

**ACE9040****HELPFUL INFORMATION AND ERRATA:****1. ACE9040 signal path analysis.**

The spread sheets that follow are provided to clarify what the typical expected response would be for given settings of the gain/loss blocks for both the transmit and receive voice paths. For convenience, EXCEL the spreadsheet files (TX: 9040TXVB.XLS and RX: 9040RXVB.XLS) are provided on the supplied diskette. The shaded areas are user adjustable.

**2. TX path MI/LI to TPLO :**

| <b>ACE9040 TRANSMIT VOICE PATH ANALYSIS</b> |               |            |           |           |        |        |
|---------------------------------------------|---------------|------------|-----------|-----------|--------|--------|
| MI/LI INPUTS:                               |               | INPUT DATA |           |           |        |        |
| MIC                                         | AMP           | IN         |           |           |        |        |
| IN/OUT?                                     |               |            |           |           |        |        |
| AUDIO                                       | FREQ          | 1          |           |           |        |        |
| (KHz)?                                      |               |            |           |           |        |        |
| VDD                                         | (VOLTS)?      | 3.75       |           |           |        |        |
| Compressor                                  |               | IN         |           |           |        |        |
| IN/OUT?                                     |               |            |           |           |        |        |
| Input level                                 | BLOCK         | GAIN       | Tolerance | GAIN/LOSS | OUTPUT |        |
|                                             |               | ADJUSTMEN  |           |           | dBV    | mVRMS  |
| dBV                                         |               | T          |           |           |        |        |
| -49.1                                       | MIG           | 22         | 0         | 22        | -27.1  | 44.16  |
| -27.1                                       | SOFT LIMITER  | 0          | 0         | 0         | -27.1  | 44.16  |
| -27.1                                       | INPSENSE      | 0          | 0         | 8         | -19.1  | 110.92 |
| -19.1                                       | TXBPF         | 0          | 0         | 0         | -19.1  | 110.92 |
| -19.1                                       | HFGAIN        | 0          | 0         | 0         | -19.1  | 110.92 |
| -19.1                                       | COMPRESSOR    | 0          | 0         | 8.05      | -11.05 | 280.22 |
| -11.05                                      | GAIN          | -11        | 0         | -11       | -22.05 | 78.98  |
|                                             | CONTROL       |            |           |           |        |        |
| -22.05                                      | PRE-EMPHASIS  | 0          | 0         | 0         | -22.05 | 78.98  |
| -22.05                                      | HARD LIMITER  | 13.5       | 0         | 13.5      | -8.55  | 373.68 |
| -8.55                                       | ATTENUATOR    | -8         | 0         | -8        | -16.55 | 148.76 |
| -16.55                                      | TXLPF,PREIN,T | 0          | 0         | 0         | -16.55 | 148.76 |
|                                             | O AUDIO DEV   |            |           |           |        |        |
| -16.55                                      | AUDIO DEV TO  | 0          | 0         | 0         | -16.55 | 148.76 |
|                                             | TLPO          |            |           |           |        |        |
| Overall Gain                                |               |            |           |           | 32.55  |        |

Nominal MIC input level for -20dBV output:

| ACE9040 TRANSMIT VOICE PATH ANALYSIS |                |                 |   |           |           |              |
|--------------------------------------|----------------|-----------------|---|-----------|-----------|--------------|
| MI/LI INPUTS:                        |                | INPUT DATA      |   |           |           |              |
| MIC                                  | AMP            | IN              |   |           |           |              |
| IN/OUT?                              |                |                 |   |           |           |              |
| AUDIO                                | FREQ           | 1               |   |           |           |              |
| (KHz)?                               |                |                 |   |           |           |              |
| VDD                                  | (VOLTS)?       | 3.75            |   |           |           |              |
| Compressor                           | IN/OUT?        | IN              |   |           |           |              |
| Input level                          | BLOCK          | GAIN ADJUSTMENT |   | Tolerance | GAIN/LOSS | OUTPUT       |
| dBV                                  |                |                 |   |           | dBV       | mVRMS        |
| -56                                  | MIG            | 22              | 0 |           | 22        | -34 19.95    |
| -34                                  | SOFT LIMITER   | 0               | 0 |           | 0         | -34 19.95    |
| -34                                  | INPSENSE       | 0               | 0 |           | 8         | -26 50.12    |
| -26                                  | TXBPF          | 0               | 0 |           | 0         | -26 50.12    |
| -26                                  | HFGAIN         | 0               | 0 |           | 0         | -26 50.12    |
| -26                                  | COMPRESSOR     | 0               | 0 |           | 11.5      | -14.5 188.36 |
| -14.5                                | GAIN CONTROL   | -11             | 0 |           | -11       | -25.5 53.09  |
| -25.5                                | PRE-EMPHASIS   | 0               | 0 |           | 0         | -25.5 53.09  |
| -25.5                                | HARD LIMITER   | 13.5            | 0 |           | 13.5      | -12 251.19   |
| -12                                  | ATTENUATOR     | -8              | 0 |           | -8        | -20 100.00   |
| -20                                  | TXLPF,PREIN,TO | 0               | 0 |           | 0         | -20 100.00   |
|                                      | AUDIO DEV      |                 |   |           |           |              |
| -20                                  | AUDIO DEV TO   | 0               | 0 |           | 0         | -20 100.00   |
|                                      | TLPO           |                 |   |           |           |              |
| Overall Gain                         |                |                 |   |           | 36        |              |

Notes:

The HFGAIN block would normally set to 0dB when not in handsfree mode. Gain adjustment would be done using INPSENSE.

Receive path - RXI to LO

| ACE9040 RECEIVE VOICE PATH ANALYSIS |              |                    |            |               |               |           |
|-------------------------------------|--------------|--------------------|------------|---------------|---------------|-----------|
| MI/LI INPUTS:                       |              |                    | INPUT DATA |               |               |           |
| EAMP IN/OUT?                        |              |                    | IN         |               |               |           |
| AUDIO FREQ (KHz)?                   |              |                    | 1          |               |               |           |
| VDD (VOLTS)?                        |              |                    | 3.75       |               |               |           |
| Expander IN/OUT?                    |              |                    | IN         |               |               |           |
| Input level                         | BLOCK        | GAIN<br>ADJUSTMENT | Tolerance  | GAIN/LOS<br>S | OUTPUT<br>dBV | mVRM<br>S |
| dBV                                 |              |                    |            |               |               |           |
| -20                                 | RXSENSE      | 0                  | 0          | 8             | -12           | 251.19    |
| -12                                 | RXBPF        | 0                  | 0          | 0             | -12           | 251.19    |
| -12                                 | EXPGAIN      | 12.3               | 0          | 12.3          | 0.3           | 1,035.1   |
| 0.3                                 | EXPANDER     | 0                  | 0          | 0.6           | 0.9           | 1,109.1   |
| 0.9                                 | RX LEVEL     | 0                  | 0          | -12           | -11.1         | 278.61    |
| -11.1                               | HF ATTEN     | 0                  | 0          | 0             | -11.1         | 278.61    |
| -11.1                               | LODRIVE      | 5                  | 0          | 5             | -6.1          | 495.45    |
| -11.1                               | EARSENSE     | 0                  | 0          | 0             | -11.1         | 278.61    |
| -11.1                               | EAMP         | 5                  | 0          | 5             | -6.1          | 495.45    |
| -6.1                                | EARPIECE DRV | 6                  | 0          | 6             | -0.1          | 988.55    |
| Overall Gain                        |              |                    |            |               | 19.9          |           |

LO  
OUT

## NOTES:

The -20dBV at RXI would be about the maximum level as this is after the de-emphasis filter which at 1 KHz could give approx. 20 dB attenuation of the discriminator output.

**5. ACE9040 I/O information:**

Some of these pins are specified with a minimum drive into a specified load rather than current drive capability.

| Pin No. | NAME       | Drive Capability/Load Resistance/Load Capacitance | COMMENTS       |
|---------|------------|---------------------------------------------------|----------------|
| 3       | HF         | 100 pF max., /RL tbd                              | note 1         |
| 6       | BIAS       | 3.5mA to maintain 5 %/<1ohm/100pf                 |                |
| 9       | TSI        | CMOS Logic input Cin<10pF, Leakage<5uA            |                |
| 10      | RSI        | Input impedance 275K                              | note 2         |
| 12      | RBPO       | /100K/50pF                                        |                |
| 13      | EAMPI      | /10K/50pF                                         |                |
| 19      | EAMPO      | 1V rms. min./15K/50pF                             |                |
| 21,22   | EPOP/<br>N | 4V p-p/(150 ohm +800 uH) parallel with 100pF      | note 3         |
| 36      | RSO        | /10K/50pF                                         | Logic Output   |
| 37      | TSO        | 300uA/10K/50pF                                    |                |
| 38      | DATO       | 300uA/10K/50pF                                    |                |
| 40      | MOD        | 1V rms min/10K/50pF                               |                |
| 41      | SUMO       | 1V rms min/10K/50pF                               |                |
| 43      | TLPO       | 300uA/10K/50pF                                    |                |
| 44      | BGAP       |                                                   | note 4         |
| 47      | DTMF       | (see DTMF section)/10K/50pF                       |                |
| 48      | AMPO       | 150uA/10K/50pF                                    |                |
| 52      | TBPO       | 1V rms/100K/50pF                                  |                |
| 58      | COUT       | 1mA/1K/50pF                                       |                |
| 61      | IPS        | 275K Input impedance                              |                |
| 62      | SLO        | 1V rms/100K/50pF                                  | RC in parallel |

**Notes:**

1. This pin is multiplexed from TXC and RXC, therefore any resistor will load one of these capacitors when it is connected to HF. The TXC and RXC pins have 15k in series internally so the range of values that can be connected is 0 to infinity, but obviously the bigger the resistor the less the effect on the capacitors.
2. Nominal input 100 mV at 6kHz  
400mV 300-3400Hz
3. Differential dynamic earpiece driver
4. Internal reference only. Decouple with 10 nF to GND

## 6. ACE9040 and speaker muting.

As the CHIPSET comes out of standby, there are some momentary transients on the earpiece output that will sound like clicks. Switching RX mute is quiet however. The audio should be kept muted until phone is out of standby.

## 7. Receive Path tap point for DTMF detectors and other voice processing requirements

The EOUT pin 15 is a convenient point to tap off the voice path. This point in the receive chain is before the volume control functions. The EOUT output can drive up to a 1 Kohm load.

## 8. DTMF set up sequence.

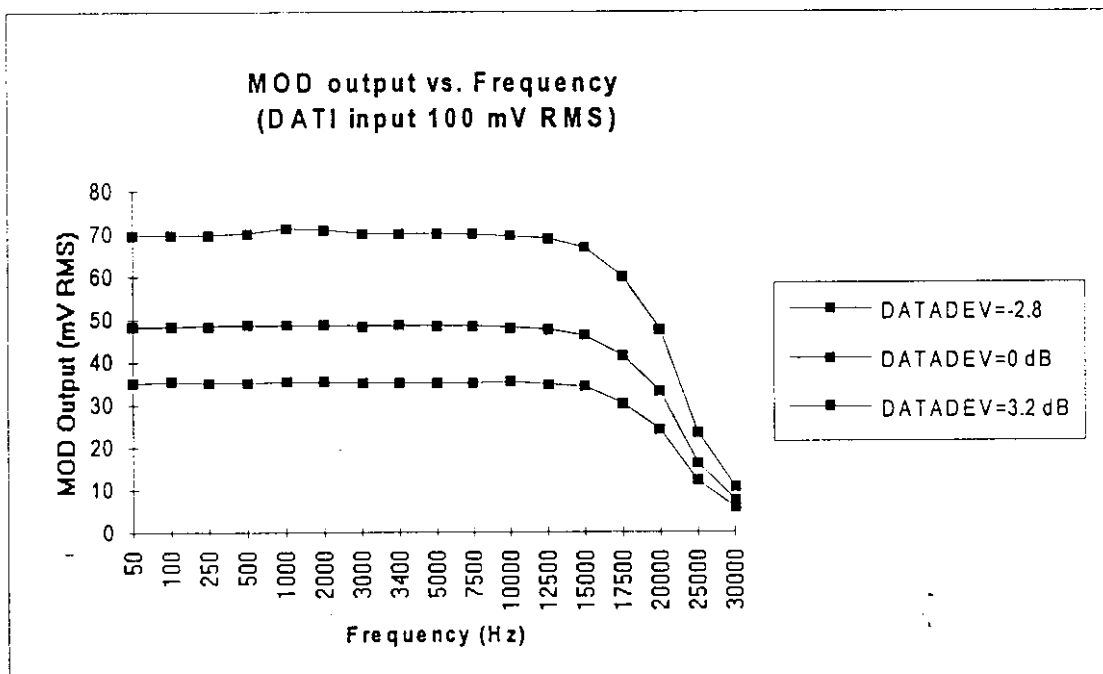
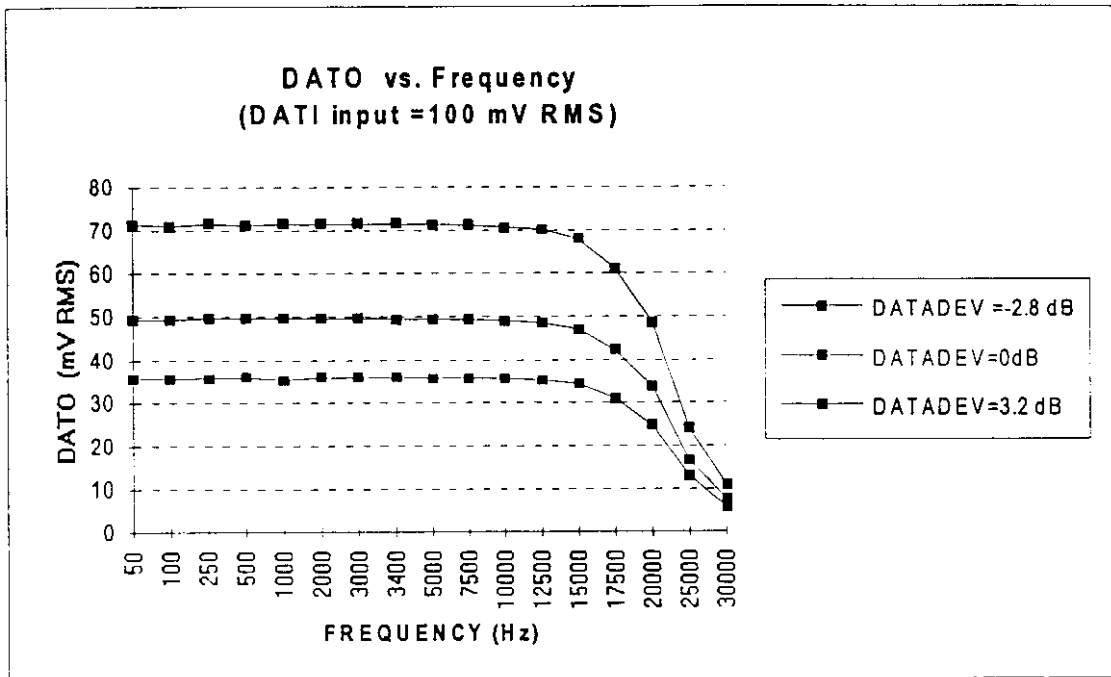
The following bits must be set in this order:

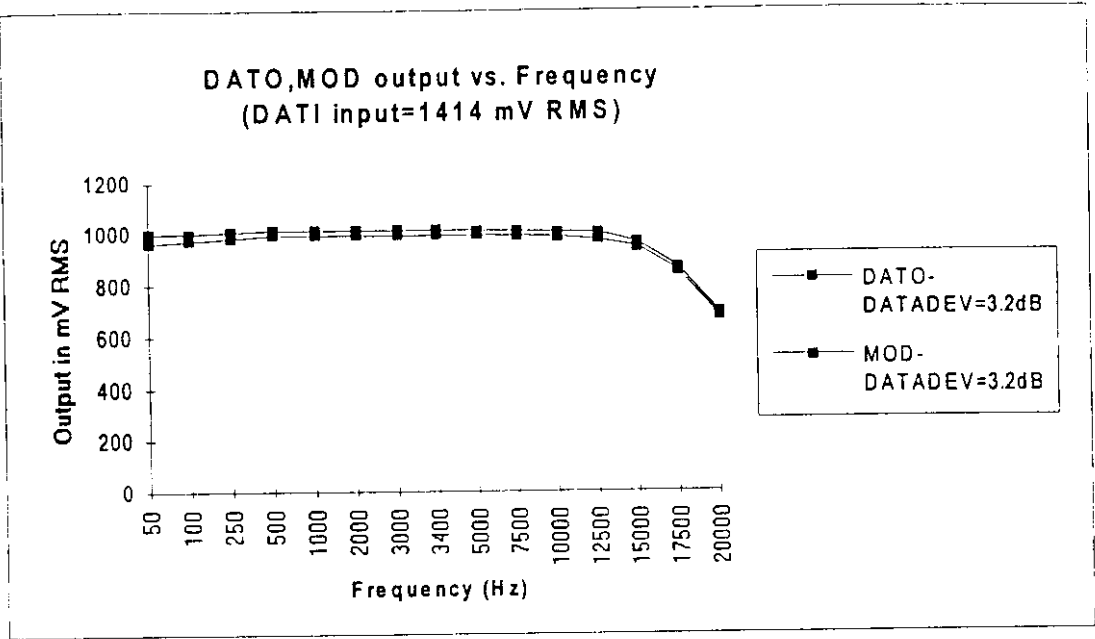
- DTMF Mode (Operation Mode - Data2 bits 6:7)  
See table 6 on page 16 of data sheet (p166 of data book)
- DTMF, TONEM (Operation mode Data1 bits 0:1)  
These switch the DTMF into TX and RX audio channels.
- DTMF (Operation mode Data1 bits 5:2)  
DTMF code/tone select see table 7 on p16 of data sheet (p166 of data book)
- DTWIST (Initializing mode 0 - Data3 bit 3)  
This bit switches in 2dB pre-emphasis on high tone.
- DTMFEN (Operation mode - data bit 5)  
This enables the DTMF generator.

The DTMFEN bit should be the final bit set so that spurious tones can not be generated. Also when changing the DTMF tone the DTMFEN line must be held low while the DTMF code is programmed. The DTMF tone can not be changed while DTMFEN is high.

Our demo software takes the above switching into account when changing tones.

## 9. Measured Frequency response plots of DATA path at various input levels.





**FAQ:****1. COMPANDER INFORMATION**

*How do the IS-19B compressor standards correspond to the ACE9040 nominal levels?*

The nominal level is not the same as the unaffected level which is -3 dBV. The nominal levels given in the data sheet, tables 20 and 21, correspond to the nominal level (0dB) for a 2.9 KHz deviation for AMPS. The max. deviation permissible for AMPS is 12 kHz, +12.3dB after compression or 25 dB pre-compression.

