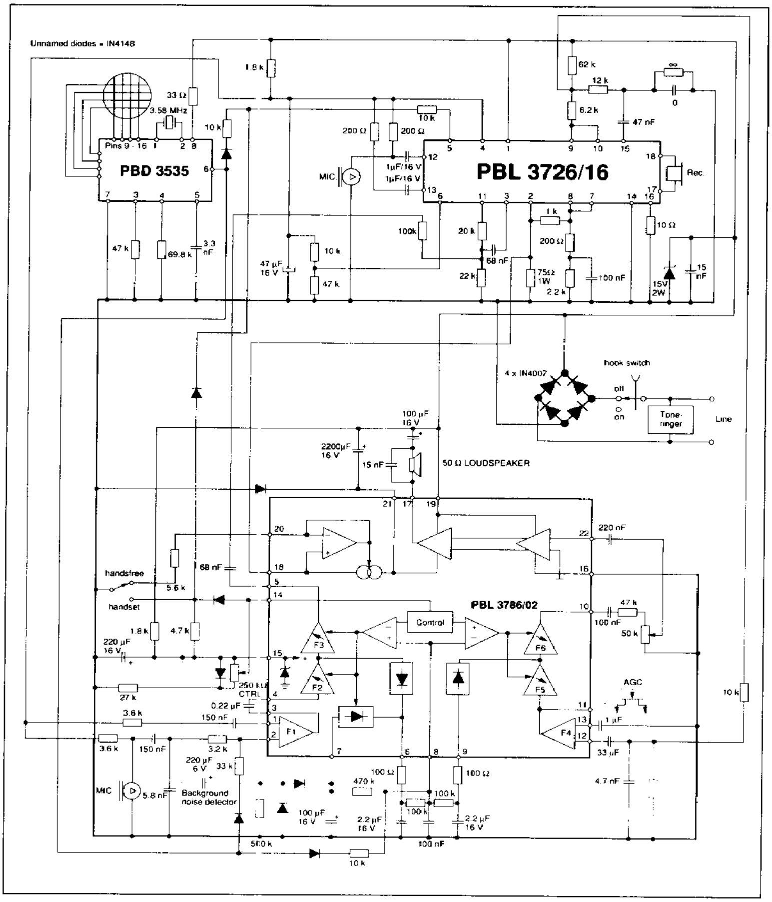


Figure 23. Application 1.

CTR input

A voltage at this input (normally V_+ - 600 mV) controls the comparators which set the gain in the receive and transmit channels continuously from full speech control mode (50 dB attenuation between channels) to duplex mode (both channels fully open). Input left open renders full speech control. See figures 15 and 16.

In full duplex mode, the CMP input is clamped to the reference voltage in order not to let this level interfere with the function.

If current is drained out of the input, the gain is reduced in both channels, and a mute mode is achieved (at approximately 35 - 40 µA). See figure 18.

Decreasing the voltage at the input below 0.9 V, a shut-down state is reached,where the transmit and receive amplifiers are switched off and the current consumption is reduced. See figure 17.

Loudspeaker amplifier

The loudspeaker amplifier drives the 50 ohm loudspeaker, which is also used by the tone ringer, directly. The amplifier is designed to work in a number of different biasing applications.

The highest output swing is obtained if pin -C is connected to ground and pin +L is connected to a stable supply. The biasing could be provided either from the mains supply or via a coil from the telephone lines. See figure 19. Current consumption is directly proportional to the voltage between pins +L and -C.

When using the application according to figure 20, pin -C is used as a negative floating-point supply for the amplifier. The output signal of the loudspeaker amplifier is referred to +L. The capacitor, C, makes it possible for the amplifier to handle peaks which are above its constant-drive capability.

The optimal design, without using a stable supply, is to balance the biasing of the circuit against the DC characteristics of the speech circuit working in parallel. See figure 21. In figure 21, the capacitor, C, is a charge reservoir for the loud-speaker amplifier. The maximum current, I_{CMax}, that can charge C, is set by R_E and the voltage, V_R. At a certain voltage, V_R, I_E is given by:

$I_E = V_R/R_E = k_1 x I_R$

This current is multiplied in the hands-free circuit and $I_{CMax} = k \cdot I_R$ (k must be <1). The capacitor, C, is charged until the voltage, V_C, is equal to the voltage across the speech circuit, i.e. V_S = 0.