**2. SOFT LIMITER**

*Describe how the soft limiter operates?*

The soft limiter does not form part of the compressor function. This only comes into action when the input signal to the compressor is >92% VDD, (1.2 Volts rms for 3.75 volt supply). This is above the input range of the compressor (1volt rms max.). The soft limiter adjusts the pre compression gain so that the signal is within the dynamic range of the compressor.

**3. SIDETONE PATH**

*Please clarify the specified level for side tone signal. The spec says 19 dB +/- 1dB with EARSENSE = 0dB. Why there is condition on EARSENSE?*

When the sidetone path is switched on, there is a fixed attenuation of 19 dB +/-1 dB from the output of the TX bandpass filter to the input of the earsense block.

**4. DTMF GENERATOR**

**What is the output level of the DTMF generator with VDD = 4V. Low frequency tone level ? High frequency tone level?**

The DTMF output for the low frequency group is as follows:

100 mVrms +/- 1 dB at Vdd=4.85 V  
83 mVrms +/- 1 dB at Vdd=4.0 V  
77 mVrms +/-1 dB at Vdd=3.85V

Pre-emphasis for the high frequency group is selectable to 0 or +2.0 dB above the low frequency group

**5. What is the HARD LIMITER output for a 0dBV input at a 3.75 volt supply voltage?**

The output will be approximately 3.5V peak to peak. This is 1.85dBV using rms voltages.





ACE9040 DATA SHEET





# ACE9040

## AUDIO PROCESSOR FOR AMPS AND TACS CELLULAR PHONES

ACE9040 provides all the speech signal processing and data/SAT tone filtering needed for AMPS or TACS analog cellular telephones.

Transmit voice channel functions comprise a microphone amplifier, soft limiter, bandpass filter, compressor, hard limiter, lowpass filter and a gain controlled amplifier to set deviation level. Additional transmit circuits include a DTMF generator, data and SAT filters, deviation setting amplifiers for data/ST and SAT and a modulation combiner.

ACE9040's receive path comprises a bandpass filter, expander, volume control and power amplifiers to directly drive an earpiece or handsfree transducer.

Gain settings, mute switches and filter characteristics are programmed via a three wire serial interface.

To implement a handsfree function, both transmit and receive paths have rectifiers for signal amplitude monitoring via an external pin and signal path attenuators controlled via the serial interface.

ACE9040 combines minimum power consumption with low external component count. Standby modes greatly reduce supply current and extend battery charge intervals.

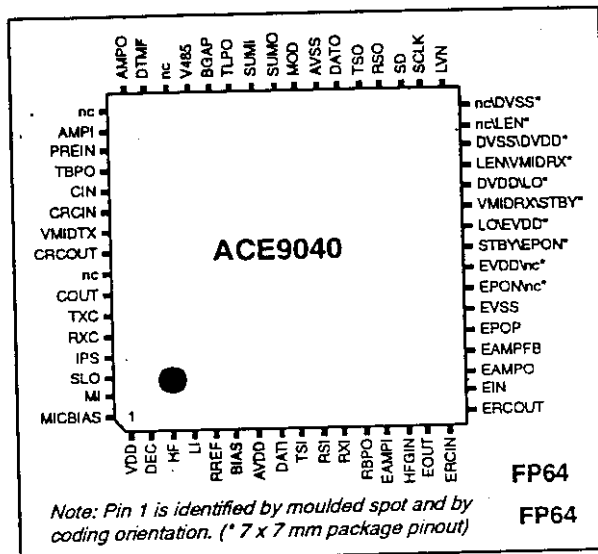


Fig.1 Pin connections - top view

### FEATURES

- Low Power and Low Voltage (3.6 to 5.0 V) Operation
- Power Down Modes
- Direct Connections to Microphone and Earpiece
- Compander with wide operating range:  
Compressor 74 dB typ., Expander 36 dB typ.
- SAT Bandpass and Data Lowpass Filters
- Handsfree Operation Supported
- DTMF Generator
- Serial Bus Controlled Gains and Filter Responses
- Part of the ACE Integrated Cellular Phone Chipset
- TQFP 64 Pin 10X10 mm or 7X7 mm Packages

### APPLICATIONS

- AMPS and TACS Cellular Telephones
- Two-Way Radio Systems

### RELATED PRODUCTS

ACE9040 is part of the following chipset:

- ACE9010 R.F. Front End with VCO
- ACE9020 Receiver and Transmitter Interface
- ACE9030 Radio Interface and Twin Synthesiser
- ACE9050 System Controller and Data Modem

### ABSOLUTE MAXIMUM RATINGS

|                       |                             |
|-----------------------|-----------------------------|
| Supply voltage        | 6 V                         |
| Storage temperature   | - 55 °C to + 150 °C         |
| Operating temperature | - 40 °C to + 85 °C          |
| Voltage at any pin    | - 0.3 V to $V_{DD} + 0.3$ V |

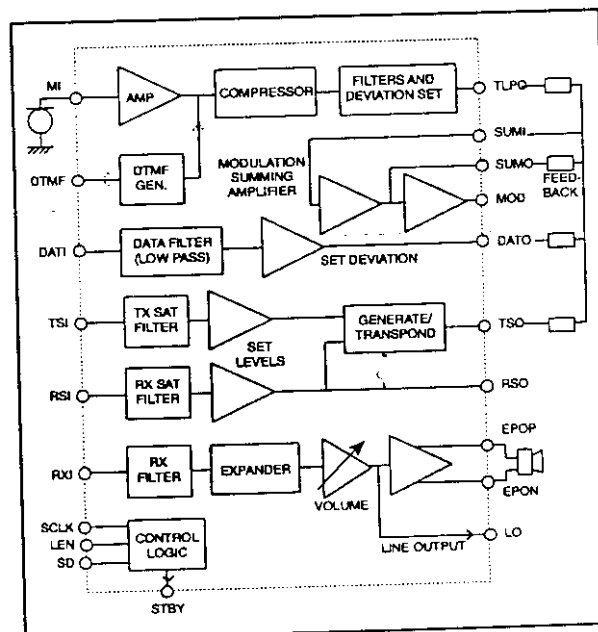


Fig. 2 ACE9040 Simplified Block Diagram

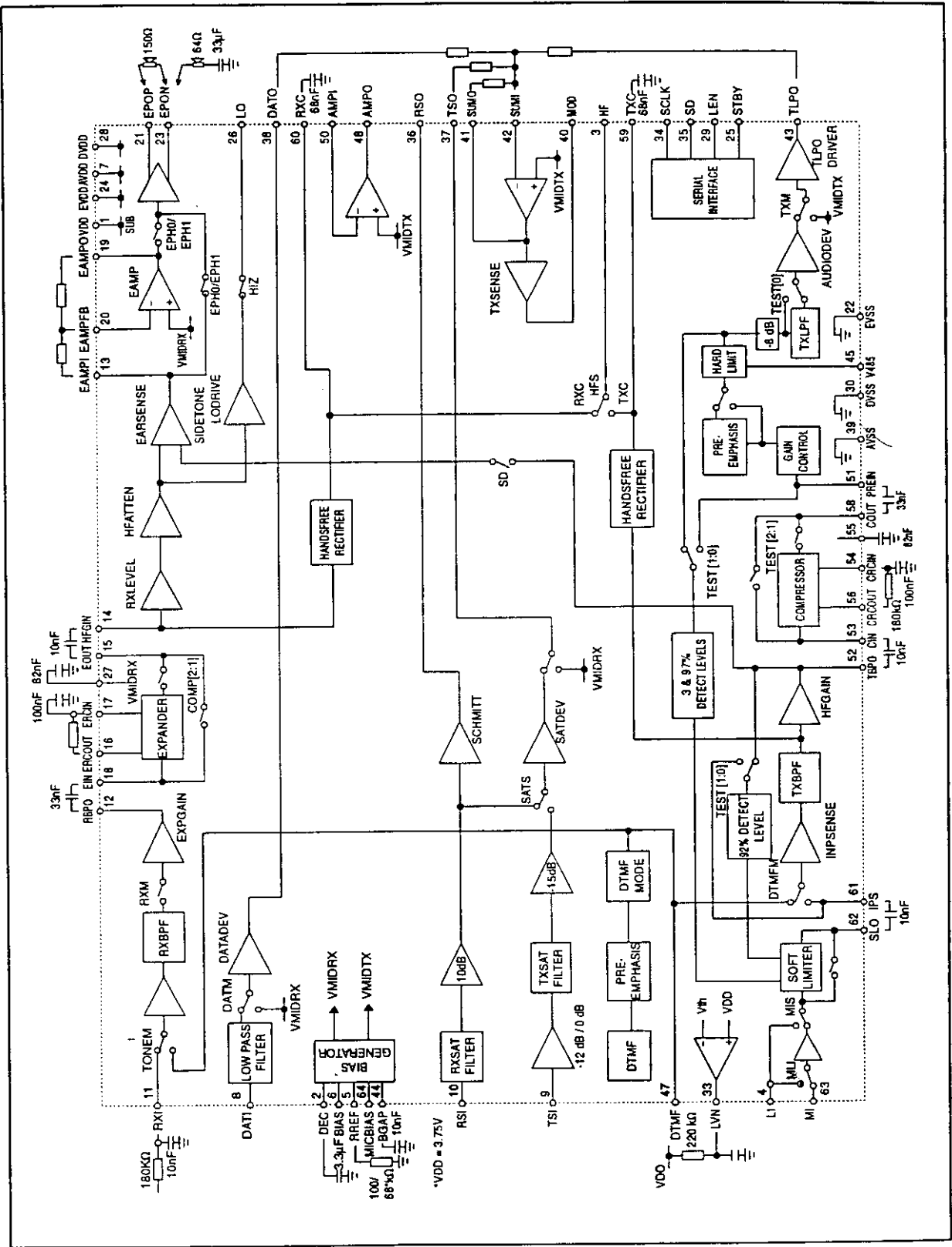


Fig. 3 ACE9040 Detailed Block Diagram

## PIN DESCRIPTIONS

| Pin No.<br>FP package | Pin No.<br>VP package | Name             | Description                                                                             |
|-----------------------|-----------------------|------------------|-----------------------------------------------------------------------------------------|
| 1                     | 1                     | V <sub>DD</sub>  | V <sub>DD</sub> supply to substrate, pin should be at highest d.c. voltage              |
| 2                     | 2                     | DEC              | Mid-supply reference decoupling connection, 3.3 $\mu$ F to GND                          |
| 3                     | 3                     | HF               | Output from TX or RX handsfree rectifier, switched by bit "HFS"                         |
| 4                     | 4                     | LI               | Line input                                                                              |
| 5                     | 5                     | RREF             | Reference bias current set for all op-amps by resistor to GND                           |
| 6                     | 6                     | BIAS             | Buffered mid-supply reference output                                                    |
| 7                     | 7                     | AV <sub>DD</sub> | Analogue V <sub>DD</sub> input                                                          |
| 8                     | 8                     | DATI             | Transmit data input                                                                     |
| 9                     | 9                     | TSI              | SAT path input for locally generated tone                                               |
| 10                    | 10                    | RSI              | SAT path receiver input for received tone                                               |
| 11                    | 11                    | RXI              | Speech path receiver input                                                              |
| 12                    | 12                    | RBPO             | Audio output from EXPGAIN block                                                         |
| 13                    | 13                    | EAMPI            | Output from EARSENSE amp                                                                |
| 14                    | 14                    | HFGIN            | Input to RX volume control and handsfree attenuator                                     |
| 15                    | 15                    | EOUT             | Expander speech output                                                                  |
| 16                    | 16                    | ERCIN            | Expander time constant input, 180 k $\Omega$ to ERCOUT, 100 nF to GND                   |
| 17                    | 17                    | ERCOUT           | Expander time constant output, 180 k $\Omega$ to ERCIN                                  |
| 18                    | 18                    | EIN              | Expander speech input, 33 nF to RBPO                                                    |
| 19                    | 19                    | EAMPO            | Output from EAMP op-amp                                                                 |
| 20                    | 20                    | EAMPFB           | Inverting input to EAMP op-amp                                                          |
| 21                    | 21                    | EPOP             | Earpiece driver positive output                                                         |
| 22                    | 22                    | EV <sub>SS</sub> | Earpiece V <sub>SS</sub> (GND) supply connection                                        |
| -                     | 23/24                 | nc               | No connection                                                                           |
| 23                    | 25                    | EPON             | Earpiece driver negative output                                                         |
| 24                    | 26                    | EV <sub>DD</sub> | Earpiece V <sub>DD</sub> supply input                                                   |
| 25                    | 27                    | STBY             | Standby output: low indicates standby state, high is V <sub>DD</sub> output @ 10 mA     |
| 26                    | 28                    | LO               | Line output                                                                             |
| 27                    | 29                    | VMIDRX           | RX path mid-supply reference voltage, 82 nF to GND                                      |
| 28                    | 30                    | DV <sub>DD</sub> | Digital V <sub>DD</sub>                                                                 |
| 29                    | 31                    | LEN              | Serial interface latch signal input, rising edge triggered                              |
| 30                    | 32                    | DV <sub>SS</sub> | Digital V <sub>SS</sub> (GND) connection                                                |
| 31/32                 | -                     | nc               | No connection                                                                           |
| 33                    | 33                    | LVN              | Low supply V <sub>DD</sub> voltage indicator comparator output, reset active low output |
| 34                    | 34                    | SCLK             | Serial interface system clock input                                                     |
| 35                    | 35                    | SD               | Serial interface data input                                                             |
| 36                    | 36                    | RSO              | Received (regenerated) SAT output                                                       |
| 37                    | 37                    | TSO              | Transmit SAT output, regenerated or transponded                                         |
| 38                    | 38                    | DATO             | Transmit data filter output.                                                            |
| 39                    | 39                    | AV <sub>SS</sub> | Analogue V <sub>SS</sub> (GND)                                                          |
| 40                    | 40                    | MOD              | Modulation output: sum of Speech, Data and SAT                                          |
| 41                    | 41                    | SUMO             | Modulation summing amplifier output                                                     |
| 42                    | 42                    | SUMI             | Modulation summing amplifier input                                                      |
| 43                    | 43                    | TLPO             | Transmit audio lowpass filter output                                                    |
| 44                    | 44                    | BGAP             | Bandgap voltage output, 10 nF to GND                                                    |
| 45                    | 45                    | V485             | Hard limiter gain selection for 3.75 V or 4.85 V nominal supplies                       |
| 46                    | 46                    | nc               | No connection                                                                           |
| 47                    | 47                    | DTMF             | DTMF tone output                                                                        |
| 48                    | 48                    | AMPO             | Auxillary op-amp output                                                                 |
| 49                    | 49                    | nc               | No connection                                                                           |
| 50                    | 50                    | AMPI             | Auxillary op-amp inverting input (non-inverting internally connected to VMIDTX)         |
| 51                    | 51                    | PREIN            | Transmit pre-emphasis filter input                                                      |
| 52                    | 52                    | TBPO             | Transmit bandpass filter output                                                         |
| 53                    | 53                    | CIN              | Compressor audio input, 10 nF from TBPO                                                 |
| 54                    | 54                    | CRCIN            | Compressor time constant input, 100 nF to GND, 180 k $\Omega$ to CRCOUT                 |
| 55                    | 55                    | VMIDTX           | TX path reference voltage, 82 nF to GND                                                 |
| 56                    | 56                    | CRCOUT           | Compressor time constant output, 180 k $\Omega$ to CRCIN                                |
| 57                    | 57                    | nc               | No connection                                                                           |
| 58                    | 58                    | COUT             | Compressor audio output, 33 nF to PREIN                                                 |
| 59                    | 59                    | TXC              | Transmit handsfree audio level sensing rectifier smoothing filter, 68 nF to GND         |
| 60                    | 60                    | RXC              | Received handsfree audio level sensing rectifier smoothing filter, 68 nF to GND         |
| 61                    | 61                    | IPS              | Transmit audio gain INPSENSE adjustment block input                                     |
| 62                    | 62                    | SLO              | Soft limiter output                                                                     |
| 63                    | 63                    | MI               | Microphone input                                                                        |
| 64                    | 64                    | MICBIAS          | Bias for electret or active microphone                                                  |

# ACE9040

## ELECTRICAL CHARACTERISTICS

These characteristics are guaranteed over the following conditions unless otherwise stated (Note 1):

$$T_{AMB} = -40^{\circ}\text{C to } +85^{\circ}\text{C}, V_{DD} = 3.6\text{ V to } 5.0\text{ V}$$

| Characteristic                                    | Symbol                 | Value |      |      | Unit | Conditions                                         |
|---------------------------------------------------|------------------------|-------|------|------|------|----------------------------------------------------|
|                                                   |                        | Min.  | Typ. | Max. |      |                                                    |
| Supply Current and Power Down Modes               |                        |       |      |      |      |                                                    |
| Operating supply current                          | I <sub>DD</sub>        |       | 15   |      | mA   | V <sub>DD</sub> = 4.85 V R <sub>REF</sub> = 100 kΩ |
|                                                   |                        |       |      | 15   | mA   | V <sub>DD</sub> = 3.75 V R <sub>REF</sub> = 68 kΩ  |
| Standby                                           |                        |       |      |      |      |                                                    |
| Attenuation of all inputs signals                 |                        | 40    |      |      | dB   |                                                    |
| Wakeup response time                              |                        |       |      | 10   | ms   |                                                    |
| Sleep (Standby with CLK stopped)                  |                        |       |      |      |      |                                                    |
| Supply current*                                   | I <sub>DD(SLEEP)</sub> |       |      | 200  | μA   | STBY bit set V <sub>DD</sub> = 3.75                |
| Delay between setting STBY bit and stopping clock |                        | 20    |      |      | μs   |                                                    |
| Delay to starting clock after wakeup              |                        | 100   |      |      | μs   |                                                    |

\* Standby current measured with the 1.008 MHz clock stopped and SCLK at a level <200 mV.

| Characteristic                                | Value |            |      | Unit       | Conditions                                        |
|-----------------------------------------------|-------|------------|------|------------|---------------------------------------------------|
|                                               | Min.  | Typ.       | Max. |            |                                                   |
| <b>Transmission Path</b>                      |       |            |      |            |                                                   |
| <b>Microphone Amp, MI to SLO pins</b>         |       |            |      |            |                                                   |
| Input bias                                    |       | $V_{DD}/2$ |      |            | Internal 150 kΩ bias resistor to $V_{DD}/2$       |
| Microphone input gain (LO)                    | 21    | 22         | 23   | dB         | MIS = 1, MLI = 0, MIG = 0                         |
| Microphone input gain (HI)                    | 31    | 32         | 33   | dB         | MIS = 1, MLI = 0, MIG = 1                         |
| Microphone crosstalk (no MI signal)           |       |            | - 40 | dB         | MIS = 1, MLI = 0, MIG = 1                         |
| <b>Line Input, LI to SLO pins</b>             |       |            |      |            |                                                   |
| Input bias                                    |       | $V_{DD}/2$ |      |            | Internal 100 kΩ bias resistor                     |
| LI input Gain (0dB)                           | - 0.5 |            | 0.5  | dB         | MIS = 0, MLI = 0, MIG = 0                         |
| LI input Gain (LO)                            | 21    | 22         | 23   | dB         | MIS = 1, MLI = 1, MIG = 0                         |
| LI input gain (HI)                            | 31    | 32         | 33   | dB         | MIS = 1, MLI = 1, MIG = 1                         |
| LI input crosstalk (no LI signal)             |       |            | - 40 | dB         | MIS = 1, MLI = 1, MIG = 1                         |
| <b>Soft Deviation Limiter, LI to SLO pins</b> |       |            |      |            |                                                   |
| Nominal gain                                  |       | 0          |      | dB         | Limiter not functioning.                          |
| Attenuation range                             | - 30  |            | - 29 | dB         |                                                   |
| Attenuation steps                             | 0.27  | 0.5        | 0.67 | dB         |                                                   |
| Distortion                                    |       |            | 2    | %THD       | Output at 1 Vrms                                  |
| Attack level:Hard limiter output              | 3     |            | 97   | % $V_{DD}$ |                                                   |
| Attack level at TBPO pin                      |       | 92         |      | % $V_{DD}$ | d.c. input at IPS<br>TEST[1:0] = 11               |
| Attack time                                   |       | 40         |      | μs         | Per gain step when signal outside threshold       |
| Decay time                                    |       | 1.68       |      | ms         | Per gain step                                     |
| <b>INPSENSE Gain Stage, IPS to TBPO pins</b>  |       |            |      |            |                                                   |
| Nominal gain                                  | 7.5   | 8          | 8.5  | dB         | Input = 100 mVrms,<br>INPS[4:0] = 15, THF = 0 dB, |
| Gain adjustment range                         | - 12  |            | 12.8 | dB         | Relative to nominal gain<br>Input = 100 mVrms,    |
| Gain step size                                | 0.6   | 0.8        | 1.2  | dB         | INPS[4:0] = 0 to 31, THF = 0 dB                   |

Note 1. 100% production tested at 25 °C but guaranteed over specified temperature range.

## ELECTRICAL CHARACTERISTICS

These characteristics are guaranteed over the following conditions unless otherwise stated (Note 1):

$T_{AMB} = -40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ ,  $V_{DD} = 3.6\text{ V}$  to  $5.0\text{ V}$

| Characteristic                                                  | Value  |      |        | Unit          | Conditions                                                                                                                                      |
|-----------------------------------------------------------------|--------|------|--------|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                 | Min.   | Typ. | Max.   |               |                                                                                                                                                 |
| TX Audio Bandpass Filter TXBPF, IPS to TBPO                     |        |      |        |               |                                                                                                                                                 |
| Noise                                                           |        |      | - 72   | dBV           |                                                                                                                                                 |
| Distortion                                                      |        |      | 1      | %THD          | 1 Vrms output                                                                                                                                   |
| Frequency response relative to 1040 Hz                          | - 60.5 |      | - 38.5 | dB            | f = 60 Hz                                                                                                                                       |
|                                                                 | - 25.5 |      | - 10.5 | dB            | f = 184 Hz INPSENSE = 0 dB                                                                                                                      |
|                                                                 | - 1.0  |      | + 0.5  | dB            | f = 430 Hz THF = 0 dB                                                                                                                           |
|                                                                 | - 0.5  |      | + 0.5  | dB            | f = 676 Hz, 1040 Hz                                                                                                                             |
|                                                                 | - 0.5  |      | + 0.5  | dB            | f = 1410 Hz, 1900 Hz                                                                                                                            |
|                                                                 | - 1.5  |      | - 0.5  | dB            | f = 3260 Hz                                                                                                                                     |
|                                                                 | - 3.0  |      | - 1.5  | dB            | f = 3500 Hz                                                                                                                                     |
|                                                                 | - 10.5 |      | - 5    | dB            | f = 4120 Hz                                                                                                                                     |
|                                                                 | - 20.5 |      | - 15.5 | dB            | f = 5590 Hz                                                                                                                                     |
|                                                                 | - 90.5 |      | - 30.5 | dB            | f = 9900 Hz                                                                                                                                     |
| TX Handsfree Gain Stage HFGAIN                                  |        |      |        |               |                                                                                                                                                 |
| Nominal gain                                                    |        | 0    |        | dB            |                                                                                                                                                 |
| Gain range                                                      | - 52.5 | - 49 | - 45.5 | dB            | THF[2:0] = 0 to 7                                                                                                                               |
| Gain step size                                                  | 6.5    | 7    | 7.5    | dB            | 0 to -21 dB                                                                                                                                     |
| Gain step size                                                  | 5      | 7    | 9      | dB            | -28 to -49 dB                                                                                                                                   |
| TX Compressor Stage, CIN to COUT pins                           |        |      |        |               |                                                                                                                                                 |
| Unity gain level                                                | 636    | 707  | 777    | mVrms         | = Vref (Unaffected level)                                                                                                                       |
| Input range                                                     | 0.79   |      | 1000   | mVrms         |                                                                                                                                                 |
| Linearity CIN to COUT:<br>(Deviation from 2:1 I/O relationship) |        |      | ± 0.5  | dB            | CIN = Vref + 3 dB to Vref - 59 dB<br>BW = 300 Hz to 3.4 kHz                                                                                     |
| Attack time                                                     |        | 3    |        | ms            | 12 dB step: - 8 dB to - 20 dB relative<br>to the unity gain (Vref) level<br>Attack & Decay levels = 1.5 and 0.75<br>of steady state final value |
| Decay time                                                      |        | 13.5 |        | ms            |                                                                                                                                                 |
| Distortion                                                      |        |      | 2      | %THD          | BW = 300 Hz - 3.4 kHz                                                                                                                           |
| Frequency response                                              |        |      | ± 0.2  | dB            | BW = 300 Hz - 3.4 kHz                                                                                                                           |
| TX Pre-emphasis, PREIN to TLPO pins                             |        |      |        |               |                                                                                                                                                 |
| Input impedance                                                 |        | 75   |        | kΩ            |                                                                                                                                                 |
| Internal compressor and BAR:                                    |        |      |        |               |                                                                                                                                                 |
| Nominal gain TACS                                               | - 7.5  | - 7  | - 6.5  | dB            | COMP[2:1] = 10 or 01 at 1 kHz                                                                                                                   |
| Nominal gain AMPS                                               | - 11.5 | - 11 | - 10.5 | dB            |                                                                                                                                                 |
| External compressor and bypass:                                 |        |      |        |               |                                                                                                                                                 |
| Nominal gain AMPS & TACS                                        | - 0.5  | 0    | + 0.5  | dB            | COMP[2:1] = 11 or 00 at 1 kHz                                                                                                                   |
| Frequency response                                              | 5.8    | 6    | 6.2    | dB/<br>Octave | TEST[1:0] = 01<br>PREEMPH = 0 (active)<br>f = 300 to 3400 Hz                                                                                    |

# ACE9040

## ELECTRICAL CHARACTERISTICS

These characteristics are guaranteed over the following conditions unless otherwise stated (Note 1):

$$T_{AMB} = -40^{\circ}\text{C to } +85^{\circ}\text{C}, V_{DD} = 3.6\text{ V to } 5.0\text{ V}$$

| Characteristic                                    | Value  |      |        | Unit  | Conditions                                                |
|---------------------------------------------------|--------|------|--------|-------|-----------------------------------------------------------|
|                                                   | Min.   | Typ. | Max.   |       |                                                           |
| <b>Hard Deviation Limiter</b>                     |        |      |        |       |                                                           |
| Gain                                              | 13     | 13.5 | 14     | dB    | V485 pin = 0 V (for V <sub>DD</sub> = 3.75 V)             |
|                                                   | 15.5   | 16   | 16.5   | dB    | V485 pin = V <sub>DD</sub> (for V <sub>DD</sub> = 4.85 V) |
| <b>Low Pass Filter TXLPF, PREIN to TLPO pins</b>  |        |      |        |       |                                                           |
| Distortion                                        |        |      | 1.5    | %THD  | 1.5 V <sub>p-p</sub> Output level                         |
| Noise                                             |        |      | - 60   | dBV   | BW = 30 Hz to 30 kHz                                      |
| Frequency response TACS/AMPS<br>Relative to 1 kHz | 0.3    |      | 0.7    | dB    | f = 307 Hz                                                |
|                                                   | - 0.5  |      | + 0.5  | dB    | f = 676 Hz, 1040 Hz                                       |
|                                                   | - 0.5  |      | + 0.5  | dB    | f = 1410 Hz, 1900 Hz                                      |
|                                                   | - 3.0  |      | - 1.5  | dB    | f = 3010 Hz                                               |
|                                                   | - 38.0 |      | - 13.0 | dB    | f = 3500 Hz                                               |
|                                                   | - 60.0 |      | - 38.0 | dB    | f = 4120 Hz                                               |
|                                                   | - 60.0 |      | - 38.0 | dB    | f = 5590 Hz                                               |
|                                                   | - 60.0 |      | - 38.0 | dB    | f = 9900 Hz                                               |
|                                                   | - 60.0 |      | - 35.0 | dB    | f = 11870 Hz                                              |
|                                                   | - 60.0 |      | - 35.0 | dB    | f = 14950 Hz                                              |
| Gain                                              | - 8.5  | - 8  | - 7.5  | dB    |                                                           |
| Attenuation with TXLPF bypassed                   |        | 8    |        | dB    | TEST[0] = 1                                               |
| <b>Gain Stage AUDIODEV, PREIN to TLPO</b>         |        |      |        |       |                                                           |
| Nominal gain                                      |        | 0    |        | dB    | Output at TLPO                                            |
| Gain adjustment                                   | - 2.8  |      | 3.2    | dB    |                                                           |
| Attenuation step size                             | 0.2    | 0.4  | 0.6    | dB    | Control bits: AUDEV[3:0]                                  |
| TXM switch attenuation                            |        |      | - 60   | dB    | AUDIODEV = 0 dB                                           |
| <b>Combined TX path</b>                           |        |      |        |       |                                                           |
| Gain with 3.5 μV at Microphone input              | 33.5   |      | 37.5   | dB    | INSENSE = 0 dB, V485 = 0 V                                |
| Distortion                                        |        |      | 1.0    | % THD | THF & AUDIODEV = 0 dB                                     |
| Noise                                             |        |      | - 55.0 | dBV   | MI gain = 22 dB, V <sub>DD</sub> = 3.6 V                  |
| Output d.c. level                                 | 1.65   |      | 1.9    | V     | Compressor Bypassed                                       |

**ELECTRICAL CHARACTERISTICS**

These characteristics are guaranteed over the following conditions unless otherwise stated (Note 1):

$$T_{AMB} = -40^{\circ}\text{C to } +85^{\circ}\text{C}, V_{DD} = 3.6\text{ V to } 5.0\text{ V}$$

| Characteristic                                             | Value  |            |           | Unit  | Conditions                                                                                                 |
|------------------------------------------------------------|--------|------------|-----------|-------|------------------------------------------------------------------------------------------------------------|
|                                                            | Min.   | Typ.       | Max.      |       |                                                                                                            |
| <b>Receive Path</b>                                        |        |            |           |       |                                                                                                            |
| <b>RX Input stage RXSENSE, RXI to RBPO pins</b>            |        |            |           |       |                                                                                                            |
| Input bias                                                 |        | $V_{DD}/2$ |           |       | Internally biased to $V_{DD}/2$ by 150 k $\Omega$                                                          |
| Nominal gain                                               | 7.25   | 8          | 8.75      | dB    |                                                                                                            |
| Gain adjustment range                                      | - 6    |            | 6.4       | dB    | Input 40 mVrms at RXI                                                                                      |
| Gain adjustment step size                                  | 0.2    | 0.4        | 0.6       | dB    | RXM = 1, RXSENSE = 0 to 31                                                                                 |
| <b>RX Audio Bandpass Filter RXBPF</b>                      |        |            |           |       |                                                                                                            |
| Gain                                                       |        | 0          |           | dB    |                                                                                                            |
| Distortion                                                 |        |            | 1         | %THD  | At 1 kHz with 40 mVrms input                                                                               |
| Noise                                                      |        |            | - 65      | dB    | BW= 30 Hz to 30 kHz                                                                                        |
| Frequency Response                                         | - 90.0 |            | - 45.0    | dB    | f = 60 Hz RXSENSE = 0 dB                                                                                   |
| Relative to 1040 Hz                                        | - 15.0 |            | - 7.0     | dB    | f = 184 Hz COMP[1:0] = 00                                                                                  |
|                                                            | - 2.0  |            | + 0.5     | dB    | f = 430 Hz                                                                                                 |
|                                                            | - 0.5  |            | + 0.5     | dB    | f = 676 Hz, 1040 Hz                                                                                        |
|                                                            | - 0.5  |            | + 0.5     | dB    | f = 1410 Hz, 1900 Hz                                                                                       |
|                                                            | - 3.0  |            | - 0.5     | dB    | f = 3260 Hz                                                                                                |
|                                                            | - 10.0 |            | - 6.0     | dB    | f = 3500 Hz                                                                                                |
|                                                            | - 40.0 |            | - 25.0    | dB    | f = 4120 Hz                                                                                                |
|                                                            | - 40.0 |            | - 25.0    | dB    | f = 5590 Hz                                                                                                |
|                                                            | - 90.0 |            | - 40.0    | dB    | f = 9900 Hz                                                                                                |
| RXM mute switch attenuation                                |        |            | - 40      | dB    | Output switched to $V_{DD}/2$ when muted.                                                                  |
| <b>Rx Internal Expander</b>                                |        |            |           |       |                                                                                                            |
| Gain EXPGAIN: internal                                     | 11.8   | 12.3       | 12.8      | dB    | COMP[2:1] = 10                                                                                             |
| external and bypass                                        |        | 0          |           | dB    | COMP[2:1] = 00 or 11                                                                                       |
| Unity gain level                                           | 850    | 1000       | 1100      | mVrms | = Vref (Unaffected level)                                                                                  |
| Linearity EIN to EOUT<br>(Deviation from 2:1 input/output) |        |            | $\pm 1$   | dB    | EIN = Vref to Vref - 33 dB<br>BW = 300 to 3400 Hz                                                          |
| Distortion                                                 |        |            | 2         | %THD  | 1 Vrms                                                                                                     |
| Frequency response                                         |        |            | $\pm 0.2$ | dB    | 300 to 3400 Hz                                                                                             |
| Attack time                                                |        | 3          |           | ms    | 6 dB step (- 4 dB and -10 dB) relative to the unity gain (Vref) level at 1 kHz to pin EIN. Output at EOUT. |
| Decay time                                                 |        | 13.5       |           | ms    | Attack and delay time levels = 0.57 and 1.5 of final steady state value.                                   |
| <b>RX Volume Control RXLEVEL</b>                           |        |            |           |       |                                                                                                            |
| Nominal Gain                                               | - 11   | - 12       | - 13      | dB    | RXV[2:0] = 3, RHF = 0 dB                                                                                   |
| Gain adjustment range                                      | - 9    |            | 12        | dB    | RXV[2:0] = 0 to 7                                                                                          |
| Gain adjust step size                                      | 2      | 3          | 4         | dB    | EARSENSE = 0 dB, Sidetone = 0 dB                                                                           |
| <b>RX Handsfree Gain Stage HFATTEN</b>                     |        |            |           |       |                                                                                                            |
| HFGAIN to EAMP nominal gain                                | - 0.4  | 0          | 0.4       | dB    | RHF, RVX, EARSENSE = 0 dB, SD = 0                                                                          |
| Gain range                                                 | - 52.5 | - 49       | - 45.5    | dB    | RHF[2:0] = 0 to 7                                                                                          |
| Gain control step size                                     | 6.5    | 7          | 7.5       | dB    | 0 to - 21 dB                                                                                               |
| Gain control step size                                     | 5      | 7          | 9         | dB    | - 28 to - 49 dB                                                                                            |
| <b>RX Line Driver LODRIVE</b>                              |        |            |           |       |                                                                                                            |
| LO gain                                                    | 4      | 5          | 6         | dB    | RVX = 0 dB, RHF = 0 dB, HIZ = 1                                                                            |
| Distortion                                                 |        |            | 2         | %THD  | 1.0 Vrms output                                                                                            |
| LO mute                                                    | - 40   |            |           | dB    | HIZ = 0                                                                                                    |
| Noise                                                      |        |            | - 80      | dBV   | BW = 30 Hz to 30 kHz                                                                                       |
| LO output during mute                                      | 1.5    | $V_{DD}/2$ | 2.1       | V     | $V_{DD}$ = 3.6 V                                                                                           |