The speech circuit sets the DC characteristics. See figure 22. At a specific supply condition, the current, I_R, is therefore kept constant. Since $I_R = I_C + I_B$ is constant, the resistor, R_E, must be chosen so that it ensures the minimum operating current for the speech circuit at all conditions.

The single-ended loudspeaker amplifier has an internal gain regulation which prevents distortion in cases when enough current from the line is not available.

Ordering Information

Package	Temp. Range	Part No.
Plastic DIP	-20 to 70°C	PBL 3786/02N

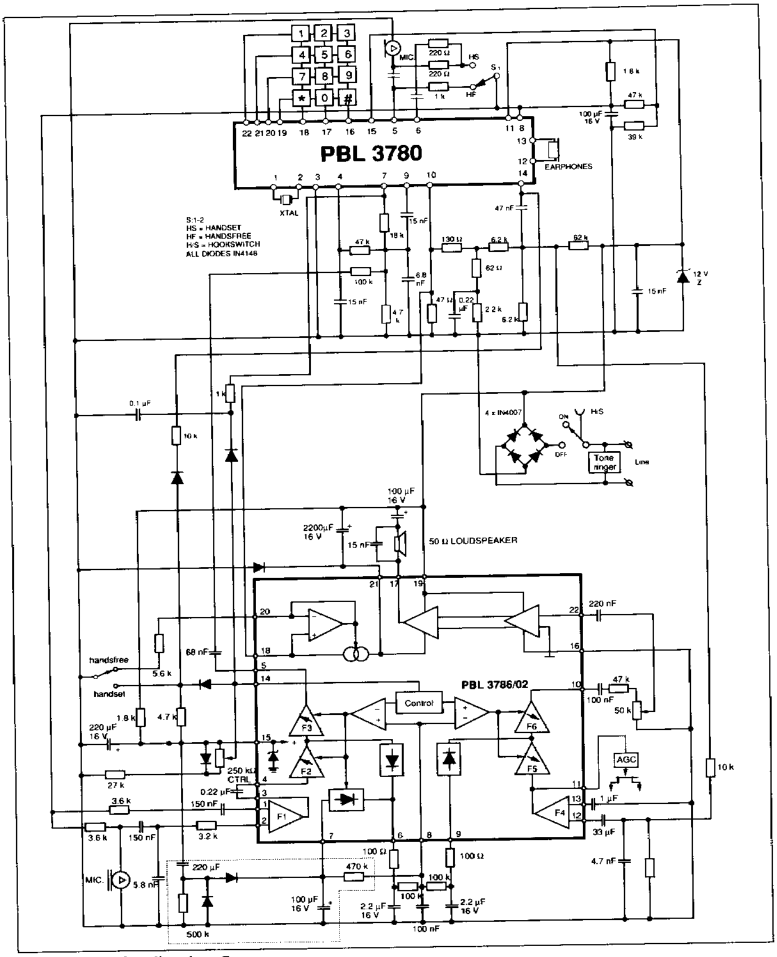


Figure 24. Application 2

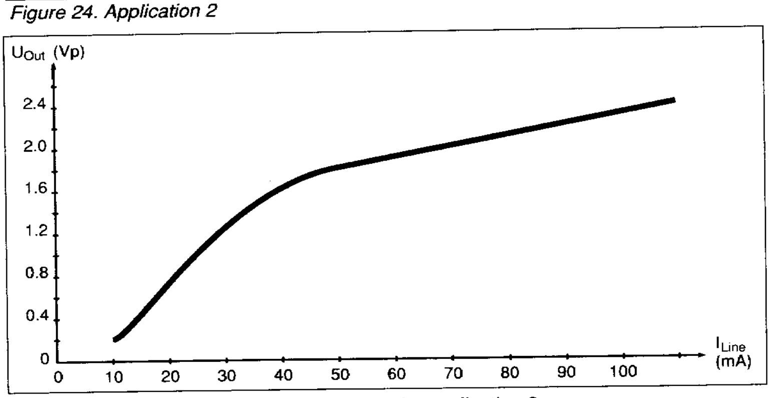


Figure 25. Typical loudspeaker output swing for application 2.