## ELECTRICAL CHARACTERISTICS

These characteristics are guaranteed over the following conditions unless otherwise stated (Note 1):

$$T_{AMB} = -40^{\circ}\text{C to } +85^{\circ}\text{C}, V_{DD} = 3.6\text{ V to } 5.0\text{ V}$$

| Characteristic                                  | Value                                                                                             |            |                                                                                              | Unit                                                           | Conditions                                                                                                                                                                                                                                                 |
|-------------------------------------------------|---------------------------------------------------------------------------------------------------|------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                 | Min.                                                                                              | Typ.       | Max.                                                                                         |                                                                |                                                                                                                                                                                                                                                            |
| Rx Earpiece Gain Adjustment EARSENSE            |                                                                                                   |            |                                                                                              |                                                                |                                                                                                                                                                                                                                                            |
| Nominal gain                                    |                                                                                                   | 0          |                                                                                              | dB                                                             |                                                                                                                                                                                                                                                            |
| Total gain                                      | - 2.8                                                                                             |            | 3.2                                                                                          | dB                                                             | EARS[3:0] = 0 to 15                                                                                                                                                                                                                                        |
| Gain adjustment step size                       | 0.2                                                                                               | 0.4        | 0.6                                                                                          | dB                                                             | RVX = 0 dB, RHF = 0 dB, SD = 0                                                                                                                                                                                                                             |
| Distortion                                      |                                                                                                   |            | 1                                                                                            | % THD                                                          | Output 1 Vrms                                                                                                                                                                                                                                              |
| Rx Sidetone Path, IPS to EAMPI                  |                                                                                                   |            |                                                                                              |                                                                |                                                                                                                                                                                                                                                            |
| Attenuation at EARSENSE amp input               | 18                                                                                                | 19         | 20                                                                                           | dB                                                             | EARSENSE = 0 dB                                                                                                                                                                                                                                            |
| Sidetone mute                                   |                                                                                                   |            | - 40                                                                                         | dB                                                             | SD = 0                                                                                                                                                                                                                                                     |
| Rx Earpiece Drivers EPOP & EPON                 |                                                                                                   |            |                                                                                              |                                                                |                                                                                                                                                                                                                                                            |
| EPON single ended gain                          | 5.5                                                                                               | 6          | 6.5                                                                                          | dB                                                             | Output = 2 Vpp,<br>120 $\Omega$ EPON to EPOP                                                                                                                                                                                                               |
| EPOP single ended d.c. level                    | 1.7                                                                                               | $V_{DD}/2$ | 1.9                                                                                          | V                                                              | $V_{DD}$ = 3.6 V, EPH1 = 1, EPH0 = 0                                                                                                                                                                                                                       |
| EPOP single ended a.c. level                    |                                                                                                   |            | - 20                                                                                         | dB                                                             |                                                                                                                                                                                                                                                            |
| EPON single ended distortion                    |                                                                                                   |            | 1                                                                                            | % THD                                                          | Output = 2 Vpp                                                                                                                                                                                                                                             |
| EPON & EPOP differential gain                   | 11.5                                                                                              | 12         | 12.5                                                                                         | dB                                                             | 150 $\Omega$ ( $\pm$ 20 %) EPON to EPOP                                                                                                                                                                                                                    |
| EPOP differential distortion                    |                                                                                                   |            | 1                                                                                            | %THD                                                           | Output = 4 Vpp, EPH1 = 1, EPH0 = 1                                                                                                                                                                                                                         |
| Earpiece mute switch attenuation                | 40                                                                                                |            |                                                                                              | dB                                                             | EPH0 = 0 & EHP1 = 0                                                                                                                                                                                                                                        |
| EPON external mode:                             |                                                                                                   |            |                                                                                              |                                                                | 64 $\Omega$ ( $\pm$ 20 %) + 3.3 $\mu$ F to GND,<br>EAMPFB open, Input = HFGIN                                                                                                                                                                              |
| EPON gain relative to EAMPI                     | 5.5                                                                                               |            | 6.5                                                                                          | dB                                                             |                                                                                                                                                                                                                                                            |
| EPON distortion                                 |                                                                                                   |            | 1                                                                                            | % THD                                                          | Output = 1.1 Vpp                                                                                                                                                                                                                                           |
| EPOP output current external mode               | - 10                                                                                              |            | 10                                                                                           | $\mu$ A                                                        | At $V_{DD}$ & 0 V                                                                                                                                                                                                                                          |
| EPON & EPOP mute                                |                                                                                                   |            | - 40                                                                                         | dB                                                             | EPH1 = 0, EPH0 = 0                                                                                                                                                                                                                                         |
| EPOP Noise                                      |                                                                                                   |            | - 80                                                                                         | dBV                                                            | EPH1 = 1, EPH0 = 1                                                                                                                                                                                                                                         |
| Transmit Data Path                              |                                                                                                   |            |                                                                                              |                                                                |                                                                                                                                                                                                                                                            |
| TX Data Filter 16 kHz & 20 kHz                  |                                                                                                   |            |                                                                                              |                                                                |                                                                                                                                                                                                                                                            |
| Input bias at DATI                              |                                                                                                   | $V_{DD}/2$ |                                                                                              | V                                                              | Internally tied via 800 k $\Omega$ resistor to $V_{DD}/2$ .                                                                                                                                                                                                |
| Nominal gain                                    | - 6.5                                                                                             | - 6        | - 5.5                                                                                        | dB                                                             | Input = 1 Vrms                                                                                                                                                                                                                                             |
| Distortion                                      |                                                                                                   |            | 1.5                                                                                          | %THD                                                           | Output = 1.5 Vp-p                                                                                                                                                                                                                                          |
| Noise                                           |                                                                                                   |            | -60                                                                                          | dBV                                                            | BW = 30 Hz to 30 kHz                                                                                                                                                                                                                                       |
| DATM mute switch attenuation                    | 40                                                                                                |            |                                                                                              | dB                                                             |                                                                                                                                                                                                                                                            |
| Data Filter frequency response<br>16 kHz (TACS) | - 0.3<br>- 0.3<br>- 0.1<br>- 0.9<br>- 2.5<br>- 5.0<br>- 5.0<br>- 6.0<br>- 7.0<br>- 11.0<br>- 12.0 |            | 0.3<br>0.3<br>- 0.7<br>- 1.6<br>- 1.5<br>- 2.0<br>- 3.0<br>- 4.0<br>- 5.0<br>- 9.0<br>- 10.0 | dB<br>dB<br>dB<br>dB<br>dB<br>dB<br>dB<br>dB<br>dB<br>dB<br>dB | f = 676 Hz, 1040 Hz<br>f = 4120 Hz<br>f = 12120 Hz<br>f = 13960 Hz<br>f = 14950 Hz<br>f = 16050 Hz<br>f = 16420 Hz<br>f = 17040 Hz<br>f = 18020 Hz<br>f = 19990 Hz<br>f = 20970 Hz<br>DATM = 1<br>DATADEV = 0 dB<br>Relative to 1040 Hz<br>DATAF[1:0] = 10 |

**ELECTRICAL CHARACTERISTICS**

These characteristics are guaranteed over the following conditions unless otherwise stated (Note 1):

$$T_{AMB} = -40\text{ }^{\circ}\text{C to } +85\text{ }^{\circ}\text{C}, V_{DD} = 3.6\text{ V to } 5.0\text{ V}$$

| Characteristic                                  | Value              |      |       | Unit | Conditions                                                              |                       |
|-------------------------------------------------|--------------------|------|-------|------|-------------------------------------------------------------------------|-----------------------|
|                                                 | Min.               | Typ. | Max.  |      |                                                                         |                       |
| TX Data Filter 16 kHz & 20 kHz (continued)      |                    |      |       |      |                                                                         |                       |
| Data Filter frequency response<br>20 kHz (AMPS) | -0.3               |      | 0.3   | dB   | f = 676 Hz, 1040 Hz                                                     |                       |
|                                                 | -0.3               |      | 0.3   | dB   | f = 4120 Hz, 16050 Hz                                                   |                       |
|                                                 | -0.3               |      | -1.5  | dB   | f = 16050 Hz                                                            |                       |
|                                                 | -2.5               |      | -1.0  | dB   | f = 18020 Hz                                                            |                       |
|                                                 | -3.0               |      | -1.5  | dB   | f = 18880 Hz DATAF[1:0] = 11                                            |                       |
|                                                 | -4.0               |      | -2.0  | dB   | f = 20240 Hz DATM = 1                                                   |                       |
|                                                 | -5.0               |      | -3.0  | dB   | f = 20540 Hz DATADEV = 0dB                                              |                       |
|                                                 | -5.5               |      | -3.5  | dB   | f = 20970 Hz Relative to 1040 Hz                                        |                       |
|                                                 | -7.0               |      | -5.0  | dB   | f = 21960 Hz                                                            |                       |
|                                                 | -8.0               |      | -6.0  | dB   | f = 22820 Hz                                                            |                       |
|                                                 | -10.0              |      | -8.0  | dB   | f = 24050 Hz                                                            |                       |
| TX Data Gain Stage DATADEV, DATI to DATO pins   |                    |      |       |      |                                                                         |                       |
| Nominal gain                                    |                    | 0    |       | dB   |                                                                         |                       |
| Gain adjustment                                 | -2.8               |      | 3.2   | dB   | DATD[3:0] = 7                                                           |                       |
| Gain adjustment steps                           | 0.2                | 0.4  | 0.6   | dB   | DATM = 1 DATAF[1:0] = 00                                                |                       |
| TXSAT and RXSAT Bandpass Filters 6 kHz          |                    |      |       |      |                                                                         |                       |
| RXSAT Filter                                    |                    |      |       |      |                                                                         |                       |
| RXSAT gain                                      | 9                  |      | 11    | dB   | Input = 400 mVrms at 6030 Hz,<br>SATDEV = 0 dB, SATM = 1,<br>SATS = 0dB |                       |
| RXSAT 6 kHz frequency response                  | -90.0              |      | -35.0 | dB   | f = 2520 Hz Relative to 6030 Hz                                         |                       |
|                                                 | -90.0              |      | -35.0 | dB   | f = 3500 Hz SATS = 0 dB,                                                |                       |
|                                                 | -90.0              |      | -35.0 | dB   | f = 4120 Hz TACS = 1,                                                   |                       |
|                                                 | -29.0              |      | -24.0 | dB   | f = 4980 Hz SATD = 15 (0 dB),                                           |                       |
|                                                 | -0.30              |      | 0.50  | dB   | f = 5900 Hz SATM = 1                                                    |                       |
|                                                 | -0.10              |      | 0.35  | dB   | f = 5960 Hz                                                             |                       |
|                                                 | -0.10              |      | 0.35  | dB   | f = 6030 Hz                                                             |                       |
|                                                 | -0.30              |      | 0.50  | dB   | f = 6090 Hz                                                             |                       |
|                                                 | -26.5              |      | -22.0 | dB   | f = 7010 Hz                                                             |                       |
|                                                 | -90.0              |      | -29.0 | dB   | f = 8060 Hz                                                             |                       |
|                                                 | -90.0              |      | -35.0 | dB   | f = 9040 Hz                                                             |                       |
|                                                 | -90.0              |      | -35.0 | dB   | f = 9290 Hz                                                             |                       |
|                                                 | RSO Schmitt output | 5.5  | 6.0   | 6.5  | kHz                                                                     | SATS = 0 dB, TACS = 1 |

# ACE9040

## ELECTRICAL CHARACTERISTICS

These characteristics are guaranteed over the following conditions unless otherwise stated (Note 1):

$T_{AMB} = -40\text{ }^{\circ}\text{C}$  to  $+85\text{ }^{\circ}\text{C}$ ,  $V_{DD} = 3.6\text{ V}$  to  $5.0\text{ V}$

| Characteristic                       | Value  |      |        | Unit  | Conditions                                    |
|--------------------------------------|--------|------|--------|-------|-----------------------------------------------|
|                                      | Min.   | Typ. | Max.   |       |                                               |
| TXSAT Filter 6 kHz                   |        |      |        |       |                                               |
| TXSAT gain                           | - 29.0 |      | - 25.0 | dB    | TACS = 1, SATS = 1, Output = 1 Vpp at 6030 Hz |
| TXSAT 6 kHz frequency response       | - 90.0 |      | - 35.0 | dB    | f = 2520 Hz Relative to 6030 Hz               |
|                                      | - 90.0 |      | - 35.0 | dB    | f = 3500 Hz SATS = 1                          |
|                                      | - 90.0 |      | - 35.0 | dB    | f = 4120 Hz TACS = 1                          |
|                                      | - 29.0 |      | - 24.0 | dB    | f = 4980 Hz SATD = 15 (0 dB)                  |
|                                      | - 0.30 |      | 0.50   | dB    | f = 5900 Hz SATM = 1                          |
|                                      | - 0.10 |      | 0.35   | dB    | f = 5960 Hz                                   |
|                                      | - 0.10 |      | 0.35   | dB    | f = 6030 Hz                                   |
|                                      | - 0.30 |      | 0.50   | dB    | f = 6090 Hz                                   |
|                                      | - 26.5 |      | - 22.0 | dB    | f = 7010 Hz                                   |
|                                      | - 60.0 |      | - 35.0 | dB    | f = 8060 Hz                                   |
|                                      | - 60.0 |      | - 35.0 | dB    | f = 9040 Hz                                   |
|                                      | - 80.0 |      | - 35.0 | dB    | f = 9290 Hz                                   |
| TXSAT Noise                          |        |      | - 71.0 | dBV   |                                               |
| Gain Stage SATDEV                    |        |      |        |       |                                               |
| Nominal gain                         |        | 0    |        | dB    |                                               |
| Gain adjustment range                | - 4.5  |      | 4.8    | dB    | SATS = 0, TACS = 1, SATM = 1                  |
| Gain adjustment size                 | 0.05   | 0.3  | 0.55   | dB    | SATD[4:0] = 0 to 31                           |
| Distortion                           |        |      | 2      | % THD | Output = 1.1 Vpp                              |
| SATM switch mute attenuation         | 40     |      |        | dB    | SATM = 0                                      |
| DTMF Generator                       |        |      |        |       |                                               |
| DTMF output level                    | 60     |      | 85     | mVrms | V <sub>DD</sub> = 3.6 V, high & low tone      |
| DTMF single tone distortion:         |        |      |        |       |                                               |
| TONEM switch on (via TBPO)           |        |      | 5      | % THD | Low group, TONEM = 1                          |
| TONEM switch off                     |        |      | - 40   | dB    | TONEM = 0                                     |
| DTMF switch on (via RBPO)            |        |      | 5      | % THD | High group, DTMFM = 1                         |
| DTMF switch off                      |        |      | - 40   | dB    | DTMFM = 0                                     |
| DTMF high group pre-emphasis         | - 0.5  |      | 0.5    | dB    | DTWIST = 0                                    |
|                                      | 1.5    |      | 2.5    | dB    | DTWIST = 1                                    |
| Gain Stage TXSENSE, SUMI to MOD pins |        |      |        |       |                                               |
| Gain                                 | - 0.5  | 0    | 0.5    | dB    | Output at MOD.                                |
| Gain adjustment                      | - 2.8  |      | 3.2    | dB    | TXSEN[3:0] = 0 to 15                          |
| Gain adjustment step size            | 0.2    | 0.4  | 0.6    | dB    |                                               |
| Distortion                           |        |      | 2      | %THD  | Output = 1 Vrms                               |
| Noise                                |        |      | - 80   | dBV   | BW = 30 Hz to 30 kHz                          |

**ELECTRICAL CHARACTERISTICS**

These characteristics are guaranteed over the following conditions unless otherwise stated (Note 1):

$T_{AMB} = -40\text{ }^{\circ}\text{C}$  to  $+85\text{ }^{\circ}\text{C}$ ,  $V_{DD} = 3.6\text{ V}$  to  $5.0\text{ V}$

| Characteristic                                                | Value               |                     |      | Unit          | Conditions                                                                  |
|---------------------------------------------------------------|---------------------|---------------------|------|---------------|-----------------------------------------------------------------------------|
|                                                               | Min.                | Typ.                | Max. |               |                                                                             |
| <b>Handsfree Rectifiers</b>                                   |                     |                     |      |               |                                                                             |
| Attack time                                                   |                     | 1                   |      | ms            | Capacitors to GND =<br>68 nF at TXC & RXC pins                              |
| Decay time                                                    |                     | 35                  |      | ms            |                                                                             |
| TX nominal output levels:                                     |                     |                     |      |               | $V_{DD} = 3.75\text{ V}$                                                    |
| d.c. offset                                                   | 0.3                 |                     | 0.5  | V             | Input at IPS = 0 mVrms                                                      |
| a.c. level                                                    | 1.4                 | 1.5                 | 1.6  | V             | Input at IPS = 40 mVrms, 1 kHz<br>INPSENSE = 0 dB, HFS = 0<br>HFP = 1       |
| RX nominal output levels:                                     |                     |                     |      |               | $V_{DD} = 3.75\text{ V}$                                                    |
| d.c. offset                                                   | 0.3                 |                     | 0.5  | V             | Input at HFGIN = 0 mVrms                                                    |
| a.c. level                                                    | 1                   | 1.1                 | 1.2  | V             | Input at HFGIN = 100 mVrms, 1 kHz<br>HFS = 1, HFP = 1                       |
| <b>Voltage Outputs</b>                                        |                     |                     |      |               |                                                                             |
| DEC & BIAS output voltage                                     | 1.70                | $(V_{DD}-V_{SS})/2$ | 1.9  | V             | $V_{DD} = 3.6\text{ V}$ , 3.3 $\mu\text{F}$ decoupling to<br>GND at DEC pin |
| Microphone Bias:                                              | Source 1 mA         | 2.7                 | 2.9  | V             | $V_{DD} = 3.6\text{ V}$<br>PD = 0                                           |
|                                                               | Sink 1 mA           | 2.7                 | 2.9  | V             |                                                                             |
|                                                               | Microphone disabled | -0.1                | 0.10 | V             |                                                                             |
| External Reference Resistor<br>connected from pin RREF to GND |                     | 100                 |      | k $\Omega$    | $V_{DD} = 4.85\text{ V}$                                                    |
|                                                               |                     | 68                  |      | k $\Omega$    | $V_{DD} = 3.75\text{ V}$                                                    |
| Bandgap at BGAP                                               | 1.10                |                     | 1.35 | V             |                                                                             |
| <b>LVN Supply Voltage Comparator</b>                          |                     |                     |      |               |                                                                             |
| $V_{DD} = 3.6\text{ V}$                                       | -10                 |                     | 10   | $\mu\text{A}$ | Default condition<br>(high at $V_{DD} - 0.2\text{ V}$ )<br>(low at 0.4 V)   |
| $V_{DD} = 3.1\text{ V}$                                       | 2.00                |                     | 20.0 | mA            |                                                                             |
| LVN comparator operating lower limit<br>of $V_{DD}$           |                     | 1                   |      | V             |                                                                             |

## ELECTRICAL CHARACTERISTICS

These characteristics are guaranteed over the following conditions unless otherwise stated (Note 1):

$T_{AMB} = -40\text{ }^{\circ}\text{C}$  to  $+85\text{ }^{\circ}\text{C}$ ,  $V_{DD} = 3.6\text{ V}$  to  $5.0\text{ V}$

| Characteristic                                       | Symbol           | Value                 |       |                       | Unit         | Conditions                                                                                                    |
|------------------------------------------------------|------------------|-----------------------|-------|-----------------------|--------------|---------------------------------------------------------------------------------------------------------------|
|                                                      |                  | Min.                  | Typ.  | Max.                  |              |                                                                                                               |
| DC Characteristics                                   |                  |                       |       |                       |              |                                                                                                               |
| Logic input high                                     | V <sub>IH</sub>  | 0.7 x V <sub>DD</sub> |       | V <sub>DD</sub> + 0.3 | V            |                                                                                                               |
| Logic input low                                      | V <sub>IL</sub>  | - 0.3                 |       | 0.3 x V <sub>DD</sub> | V            |                                                                                                               |
| Input Capacitance                                    | C <sub>in</sub>  |                       |       | 10                    | pF           |                                                                                                               |
| logic inputs leakage current                         | I <sub>LX</sub>  |                       |       | ± 1                   | µA           | SCLK, SD, LEN inputs<br>V <sub>DD</sub> = 3.6 V & 0.0 V                                                       |
| AC Characteristics                                   |                  |                       |       |                       |              |                                                                                                               |
| Clock input frequency: Serial interface & SC Filters | f <sub>CLK</sub> |                       | 1.008 |                       | MHz          | Deviation from 1.008 MHz                                                                                      |
|                                                      |                  | -100                  |       | 100                   | ppm          |                                                                                                               |
| Clock duty cycle                                     | D                | 40                    | 50    | 60                    | %            |                                                                                                               |
| Number of clock rising edges to input data           |                  | 24                    |       |                       | clock cycles |                                                                                                               |
| Clock cycles between latch pulses on LEN             |                  | 30                    |       |                       | clock cycles |                                                                                                               |
| Clock cycles before power-up and after powerdown     |                  | 8                     |       |                       | clock cycles |                                                                                                               |
| Data setup time                                      | t <sub>ds</sub>  | 80                    |       |                       | ns           | V <sub>DD</sub> = 3.75 V ± 0.1 V.                                                                             |
| Data hold time                                       | t <sub>dh</sub>  | 80                    |       |                       | ns           | T <sub>A</sub> = - 40 °C to + 85 °C                                                                           |
| Clock low                                            | t <sub>cl</sub>  | 400                   |       | 600                   | ns           |                                                                                                               |
| Clock high                                           | t <sub>ch</sub>  | 400                   |       | 600                   | ns           |                                                                                                               |
| Clock high to latch high                             | t <sub>clh</sub> | 440                   |       |                       | ns           |                                                                                                               |
| Latch high to clock high                             | t <sub>lch</sub> | 220                   |       |                       | ns           |                                                                                                               |
| Latch high                                           | t <sub>lh</sub>  | 240                   |       |                       | ns           |                                                                                                               |
| Rise and fall times                                  |                  |                       |       | 50                    | ns           | All digital inputs                                                                                            |
| Power Supply Rejection Ratio:                        | PSRR             |                       |       |                       |              | V <sub>DD</sub> = 3.8 V + 100 mVpp (a.c.)<br>COMP[2:1] = 00.                                                  |
| TX path (LI to TLPO)                                 |                  |                       |       | - 12                  | dB           | LI = 0 dB, V485 = 13.5 dB                                                                                     |
| RX path (RXI to EPOP)                                |                  |                       |       | - 20                  | dB           | INPSENSE = 0 dB, softlimit on.<br>AUDIODEV, RXSENSE = 0 dB<br>THF, RHF, EARSENSE = 0 dB<br>RXV, SIDETONE off. |
| Crosstalk TX to RX (MOD to EPOP/EPON)                |                  |                       |       | -45                   | dB           | MOD = 0.2 V <sub>RMS</sub>                                                                                    |

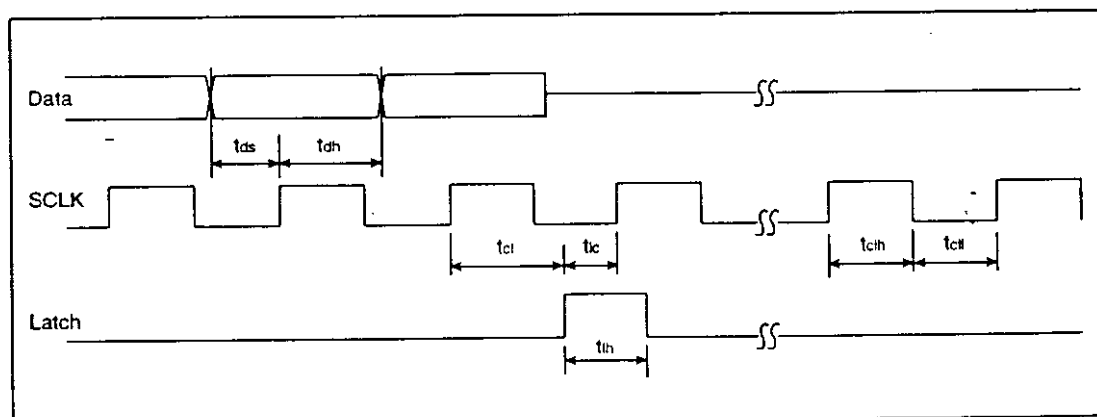


Fig.3a Serial Interface Input Timing

## TYPICAL FREQUENCY RESPONSES

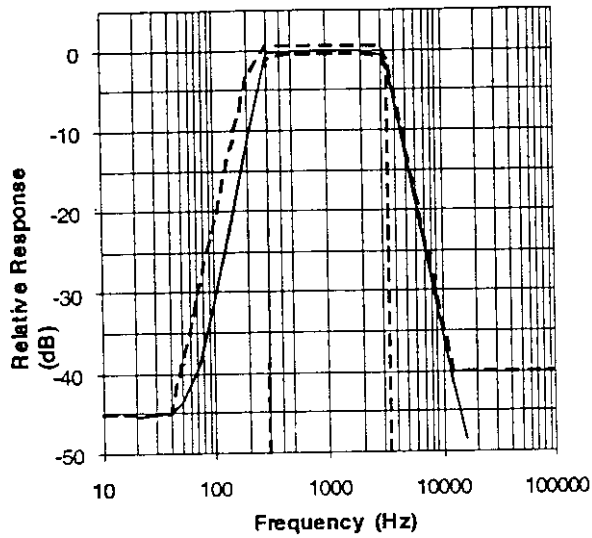
TXBPF Relative Response  
vs Frequency

Figure 4

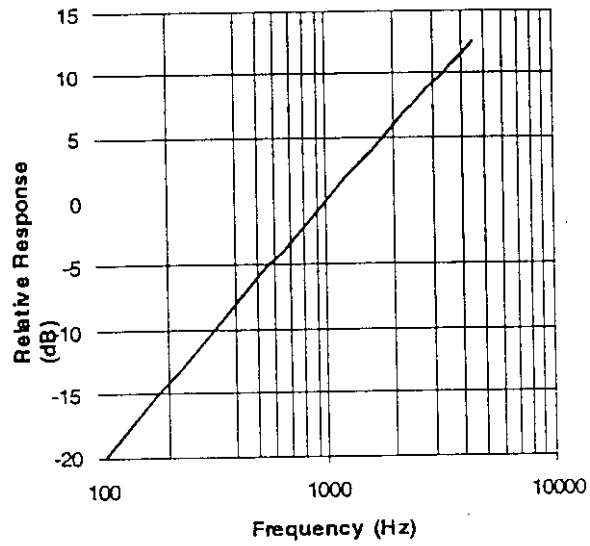
Pre-emphasis Relative Response  
vs Frequency

Figure 5

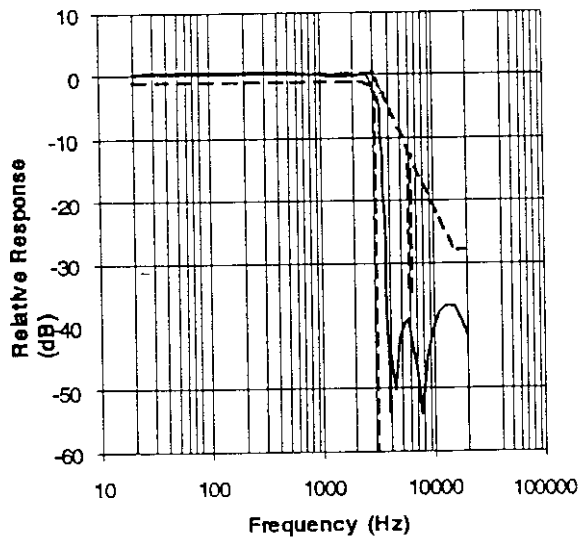
TXLPF Relative Response  
vs Frequency

Figure 6

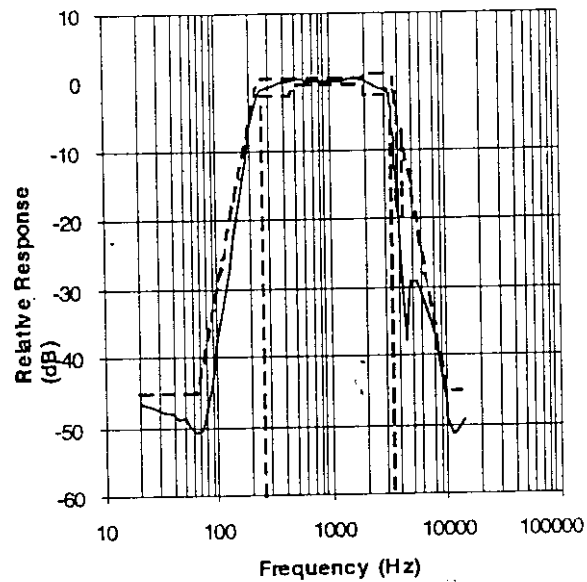
RXBPF Relative Response  
vs Frequency

Figure 7

TYPICAL FREQUENCY RESPONSES

Transmit Overall Relative Response vs Frequency

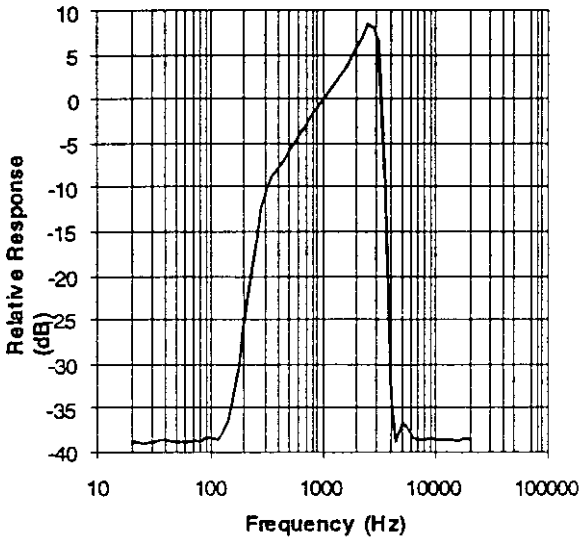


Figure 8

SAT Filter Relative Response vs Frequency

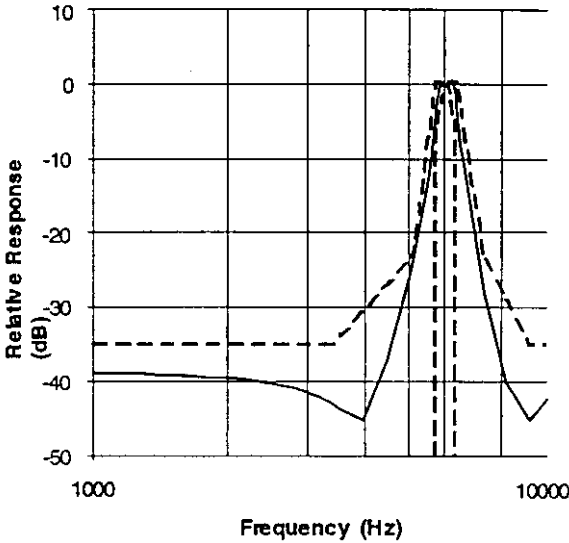


Figure 9

## DESCRIPTION

ACE9040 combines all the voice, data and signalling processing circuits for analog cellular telephones operating with the AMPS or TACS systems.

Transmit channel functions comprise a microphone amplifier, soft limiter, bandpass speech filter, compressor, pre-emphasis filter, hard limiter, lowpass transmit filter and a gain control stage to set the deviation. Additional transmit circuits include a DTMF generator, a lowpass filter for either control data or signalling tone (ST), filters for supervisory audio tone (SAT), either transponded or locally re-generated, and deviation setting amplifiers for Data, ST and SAT. The outputs from the transmit functions feed a modulation combiner whose gain can be adjusted before driving a modulator and external power amplifier.

ACE9040's receive path consists of a bandpass filter, expander, volume control and power amplifier to directly drive the earpiece, either differentially or in single ended modes. Sidetone and DTMF tones can be introduced into the receive path.

Gain settings, filter characteristics and system control is programmed via a three wire serial interface to give optimum operation with either the AMPS or TACS analog cellular systems.

To implement a handsfree function, both transmit and receive paths have rectifiers which enable signal amplitude monitoring via an external pin and signal path attenuators controlled via the serial interface.

All filter characteristics are set by ratioed on-chip components and by a fixed externally input clock rate of 1.008 MHz and do not need trimming, filter response options are selected via the serial interface.

Gain adjustments for different system specifications and component tolerancing are set via the serial interface using gain control blocks in the transmit and receive signal paths. These eliminate the need for any mechanically adjusted potentiometers. Some gain levels change automatically when

the control bits for one of the standards are set, others are under user control.

Power saving operates when an individual block is de-selected and for the whole circuit when in Standby. The circuit combines high performance with minimum power consumption and uses as few external components as possible.

## SERIAL CONTROL BUS

All functions are controlled via a three wire serial interface. Input is via pins SD for serial data, SCLK for the clock input and LEN for the control message latch signal.

Incoming data bits are clocked in on the rising edges of SCLK clock input. At the end of each control message comprising three 8-bit data bytes, the rising edge of the LEN pulse latches in the data. A system controller should clock data out on clock falling edges to ensure the maximum timing margins.

The SCLK clock input must be at 1.008 MHz and continuous whenever the ACE9040 is active because ACE9040's switched capacitor filters use clocks derived from SCLK to set frequency responses.

ACE9040 expects a minimum of 30 clock cycles between LEN latch pulses, including the clock cycle containing the latch pulse. A minimum of 8 clock cycles before the beginning of an Operate command or after a Standby command are expected.

Three data bytes DATA1, DATA2, and DATA3 contain bits for system selection, control and mute switches, gain control and filter response settings, as shown in figure 10. The last two bits of DATA3, DATA3[1] and [0], determine the message type, either "Operation", "Initializing mode 0", "Initializing mode 1" or "Handsfree". The details of these four modes are described in tables 2 to 19.

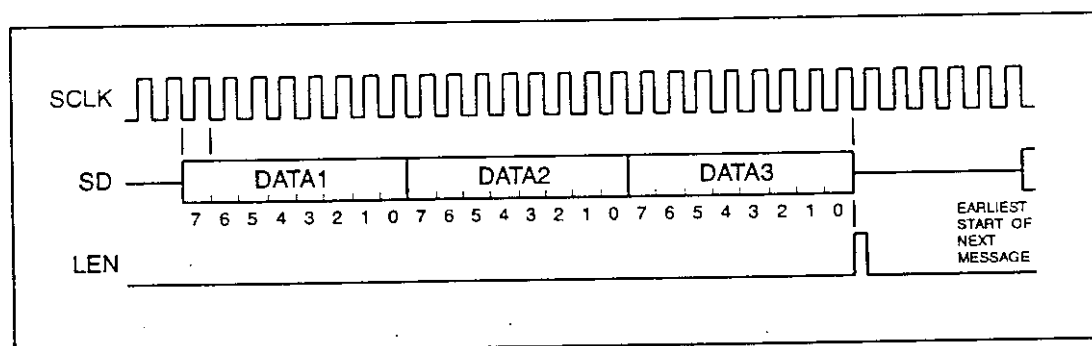


Fig. 10 Serial Receive Bus Timing

| DATA3[1] | DATA3[0] | Mode                  |
|----------|----------|-----------------------|
| 0        | 1        | "Operation"           |
| 0        | 0        | "Initializing mode 0" |
| 1        | 0        | "Initializing mode 1" |
| 1        | 1        | "Handsfree"           |

Table 1 Mode Selections

## CONTROL BUS: OPERATION MODE

| Data bit | Bit Name      | Function                         | Effect when at 0 | Effect when at 1 |
|----------|---------------|----------------------------------|------------------|------------------|
| DATA3:   |               |                                  |                  |                  |
| [0]      | DATA3[0]      | Bus Mode Select                  | Must be "1"      | Must be "1"      |
| [1]      | DATA3[1]      | Bus Mode Select                  | Must be "0"      | Must be "0"      |
| [2]      | PD            | Power Down                       | Operate          | Standby          |
| [5:3]    | RXV[2:0]      | Receive Volume                   | See table 3      | See table 3      |
| [6]      | HIZ           | Line Output Drive Enable         | Off              | On               |
| [7]      | EPH1          | Earpiece Mute                    | See table 5      | See table 5      |
| DATA2:   |               |                                  |                  |                  |
| [0]      | RXM           | Receiver Audio Mute              | Muted            | On               |
| [1]      | SATM          | Transmit SAT Mute                | Muted            | On               |
| [2]      | DATM          | Transmit Data Mute               | Muted            | On               |
| [3]      | TXM           | Transmit Audio Mute              | Muted            | On               |
| [4]      | MLI           | Microphone Select                | See table 4      | See table 4      |
| [5]      | DTMFEN        | Enables each DTMF tone selection | Disabled         | Enabled          |
| [7:6]    | DTMFMODE[1:0] | DTMF Tone Select                 | See table 6      | See table 6      |
| DATA1:   |               |                                  |                  |                  |
| [0]      | DTMFM         | Transmit DTMF Switch             | Speech           | DTMF             |
| [1]      | TONEM         | DTMF RX path Confirm Tone Switch | Speech           | DTMF             |
| [5:2]    | DTMF[3:0]     | DTMF Code Select                 | See table 7      | See table 7      |
| [6]      | MIS           | Line Input Select                | See table 4      | See table 4      |
| [7]      | PREEMPH       | Transmit Pre-emphasis Bypass     | Active           | Bypassed         |

Table 2 "Operation Mode", DATA3[1:0] = 01.

| RXV[2] | RXV[1] | RXV[0] | Gain in dB |
|--------|--------|--------|------------|
| 0      | 0      | 0      | -21        |
| 0      | 0      | 1      | -18        |
| 0      | 1      | 0      | -15        |
| 0      | 1      | 1      | -12        |
| 1      | 0      | 0      | -9         |
| 1      | 0      | 1      | -6         |
| 1      | 1      | 0      | -3         |
| 1      | 1      | 1      | 0          |

Table 3 Receiver Volume Control Nominal Levels set by RXV[2:0].

| EPH1 | EPH0 | Function                            |
|------|------|-------------------------------------|
| 0    | 0    | Earphone mute                       |
| 0    | 1    | External Earpiece (EPON to ground)  |
| 1    | 0    | Single ended output (EPON to EPOP)  |
| 1    | 1    | Differential output (EPON and EPOP) |

Table 5 Earphone Mode Select  
(EPH0 in Initializing mode 0)

| DTMFMODE[1:0] bits<br>1 and 0 | Tone generated       |
|-------------------------------|----------------------|
| 0 and 0                       | No tone.             |
| 0 and 1                       | Low frequency only.  |
| 1 and 0                       | High frequency only. |
| 1 and 1                       | Dual tones.          |

Table 6 DTMF Mode Selection

| MLI | MIS | Function                 |
|-----|-----|--------------------------|
| 0   | 0   | LI selected, no gain     |
| 0   | 1   | MI selected, Micamp gain |
| 1   | 0   | NOT ALLOWED              |
| 1   | 1   | LI selected, Micamp gain |

Table 4 Microphone Input Select

| DTMF[3:0] bits<br>3 2 1 0 | Keypad<br>legend | Low Freq.<br>Hz. | High Freq.<br>Hz. |
|---------------------------|------------------|------------------|-------------------|
| 0 0 0 0                   | 1                | 697              | 1209              |
| 0 0 0 1                   | 2                | 697              | 1336              |
| 0 0 1 0                   | 3                | 697              | 1477              |
| 0 0 1 1                   | A                | 697              | 1633              |
| 0 1 0 0                   | 4                | 770              | 1209              |
| 0 1 0 1                   | 5                | 770              | 1336              |
| 0 1 1 0                   | 6                | 770              | 1477              |
| 0 1 1 1                   | B                | 770              | 1633              |
| 1 0 0 0                   | 7                | 852              | 1209              |
| 1 0 0 1                   | 8                | 852              | 1336              |
| 1 0 1 0                   | 9                | 852              | 1477              |
| 1 0 1 1                   | C                | 852              | 1633              |
| 1 1 0 0                   | *                | 941              | 1209              |
| 1 1 0 1                   | 0                | 941              | 1336              |
| 1 1 1 0                   | #                | 941              | 1477              |
| 1 1 1 1                   | D                | 941              | 1633              |

Table 7 DTMF Tones

## CONTROL BUS: INITIALIZING MODE 0

| Data bit | Bit Name   | Function                   | Effect when at 0 | Effect when at 1 |
|----------|------------|----------------------------|------------------|------------------|
| DATA3:   |            |                            |                  |                  |
| [0]      | DATA3[0]   | Bus Mode Select            | Must be "0"      | Must be "0"      |
| [1]      | DATA3[1]   | Bus Mode Select            | Must be "0"      | Must be "0"      |
| [2]      | EPH0       | Earpiece Mode Select       | See table 5      | See table 5      |
| [3]      | DTWIST     | DTMF Pre-emphasis          | 0 dB             | 2 dB             |
| [4]      | PDLVC      | Power Supply Comparator    | Active           | Power Down       |
| [6:5]    | COMP[2:1]  | Compander Control          | See table 9      | See table 9      |
| [7]      | INPS[0]    | Transmit Audio Gain Adjust | See table 10     | See table 10     |
| DATA2:   |            |                            |                  |                  |
| [3:0]    | INPS[4:1]  | Transmit Audio Gain Adjust | See table 10     | See table 10     |
| [7:4]    | RXSEN[3:0] | Receive Audio Gain Adjust  | See table 11     | See table 11     |
| DATA1:   |            |                            |                  |                  |
| [0]      | RXSEN[4]   | Receive Audio Gain Adjust  | See table 11     | See table 11     |
| [5:1]    | SATD[4:0]  | SAT Modulation Gain        | See table 12     | See table 12     |
| [6]      | SD         | Sidetone Enable            | Off              | On               |
| [7]      | SOFTLIMIT  | Enables Softlimiter        | Off              | On               |

Table 8 "Initializing Mode 0", DATA3[1:0] = 00.

| COMP[2] | COMP[1] | Mode                                              |
|---------|---------|---------------------------------------------------|
| 0       | 0       | Bypass Compander                                  |
| 1       | 0       | Internal Compander                                |
| 1       | 1       | External Compander                                |
| 0       | 1       | BAR Signal Input Mode<br>(RBPO at high impedance) |

Table 9 Compander Operating Modes set by COMP[2:1].

| INPS[4] | INPS[3] | INPS[2] | INPS[1] | INPS[0] | Gain (dB) |
|---------|---------|---------|---------|---------|-----------|
| 0       | 0       | 0       | 0       | 0       | -12.0     |
| 0       | 0       | 0       | 0       | 1       | -11.2     |
| :       | :       | :       | :       | :       | :         |
| :       | :       | :       | :       | :       | :         |
| 1       | 1       | 1       | 1       | 0       | +12.0     |
| 1       | 1       | 1       | 1       | 1       | +12.8     |

Table 10 INPSENSE Transmit Audio Nominal Gain settings by INPS[4:0].

| RXSEN[4] | RXSEN[3] | RXSEN[2] | RXSEN[1] | RXSEN[0] | Gain (dB) |
|----------|----------|----------|----------|----------|-----------|
| 0        | 0        | 0        | 0        | 0        | -6.0      |
| 0        | 0        | 0        | 0        | 1        | -5.6      |
| :        | :        | :        | :        | :        | :         |
| :        | :        | :        | :        | :        | :         |
| 1        | 1        | 1        | 1        | 0        | +6.0      |
| 1        | 1        | 1        | 1        | 1        | +6.4      |

Table 11 RXSENSE Receive Audio Nominal Gain settings by RXSEN[4:0].

| SATD[4] | SATD[3] | SATD[2] | SATD[1] | SATD[0] | Gain (dB) |
|---------|---------|---------|---------|---------|-----------|
| 0       | 0       | 0       | 0       | 0       | -4.5      |
| 0       | 0       | 0       | 0       | 1       | -4.2      |
| :       | :       | :       | :       | :       | :         |
| :       | :       | :       | :       | :       | :         |
| 1       | 1       | 1       | 1       | 0       | +4.5      |
| 1       | 1       | 1       | 1       | 1       | +4.8      |

Table 12 SATDEV Transmit SAT Nominal Modulation Gain settings by SATD[4:0].

ACE9040

CONTROL BUS: INITIALIZING MODE 1

| Data bit | Bit Name   | Function                     | Effect when at 0 | Effect when at 1 |
|----------|------------|------------------------------|------------------|------------------|
| DATA3:   |            |                              |                  |                  |
| [0]      | DATA3[0]   | Bus Mode Select              | Must be "0"      | Must be "0"      |
| [1]      | DATA3[1]   | Bus Mode Select              | Must be "1"      | Must be "1"      |
| [3:2]    | TEST[1:0]  | Test Mode Select             | see table 14     | see table 14     |
| [4]      | SATS       | SAT source Select            | RXSAT            | TXSAT            |
| [6:5]    | DATAF[1:0] | Data Filter Bandwidth Select | see table 15     | see table 15     |
| [7]      | TACS       | Cellular System Select       | *                | TACS*            |
| DATA2:   |            |                              |                  |                  |
| [3:0]    | TXSEN[3:0] | Combined Modulation Gain     | see table 16     | see table 16     |
| [7:4]    | DATD[3:0]  | Data Modulation Gain         | see table 16     | see table 16     |
| DATA1:   |            |                              |                  |                  |
| [3:0]    | AUDEV[3:0] | Audio Modulation Gain        | see table 16     | see table 16     |
| [7:4]    | EARS[3:0]  | Earpiece "EARSENSE" Gain     | see table 16     | see table 16     |

\*See table 19.

Table 13 "Initializing Mode 1", DATA3[1:0] = 10.

| TEST[1] | TEST[0] | Test Mode                       |
|---------|---------|---------------------------------|
| 0       | 0       | Operate mode (not in test mode) |
| 1       | 0       | Test DTMF                       |
| 0       | 1       | Bypass TXLPF                    |
| 1       | 1       | Bypass TXLPF & Softlimiter test |

Table 14 Test Modes selected by TEST[1:0].

| DATAF[1] | DATAF[0] | Cut-off Frequency |
|----------|----------|-------------------|
| 1        | 0        | 16 kHz            |
| 1        | 1        | 20 kHz            |

Table 15 Data Filter Bandwidths selected by DATAF[1:0].

| TXSEN[3]<br>DATD[3]<br>AUDEV[3]<br>EARS[3] | TXSEN[2]<br>DATD[2]<br>AUDEV[2]<br>EARS[2] | TXSEN[1]<br>DATD[1]<br>AUDEV[1]<br>EARS[1] | TXSEN[0]<br>DATD[0]<br>AUDEV[0]<br>EARS[0] | Gain<br>(dB) |
|--------------------------------------------|--------------------------------------------|--------------------------------------------|--------------------------------------------|--------------|
| 0                                          | 0                                          | 0                                          | 0                                          | -2.8         |
| 0                                          | 0                                          | 0                                          | 1                                          | -2.4         |
| :                                          | :                                          | :                                          | :                                          | :            |
| :                                          | :                                          | :                                          | :                                          | :            |
| 1                                          | 1                                          | 1                                          | 0                                          | +2.8         |
| 1                                          | 1                                          | 1                                          | 1                                          | +3.2         |

Table 16 TXSENSE, DATADEV, AUDIODEV, and EARSENSE Nominal Gains set, respectively, by TXSEN[3:0], DATD[3:0], AUDEV[3:0], and EARS[3:0].

## CONTROL BUS: HANDSFREE MODE

| Data bit                                                  | Bit Name                                               | Function                                                                                                                      | Effect when at 0                                           | Effect when at 1                                                       |
|-----------------------------------------------------------|--------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------------------------|
| DATA3:<br>[0]<br>[1]<br>[4:2]<br>[7:5]                    | DATA3[0]<br>DATA3[1]<br>THF[2:0]<br>RHF[2:0]           | Bus Mode Select<br>Bus Mode Select<br>Transmit Handsfree Gain<br>Receive Handsfree Gain                                       | Must be "1"<br>Must be "1"<br>see table 18<br>see table 18 | Must be "1"<br>Must be "1"<br>see table 18<br>see table 18             |
| DATA2:<br>[0]<br>[1]<br>[2]<br>[4:3]<br>[5]<br>[6]<br>[7] | HFP<br>HFS<br>MIG<br>not used<br>AMPS<br>not used<br>- | Handsfree Rectifiers Power<br>HF Output Connection Path<br>Microphone Amplifier Gain<br>-<br>Cellular System Select<br>-<br>- | Off<br>Transmit<br>+ 22 dB<br>-<br>-<br>must be "0"        | On<br>Receive<br>+ 32 dB<br>-<br>AMPS <sup>†</sup><br>-<br>must be "0" |
| DATA1:<br>[2:0]<br>[5:3]<br>[7:6]                         | -<br>not used<br>not used                              | -<br>-<br>-                                                                                                                   | must be "0"<br>-<br>-                                      | must be "0"<br>-<br>-                                                  |

<sup>†</sup>See table 19.

Table 17 "Handsfree Mode", DATA3[1:0] = 11.

| THF[2]<br>RHF[2] | THF[1]<br>RHF[1] | THF[0]<br>RHF[0] | Gain<br>(dB) |
|------------------|------------------|------------------|--------------|
| 0                | 0                | 0                | 0            |
| 0                | 0                | 1                | - 7          |
| 0                | 1                | 0                | - 14         |
| 0                | 1                | 1                | - 21         |
| 1                | 0                | 0                | - 28         |
| 1                | 0                | 1                | - 35         |
| 1                | 1                | 0                | - 42         |
| 1                | 1                | 1                | - 49         |

Table 18 TXHFGAIN and RXHFGAIN Handsfree Attenuator  
Nominal Gains, set by THF[2:0] and RHF[2:0].

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CIRCUIT OPERATING MODES

ACE9040 has three operating modes: Operate, Standby and Sleep. In Operate mode all parts of the circuit are active, except for any explicitly powered down and the DTMF generator which only powers up when tones are generated. The pin STBY is pulled high in Operate mode to supply  $V_{DD}$  to external audio circuits, such as a compander.

Standby Mode

Standby mode is used when the cellular terminal is waiting for a call and is selected by an "Operation mode" control message with bit PD at "1". In this mode all analog circuits, data paths, filters and their clock drivers are powered down giving a greatly reduced supply current. In standby mode all switch and level controls retain their previous state, the pin STBY is not driven removing the  $V_{DD}$  supply from external circuits. To leave Standby mode an operate command should be given by using an "Operation mode" control message with bit PD at "0".

Sleep Mode

Sleep mode is the same as Standby but without a clock input. To enter sleep mode the standby command should be given and after a delay of at least 20  $\mu$ s the SCLK clock stopped. To wake-up from sleep mode, the SCLK clock must be started and after a delay of at least 100  $\mu$ s an operate command given.

Power on Reset

At power up ACE9040 is put into Standby mode. ACE9040 is set up by the controlling processor via the serial interface using four control messages: "Operation", "Initializing mode 0", "Initializing mode 1" and "Handsfree". Usually the "Operation" control message would be sent last as it contains the power down/up bit PD.

CELLULAR SYSTEM SELECTION

Two control bits are used to set the filter responses and gain levels for the AMPS or TACS cellular systems. These bits are TACS in control message "Initializing mode 1" and AMPS in control message "Handsfree mode" and select the system as shown in table 19.

| Bits |      | System Selected |
|------|------|-----------------|
| AMPS | TACS |                 |
| 0    | 0    | Not valid       |
| 0    | 1    | TACS            |
| 1    | 0    | AMPS            |
| 1    | 1    | Not valid       |

Table 19 Cellular System Selection

TRANSMIT VOICE PATH

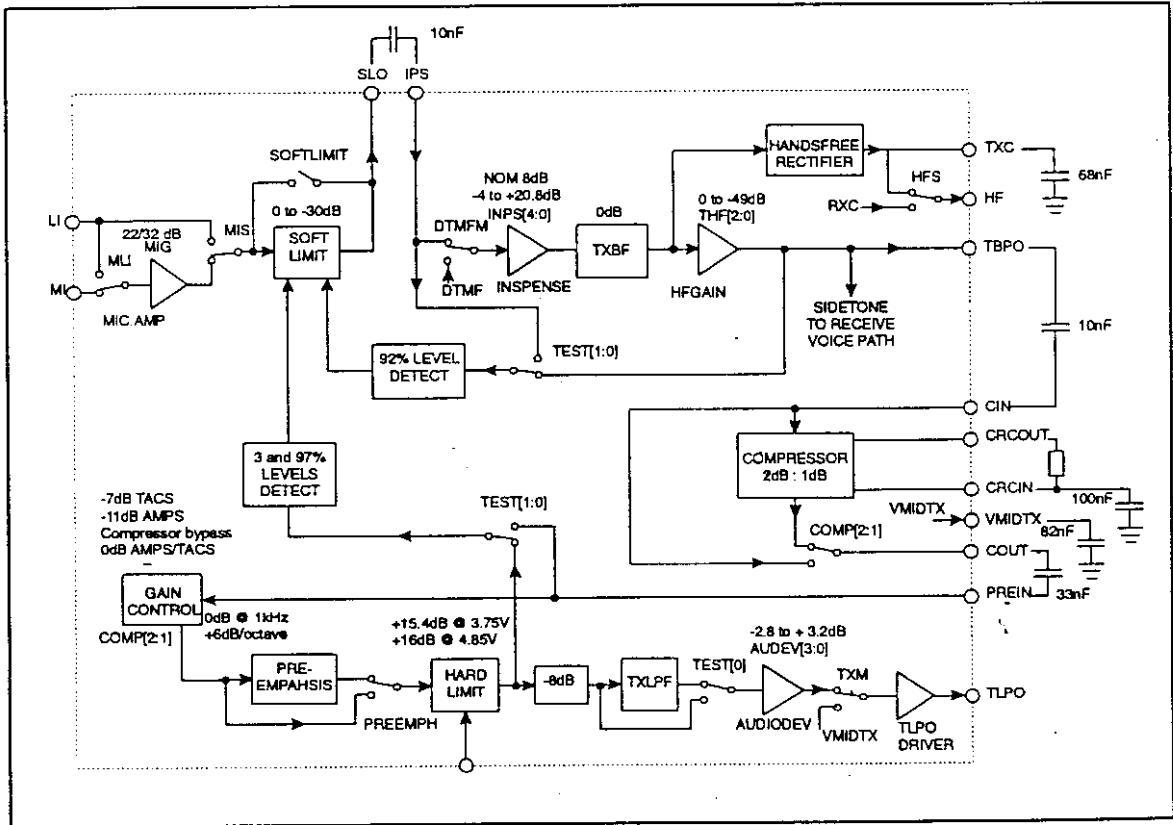


Fig. 11 Transmit Voice Path

## TRANSMIT INPUT SIGNAL PRECONDITIONING

### Microphone Amplifier (MIG)

Microphone signals input at MI via switch MLI are amplified by a gain selectable amplifier of either 22 dB or 32 dB, controlled by the MIG bit in the "Handsfree mode" control message. The microphone amplifier's input can also be connected to the line input LI via the MLI switch. The microphone amplifier's output drives the soft limiter via switch MIS which also allows higher level signals from the line input LI to bypass the microphone amplifier to drive the soft limiter directly. These two switches are controlled by the MIS and MIL bits in the "Operation mode" control message.

### Soft Limiter

Signal amplitude is restricted without clipping to the correct level for maximum F.M. deviation by the soft limiter. This operates as an AGC system, controlled by the signal amplitude at the compressor input and the hard limiter output later in the signal processing path. If the signal is too large at either of these points the soft limiter forward gain is reduced. The nominal soft limiter gain range of 0 to -30 dB in 64 steps of 0.5 dB covers all normal volume changes occurring during a conversation. Soft limiter attack and decay times are set by internal clocks derived from SCLK and ramp the gain steps at nominal rates of one step down every 40  $\mu$ s when the signal is too large and one step up every 1.68 ms when the signal is too small.

The soft limiter output at pin SLO is externally coupled with a capacitor to the input pin IPS of the following gain adjust stage, INPSENSE. When the speech channel is used to send DTMF signalling tones a switch, controlled by bit DTMFM in the "Operation mode" control message, selects the internal DTMF signal rather than the speech signal at input IPS.

For test purposes TEST[1:0] bits in the "Initializing Mode 1" control message can configure switches to give access to the softlimiter comparator inputs. When TEST[1:0] bits are high the 3 & 97 % window comparator is switched from the hard limiter output to PREIN input and the 92 % comparator is switched to IPS input.

### INPSENSE AMPLIFIER and TXBPF FILTER

Both microphone and transmit voice path tolerances are trimmed in the INPSENSE gain adjustment block following the soft limiter and DTMF switch. INPSENSE has a nominal gain of 8.0 dB with a trim range of -12.0 to +12.4 dB relative to the nominal gain set by bits INPS[4:0] in the "Initializing mode" control message.

Transmit signal preconditioning is completed by a bandpass filter TXBPF to limit the audio signal to a speech bandwidth of 300 Hz to 3.4 kHz. This filter uses switched capacitor techniques and is preceded by an anti-alias filter and followed by a smoothing filter to remove the clock from its output. The typical frequency response is shown in figure 4 which also shows the mask defined by type approval limits.

## HANDSFREE FUNCTIONAL BLOCKS

Between the transmit bandpass filter and the compressor two extra functions are included for use with handsfree operation. Firstly an attenuator HFGAIN is provided to give progressive signal reduction in handsfree mode with a range of 0 to -49 dB in 7 dB steps, set by bits THF[2:0] in the "Handsfree mode" control message. The HFGAIN attenuator's output drives pin TBPO which is externally capacitively coupled to the compressor input at pin CIN and internally drives both the soft limiter and sidetone circuits.

The second function provided for handsfree operation is a signal rectifier whose output, filtered by an external capacitor at pin TXC, drives output pin HF via switch HFS with a d.c. transmit level. Switch HFS is controlled by bit HFS in the "Handsfree mode" control message. Under control of bit HFS both receive and transmit levels are available at HF output pin for external comparison to implement the handsfree function. The handsfree system is further described in the section HANDSFREE OPERATION.

## COMPRESSOR

ACE9040 provides a 2:1 compressor to halve the transmit dynamic range as required by analog cellular systems. Within the operating signal range each 2 dB change in input level gives a 1 dB change in output level. A transmit signal is input through pin CIN and output on pin COUT, the signal is referenced to a mid-supply voltage. CRCIN and CRCOUT are connections for the external attack and delay time constant setting components.

The compressor's nominal unity gain level is 707 mV. Above this level the signal at CIN is attenuated and below this level the signal is amplified to achieve the 2:1 dB compression. Table 20 gives the nominal, Vmax and Vmin levels at CIN and nominal levels at COUT corresponding with the TACS and AMPS systems for 0 dB, maximum and minimum deviation.

The gain of the INPSENSE amplifier should be set so that the compressor operates within these signal levels for a given input signal at the MIC or LI input.

For the usual attack time of 3.0 ms and decay time of 13.5 ms a 180 k $\Omega$  resistor is connected between CRCIN and CRCOUT pins and a 100 nF capacitor between CRCIN and GND pins. An 82 nF capacitor should be connected between the VMIDTX and GND pins. Attack and decay time is measured with a 12 dB step, -8 dB to -20 dB relative to the unaffected level. Attack and decay times are respectively defined at points on the output envelope where it reaches x 1.5 and x 0.75 of the final steady state level.

External compressor connections allow the use of external coupling capacitors to remove d.c. offsets and optionally an external compander. The compressor can be internally bypassed allowing use of ACE9040 without companding in non-cellular applications, or for test purposes. Bits COMP[2:1] in the "Initializing mode 0" control message control the operation of the internal compander and are used to switch both the transmit compressor and receive expander into or out of the signal path. When not in use the internal compressor and expander are both powered down.

| System | Vmax at CIN |     | Vmin at CIN |     | Nominal Input at CIN<br>(0dB) levels mVrms | Nominal Output at COUT<br>levels mVrms |
|--------|-------------|-----|-------------|-----|--------------------------------------------|----------------------------------------|
|        | Vrms        | dB  | mVrms       | dB  |                                            |                                        |
| TACS   | 1.0         | +25 | 1.77        | -30 | 56                                         | 200                                    |
| AMPS   | 1.0         | +23 | 2.25        | -30 | 71                                         | 225                                    |

Table 20 Compressor CIN and COUT signal levels for TACS and AMPS

## FINAL MODULATION PREPARATION

## Pre-emphasis

A pre-emphasis filter follows the compressor to boost the amplitude of higher audio frequencies by tilting the frequency response by 6 dB per octave across the whole speech band as shown in figures 5 and 8. To prevent overload in the pre-emphasis filter the signal first passes through an attenuator set to suit the system in use. If an external compander is used or the companding function is bypassed the gain is set to 0 dB. When using the internal compander the gain is set to -7 dB for TACS or -11.0 dB for AMPS. Compander bypass is determined by control bits COMP[2:1]. The pre-emphasis filter and attenuator input is pin PREIN and the output is an internal connection to the hard limiter. The pre-emphasis filter, but not the attenuator, can be bypassed if the PREEMPH bit in the "Operation mode" control message is set to "1".

## Hard Limiter

To ensure compliance with the peak deviation specification for cellular telephone systems, a hard limiter follows the pre-emphasis filter to remove any transient level changes that have passed through the soft limiter. This limiter will handle large signals and has symmetrical clipping levels close to the supply rails  $V_{DD}$  &  $V_{SS}$  (GND). To ensure clipping at the same hard limiter input signal level with both the nominal power supply voltages, hard limiter gain is adjusted by an external pin

"V485". For the nominal supply voltages of 4.85 V and 3.75 V gain is respectively 16 dB (V485 pin at "1") and 13.5 dB (V485 pin at "0"). An 8 dB attenuator follows the limiter to prevent any further clipping of the signal in the following transmit lowpass filter.

## TX Lowpass Filter TXLPF

A TXLPF lowpass filter with an optimised stop band response limits the signal bandwidth to a cut-off frequency of 3.0 kHz, the frequency response is shown in figure 6. The combined frequency response of the pre-emphasis and lowpass filter stages is shown in figure 8. It is possible for test purposes to bypass this lowpass filter by setting bit TEST[0] in the "Initializing mode 1" control message to a "1".

## Speech Deviation Level Setting

A controlled gain stage AUDIODEV sets the output level to give the required FM deviation for speech. The gain is set by bits AUDEV[3:0] in the "Initializing mode 1" control message. AUDIODEV is followed by a transmit audio mute switch enabled by bit TXM in the "Operation mode" control message. A buffer drives output pin TLPO with the transmit speech signal (and DTMF when in use) which is added with DATA/ST and SAT tones in the modulation combiner.

## TRANSMIT DATA AND DTMF PATHS

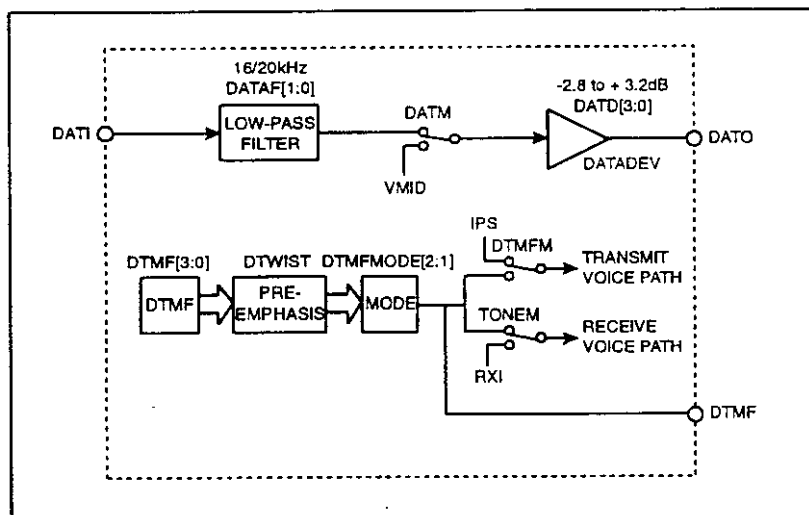


Fig. 12 Transmit Data and DTMF Paths

## Transmit Data

Data communication from mobile terminals to base stations in the AMPS and TACS cellular phone systems takes place over the Reverse Control Channel (RECC) during call set-up and in short bursts over the Reverse Voice Channel (RVC) during a call.

RECC or RVC data is transmitted for AMPS or TACS as a 10 kHz or 8 kHz Manchester Coded FSK signal

respectively. The data signal is generated by the ACE9050 "System Controller and Data Modem" or similar digital circuit to drive ACE9040's DATI input pin. The DATI input data signal is filtered using a 4th order Butterworth lowpass filter with nominal -3 dB points of 16 kHz for TACS, or 20 kHz for AMPS. This filter is implemented using switched capacitor techniques and is preceded by a continuous time anti-alias

filter, the output buffer includes a clock rejection filter. The cut-off frequencies are programmed by bits DATAF[1:0] in the "Initializing mode 1" control message. Filtered data passes through the mute switch DATM and a variable gain stage DATADEV with a range of  $-2.8$  to  $+3.2$  dB to set the required level of deviation. The mute switch is controlled by bit DATM in the "Operation mode" control message. DATADEV is controlled by bits DATD[3:0] in the "Initialising Mode 1" control message. The data signal is buffered out to pin DATO to drive the modulation combiner.

## DTMF

DTMF tones are generated when commanded via the serial interface and conform to the standard CCITT frequencies. All 16 standard tone pairs or any individual tone can be generated. To select DTMF tones data bits for transmission DTMFEN, DTMFMODE[1:0] and DTMF[3:0] need to be set using an "Operation mode" control message. Data bits DTMFMODE[1:0] select low, high or both tones of the pair as shown in table 6. Bits DTMF[3:0] select the tone pair as shown in table 7. DTMFEN set to "1" enables DTMF

operation. To change DTMF tones, an "Operation mode" control message with DTMFEN set to "0" must be sent to cancel the previous selection as the DTMF tone can only be changed when DTMFEN=0. This prevents any spurious tones being generated.

An optional pre-emphasis of 2 dB of the high frequency tone group above the level of the low frequency group is enabled by bit DTWIST in the "Initializing mode 0" control message.

DTMF tones can be selected to replace the speech in either or both the transmit and receive paths. In the transmit path setting bit DTMFM to "1" as in the "Operation mode" control message will connect the DTMF signal to INPSENSE gain adjustment block's input in place of the speech signal. In the receive path setting bit TONEM to "1" in the "Operation mode" control message will connect the DTMF signal to the input to RXSENSE gain adjustment block in place of the speech input at pin RXI. In each case the DTMFEN bit must also be "1".

DTMF signals are generated as sinewaves by an internal digital to analog converter and are smoothed by the transmit and receive filters. DTMF waveforms start and stop at a zero crossing to avoid transients in the filters and to limit their bandwidth. The DTMF signal is brought out directly on pin DTMF without further buffering.

The DTMF generator is powered down whenever a tone is not being generated, by setting DTMFMODE[1:0] to "00".

## TRANSMIT & RECEIVE SAT PATHS

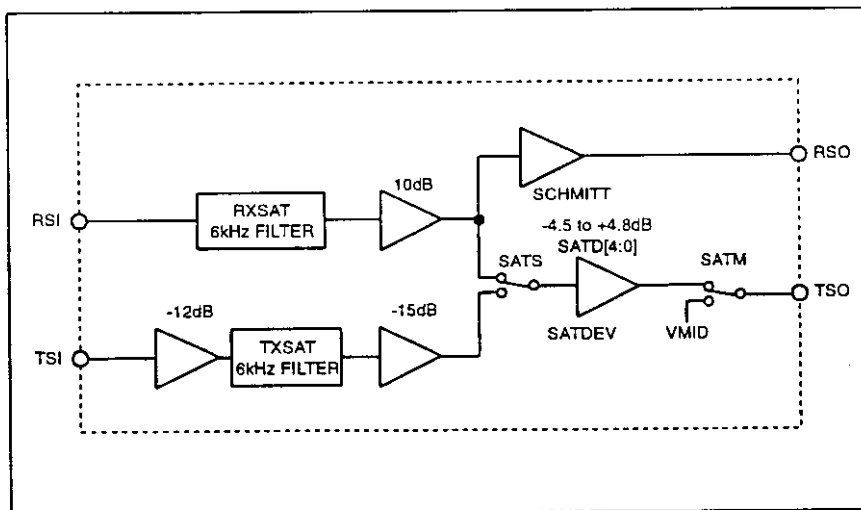


Fig. 13 Transmit and Receive SAT Paths.

### Re-transmitted SAT

ACE9040 provides two alternative paths for Supervisory Audio Tones (SAT). The first of these re-transmits the received SAT tone to the base station after narrow band filtering and providing signal level adjustment. This path is selected by setting SATS bit to "0" in the "Initializing mode 1" control message. The baseband signal from the receiver FM discriminator drives the ACE9040 through the RSI pin into the RXSAT 6 kHz bandpass filter required for AMPS or TACS. The recovered SAT signal then passes through a 10 dB amplifier and the SATS selector switch to the deviation setting

amplifier SATDEV. This is controlled by bits SATD[4:0] in the "Initializing mode 0" control message. SAT then passes through the SATM mute switch, controlled by bit SATM in the "Operation mode" control message, to output pin TSO for input to the modulation combiner.

### Regenerated SAT

The alternative SAT path externally measures the SAT frequency and generates a local tone to match. This route is

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selected by setting the SATS bit to "1" in the "Initializing mode 1" control message. The ACE9040 connects the receive filter RXSAT output through a Schmitt trigger to drive pin RSO with a logic level version of the received SAT. A system controller, such as an ACE9050, detects the frequency and generates a digital signal to drive back into the ACE9040 on pin TSI. After the signal level is reduced by -12 dB a 6 kHz bandpass filter TXSAT converts this square-wave into a sine wave. This is followed by a -15 dB attenuator to reduce the near logic level signal to a normal modulation level. This signal drives the same SATDEV deviation setting stage and

mute switch SATM as the returned signal to give an output at TSO.

### Base Station Originated SAT

ACE9050, System Controller, can be used to generate a squarewave SAT at 6 kHz which is input to pin TSI and filtered by the TXSAT filter and output at TSO. The RXSAT filter path with its output at RSO, can be used to filter the received SAT from a mobile for verification by an external frequency detector that the mobile is transponding the correct tone. This is the same as the regeneration loop above but starting with generation.

## TRANSMIT SIGNAL COMBINER

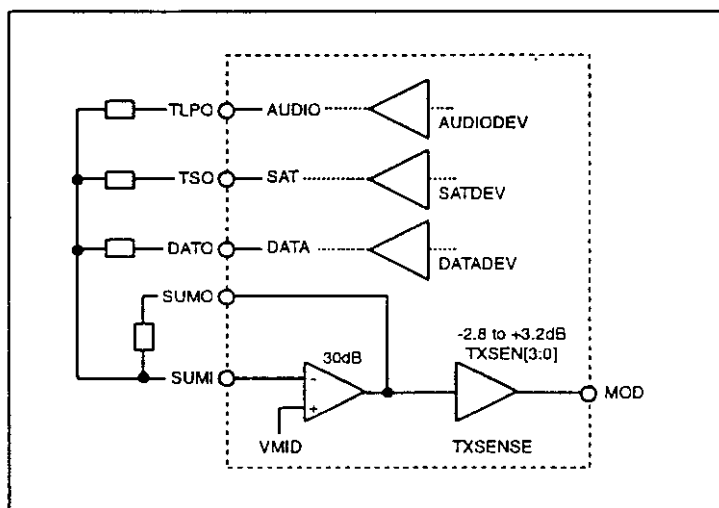


Fig. 14 Transmit Signal Combining Network and Modulation Driver

Used to modulate the transmitted r.f. output, the speech and optional DTMF signals at TLPO, SAT at TSO, and data and ST at DATO, are combined using an internal op-amp. This op-amp has an inverting input at pin SUMI and output at pin SUMO, the non-inverting input is internally biased to VMID. With an external feedback resistor between SUMI and SUMO, external resistors sum the inputs into pin SUMI and are chosen for each different cellular system to select the relative and absolute gains to give the correct deviation for each component of the modulation. Individual fine adjustments to take out

component value tolerances can be made by setting: AUDIODEV, SATDEV and DATADEV gains, described in more detail in the sections TRANSMIT VOICE PATH, TRANSMIT AND RECEIVE SAT PATHS, and TRANSMIT DATA AND DTMF PATHS. A fine adjustment is made to the combined signal level by TXSENSE which drives the modulator through pin MOD. The gain of TXSENSE is set by bits TXSEN[3:0] in the "Initializing mode 1" control message over the range - 2.8 to + 3.2 dB.

## RECEIVE VOICE PATH

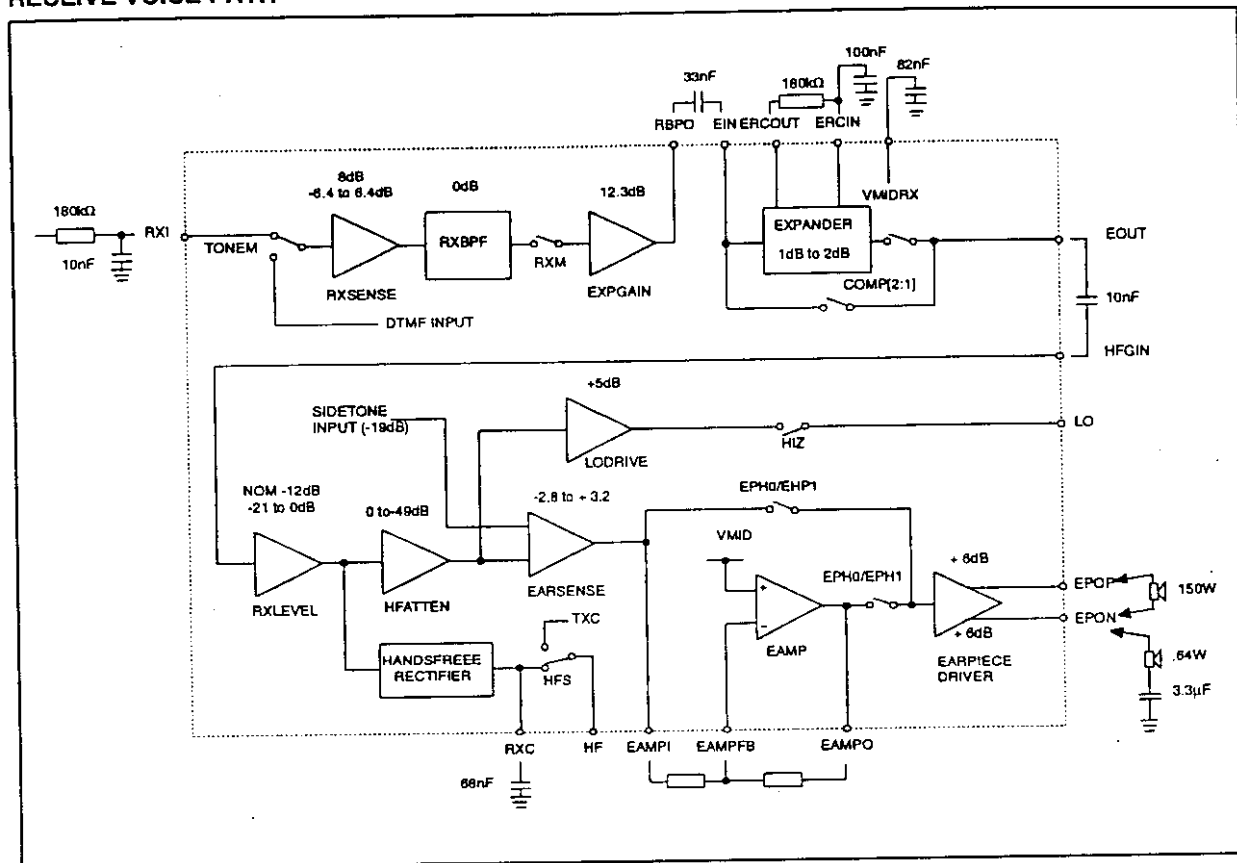


Fig. 15 Receive Voice Path

## De-emphasis and Receive Signal Input

Demodulated FM signals drive the RXI input pin via an external de-emphasis lowpass R-C filter of typically 180 k $\Omega$  and 10 nF. With TONEM switch set to RXI the input signal is amplified in the block RXSENSE with a gain of +8 dB. RXSENSE also provides fine adjustment over a range of -6.0 dB to +6.4 dB to take up signal level tolerances in the receiver output. Fine gain adjustment is controlled by RXSEN[4:0] bits in the "Initializing mode 0" control message.

When the DTMF generator in the transmit section is in use its output can be switched into the receive path to replace the RXI signal by setting bit TONEM in the "Operation mode" control message to "1". This does not affect the transmitted signal but allows the user to hear DTMF tones to confirm key press operation.

## RX Bandpass Filter

The RXSENSE amplifier's output is bandpass filtered to the speech bandwidth of 300 to 3400 Hz by receive bandpass filter RXBPF, as shown in figure 7. RXBPF uses switched capacitor filter techniques but does not include an anti-alias input filter as signals at RXI from the external receiver's output and the internal DTMF generator's output are already bandlimited. The F.M. discriminator output signals from

ACE9040's companion device "ACE9030: Radio Interface and Twin Synthesiser" are bandlimited by its output filter and ACE9040's internal DTMF tones are generated as sinewaves without the need for a further anti-aliasing filter.

RXBPF filter output passes through the receive mute switch controlled by bit RXM in the "Operation mode" control message and is buffered to drive pin RBPO by amplifier EXPGAIN. During mute the RBPO pin is driven to the signal ground voltage at mid supply (as found on pin BIAS). EXPGAIN gain is nominally 12.3 dB when using the internal expander and 0 dB when using an external expander. The output circuit driving RBPO includes a smoothing filter to remove clock noise.

## Expander

Input to the expander at pin EIN is coupled by an external capacitor from RBPO to remove any d.c. voltage offsets. Using external coupling also allows the option of using an external compander or bypassing the expander if a linear system is required. In either case the signal should feed back into ACE9040 at pin HFGIN. ACE9040's compander can be bypassed by setting bits COMP[2:1] in the "Initializing mode 0" control message to "00".

A ring tone from the BAR (Beep, Alarm, Ring) generator of ACE9050 "System Controller" can be added to the

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expander input EIN by using an external summing network and internally open circuiting the drive to pin RBPO during the tone (not just muting the speech). This is achieved with bits COMP[2:1] in the "Initializing mode 0" control message set to "01".

Signal dynamic range at input pin EIN is doubled in the 1:2 expander to restore the original signal. Within the operating signal range each 1 dB change in input level gives a 2 dB change in output level. The expander output drives pin EOUT which is coupled by an external capacitor to the input pin HFGIN. The external connection allows use of an external compander and removes any d.c. voltage offsets. Bits COMP[2:1] in the "Initializing mode 0" control message can be used to select external companding mode and power down the internal compressor and expander.

The expander's unity gain level EIN to EOUT is 1V. Above this level gain is applied to the signal at EIN and below this level the signal is attenuated to achieve 1:2 dB expansion. Table 21 gives nominal, Vmax and Vmin levels at EIN and nominal levels at EOUT corresponding with the TACS and AMPS systems for 0 dB, maximum and minimum deviation.

The gain of the RXSENSE amplifier should be set so that the expander operates within these signal levels for a given demodulated signal range at the RXI input.

Expander pins ERCIN and ERCOUT are used to set the attack and decay times for the expansion process. For the usual attack time of 3.0 ms and decay time of 13.5 ms, a resistor of 180 k $\Omega$  is connected between ERCIN and ERCOUT pins and a capacitor of 100 nF from ERCIN to GND. An 82 nF capacitor should be connected between VMIDRX and GND. Attack and decay time is measured with a 6 dB step, -4 dB to -10 dB relative to the unaffected level. Attack and decay times are defined respectively at points on the output envelope where it reaches  $\times 0.57$  and  $\times 1.5$  of the final steady state level.

### Volume Control and Handsfree Attenuator

Two variable gain stages follow the expander, RXLEVEL for the volume control and HFATTEN for use with handsfree mode. Both blocks provide attenuation, expressed as gain to assist system level design, RXLEVEL from 0 to -21 dB and HFATTEN from 0 to -49 dB. RXLEVEL is controlled by bits RXV[2:0] in the "Operation mode" control message and HFATTEN is controlled by bits RHV[2:0] in the "Handsfree mode" control message.

### RX Audio Output: Line Output and Earpiece

Following the handsfree attenuator the signal path splits into two parallel paths: a line output for loudspeaking phones and drivers for a dynamic earpiece or external handsfree earpiece. Bits EPH1 and EPH0 in the "Operation Mode" and "Initializing Mode 0" control messages respectively control the operation of these outputs, see table 5.

The earpiece output path begins with a variable gain stage EARSENSE which is controlled by bits EARS[3:0] in the "Initializing mode 1" control message to give a gain range of -

2.8 to +3.2 dB. A sidetone signal from the output of the handsfree attenuator HFGAIN at pin TBPO is added at EARSENSE's input if bit SD in the "Initializing mode 0" control message is set to "1". The output of this block is at pin EAMPI.

The signal at pin EAMPI is amplified by an opamp whose gain is set by external resistors, allowing overall gain setting for different models of cellular terminal. A resistor is connected from EAMPI to the amplifier input pin EAMPFB and a feedback resistor is connected from the amplifier output EAMPO to EAMPFB. The ratio of these two resistors sets the gain and the opamp's output including feedback resistors should not be loaded with less than 15 k $\Omega$ . Additional filtering can also be added to the receive path using the EAMP opamp.

### Earpiece

The earpiece drivers have outputs at pins EPOP and EPON. One of three modes of output drive or a muted output condition is selected by bits EPH1 and EPH0, see table 5.

A dynamic earpiece, typically of 150  $\Omega$  resistance in series with 800  $\mu$ H, can be driven when connected between pin EPON and EPOP. The drive mode can be either differential (EPH1 = 1, EPH0 = 1) or single ended (EPH1 = 1, EPH0 = 0). The differential output, drives a minimum of 4 Vpp into the load. The single ended output appears at EPON and drives a minimum of 2 Vpp into a load referenced to pin EPOP, which provides an output voltage at mid-supply.

Output drive is setup for an external handsfree earpiece with EPH1 = 0 and EPH0 = 1. This load, typically of 64  $\Omega$  resistance in series with 3.3  $\mu$ F, is driven from pin EPON to ground and the EPOP output is put into a high impedance state. The minimum drive into this load is 1.1 Vpp.

The input for the EPOP and EPON output drivers is driven by the signal at the EAMPO pin for single ended and differential outputs or from EAMPI directly for a handsfree earpiece, bypassing the EAMP opamp. The gain from the earpiece drivers' common input, to both EPON's inverting and and EPOP's non-inverting outputs, is nominally +6 dB.

### Line Output

Line output amplifier LODRIVE with its output at pin LO has a gain of +5 dB and is used to drive an external audio power amplifier. LODRIVE can drive a 1 k $\Omega$  load with a minimum of 1 Vrms. The LO output can be put into a high impedance state by setting bit HIZ in the "Operation mode" control message to "0". During power down EPON and EPOP and LO are tied to mid-supply voltage.

### HANDSFREE OPERATION

In a handsfree telephone the simplest method of preventing 'howl round' caused by acoustic feedback is to attenuate either the forward or return path until the loop gain is too low for sustained oscillation. The least active path is attenuated so the signal level in each path must be detected and compared so that the quieter can be attenuated.

In the ACE9040 the signal level in both the transmit and the receive paths are rectified, with smoothing capacitors at

| System | Vmax at EIN |       | Vmin at EIN |     | Nominal Input at EIN<br>(0dB) levels mVrms | Nominal Output at EOUT<br>levels mVrms |
|--------|-------------|-------|-------------|-----|--------------------------------------------|----------------------------------------|
|        | Vrms        | dB    | mVrms       | dB  |                                            |                                        |
| TACS   | 1.0         | +12.5 | 43          | -15 | 245                                        | 60                                     |
| AMPS   | 1.0         | +12.3 | 22          | -21 | 245                                        | 60                                     |

Table 21 Expander EIN and EOUT signal levels for TACS and AMPS

pins TXC and RXC respectively, to give d.c. voltages corresponding to the signal levels.

A switch HFS with its output at pin HF can be internally toggled between TXC and RXC to allow measurement of the two levels at these pins by an external level sensing circuit such as an analog to digital converter input of ACE9030. The HFS switch is controlled by bit HFS in the "Handsfree mode" control message.

The system controller after comparison of the voltage levels at TXC and RXC pins can attenuate the weaker signal path by up to 49 dB, in 7 dB steps using blocks HFGAIN for transmit and HFATTEN for receive. Bits THF[2:0] and RHF[2:0] in the "Handsfree mode" control message are used to set the gains of HFGAIN and HFATTEN respectively. The rate of change of gain should be limited in the system controller to allow normal conversation.

Attack and decay time constants are set by the resistance and capacitance on the TXC and RXC pins. With the internal resistor to ground of approximately 500 k $\Omega$  and an external capacitor to ground of 68 nF the normal attack time of 1 ms and decay time of 35 ms is achieved. By adding a parallel resistor the ratio of attack to decay time can be altered.

To save power in a hand portable when handsfree operation is not needed, the transmit and receive signal rectifiers can be switched off by setting bit HFP in the "Handsfree mode" control message to "0".

## BIASES AND REFERENCES

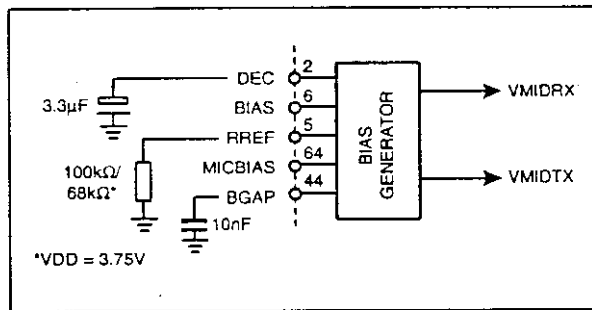


Fig. 16 Bias Circuits

### BIAS, VMID and MICBIAS

Within ACE9040 most signals are single ended and swing either side of a mid-supply reference voltage. These internal references are all labelled VMIDxx in this data sheet.

A low impedance voltage source at mid-supply for use as an external signal ground is available on pin BIAS. This is a buffered copy of the voltage at pin DEC which is from an internal high impedance potential divider between  $V_{DD}$  and  $V_{SS}$ . The DEC pin should be decoupled to ground with a capacitor of greater than 3.3  $\mu$ F. Two additional buffers provide copies of DEC's voltage at pins VMIDTX and VMIDRX, these are used as internal signal grounds for the transmit and receive paths respectively. VMIDTX and VMIDRX pins should be decoupled to GND with 82 nF capacitors. By using separate mid-supply signal grounds crosstalk due to the compander time constant circuits and the speech and tone signals are kept to a minimum.

Pin MICBIAS gives the bias needed for an electret microphone nominally 0.8 times  $V_{DD}$ , e.g. when  $V_{DD}$  is 3.75 V MICBIAS = 3 V

### OP-AMP Reference Current

Reference currents for all the internal op-amps are set by an external resistor connected from pin RREF to ground ( $V_{SS}$ ). Nominal values are 100 k $\Omega$  for  $V_{DD}$  = 4.85 V and 68 k $\Omega$  for  $V_{DD}$  = 3.75 V. A stable discrete resistor should be used to ensure consistent operation over a wide temperature range.

### Power Supply Comparator - Reset Output

A power supply comparator is provided to give a reset at power-on and enable the system controller to initiate a clean shut-down sequence if the battery voltage falls too low. When  $V_{DD}$  is below a band-gap derived threshold the open-drain output pin LVN drives to a logic low. This occurs for  $V_{DD}$  exceeding 1 V but less than a typical threshold of 3.35 V. An external resistor at LVN provides a pull-up to  $V_{DD}$  with a capacitor to ground ( $V_{SS}$ ) to give a power-on reset delay. Typical values for RC are 220 k $\Omega$  and 150 nF. This RC combination also removes short transients or noise pulses from the signal at LVN during power up. If this comparator is not required the bandgap and comparator can be powered down by setting bit PDLVC in the "Initializing mode 0" control message to a "1".

### Serial Data Clock

All switched capacitor filter switching clocks are derived from the serial data clock SCLK which must be fixed at 1.008 MHz to ensure correct frequency responses.

### AMPLIFIER

An uncommitted op-amp is provided with its non-inverting input internally connected to VMID, inverting input at pin AMPI and output at pin AMPO.

## ACE9040

### APPLICATIONS INFORMATION

To help with system set up tables 22 to 25 show ACE9040's functions and their respective controlling bits. Table 23 shows the gains and filter characteristics pre-determined when setting the TACS & AMPS cellular system

selection bits. Tables 23 & 24 show these functions respectively for the transmit and receive sections of ACE9040. Table 25 shows the four control messages with an example of the data to turn all ACE9040 functions on.

| Function Controlled by TACS & AMPS Bits |                  |      |      |
|-----------------------------------------|------------------|------|------|
|                                         |                  | TACS | AMPS |
| Internal pre-emphasis gain control.     | TACS = - 7.0 dB  | 1    | 0    |
|                                         | AMPS = - 11.0 dB | 0    | 1    |

Table 22 Functions Controlled by TACS & AMPS Bits

| Gain and filter set-ups for TACS, AMPS and user control bits: Transmit |                                                                |                                                                |                     |
|------------------------------------------------------------------------|----------------------------------------------------------------|----------------------------------------------------------------|---------------------|
|                                                                        | TACS                                                           | AMPS                                                           | User control bit(s) |
| Microphone amp                                                         | 22 or 32 dB                                                    | 22 or 32 dB                                                    | MIG                 |
| Soft limiter                                                           | 0 to - 30 dB                                                   | 0 to - 30 dB                                                   | Internal            |
| INPSENSE gain adjust                                                   | + 8 dB<br>(- 12.8 to + 12 dB)                                  | + 8 dB<br>(- 12.8 to + 12 dB)                                  | INPS[4:0]           |
| TXBPF TX bandpass filter                                               | 0 dB                                                           | 0 dB                                                           | Fixed               |
| HFGAIN, TX Handsfree attenuator                                        | 0 to - 49 dB                                                   | 0 to - 49 dB                                                   | THF[2:0]            |
| Compressor: Compression about unaffected level. (707 mVrms, - 3 dBV)   | 2:1 <sup>1</sup>                                               | 2:1 <sup>1</sup>                                               | Fixed               |
| Pre-emphasis gain control (Internal compressor)                        | - 7 dB                                                         | - 11 dB                                                        | TACS & AMPS         |
| Pre-emphasis gain control                                              | 0 dB                                                           | 0 dB                                                           | Fixed               |
| HARD LIMIT, Hard deviation limiter                                     | + 16.5 dB @ 4.85V<br>+ 13.5 dB @ 3.75V                         | + 13.5 dB @ 3.75V<br>+ 16.5 dB @ 4.85V                         | V485 pin            |
| TXLPF TX low pass filter                                               | - 8 dB                                                         | - 8 dB                                                         | Fixed               |
| AUDIODEV,                                                              | 0 dB<br>(-2.8 to +3.2 dB)                                      | 0 dB<br>(-2.8 to +3.2 dB)                                      | AUDEV[3:0]          |
| TXSENSE, signal                                                        | 0 dB<br>(-2.8 to +3.2 dB)                                      | 0 dB<br>(-2.8 to +3.2 dB)                                      | TXSEN[3:0]          |
| Nominal TX Channel Gain (bypassed compressor)                          | 28.5 <sup>2</sup> dB @ 3.75 V<br>31.5 <sup>2</sup> dB @ 4.85 V | 23.5 <sup>2</sup> dB @ 3.75 V<br>26.5 <sup>2</sup> dB @ 4.85 V |                     |

Notes: 1. Above the unaffected (0 dB gain) level the compressor attenuates and below this level it provides gain.  
2. MIC gain = 22 dB

Table 23 Transmit gain and filter set-ups for TACS, AMPS and user control bits

| <b>Gain and filter set-ups for user control bits: Receive</b> |                             |                             |                            |
|---------------------------------------------------------------|-----------------------------|-----------------------------|----------------------------|
|                                                               | <b>TACS</b>                 | <b>AMPS</b>                 | <b>User control bit(s)</b> |
| External De-emphasis                                          | - 21 dB <sup>1</sup>        | - 21 dB <sup>1</sup>        | Fixed externally           |
| RXSENSE: Receive audio gain                                   | + 8 dB                      | + 8 dB                      | Fixed                      |
| RXSENSE: Receive audio gain adjustment range                  | - 6 to + 6.4 dB             | - 6 to + 6.4 dB             | RXSEN[4:0]                 |
| RXBPF: RX bandpass filter                                     | 0 dB                        | 0 dB                        | Fixed                      |
| RX Expander gain EXPGAIN: Internal                            | + 12.3 dB                   | + 12.3 dB                   | Fixed                      |
| RX Expander gain EXPGAIN: External                            | 0 dB                        | 0 dB                        | Fixed                      |
| Expander: Expansion about unaffected level (1000 mV, 0 dBV)   | 1:2 <sup>2</sup>            | 1:2 <sup>2</sup>            | Fixed                      |
| RXLEVEL, Receive volume control                               | - 12 dB<br>(+ 12 to - 9 dB) | - 12 dB<br>(+ 12 to - 9 dB) | RXV[2:0]                   |
| HFATTEN, RX handsfree attenuator                              | 0 to - 49 dB                | 0 to - 49 dB                | RHF[2:0]                   |
| EARSENSE                                                      | 0 dB<br>(- 2.8 to + 3.2 dB) | 0 dB<br>(- 2.8 to + 3.2 dB) | EARS[3:0]                  |
| Ear piece driver                                              | 6 dB                        | 6 dB                        | Fixed                      |
| Nominal Receive Gain<br>(Expander bypassed)                   | - 6.7 dB                    | - 6.7 dB                    | Fixed                      |
| DATA and SAT Filters                                          |                             |                             |                            |
| TX data path filter cut-off                                   | 16 kHz                      | 20 kHz                      | DATAF[1:0]                 |
| TX & RX bandpass SAT filter centre frequency                  | 6 kHz                       | 6 kHz                       | Fixed                      |

Notes: 1. Attenuation with an external de-emphasis network of series 180 k $\Omega$  with 10 nF to GND at RXI input.  
2. Above the unaffected (0 dB gain) level the expander provides gain and below this level it attenuates

*Table 24 Receive, Data and SAT gain and filter set-ups for user control bits*

| OPERATING MODE        |           |           |        |       |       |       |       |       |
|-----------------------|-----------|-----------|--------|-------|-------|-------|-------|-------|
| WORD/BIT              | D7        | D6        | D5     | D4    | D3    | D2    | D1    | D0    |
| DATA 1                | PREEMPH   | MIS       | DTMF3  | DTMF2 | DTMF1 | DTMF0 | TONEM | DTMFM |
| DATA 2                | DTMFMODE1 | DTMFMODE0 | DTMFEN | MLI   | TXM   | DATM  | SATM  | RXM   |
| DATA 3                | EPH1      | HIZ       | RXV2   | RXV1  | RXV0  | PD    | 0     | 1     |
| START-UP BIT SETTINGS |           |           |        |       |       |       |       |       |
| DATA 1                | 0         | 0         | 0      | 0     | 0     | 0     | 0     | 0     |
| 00 <sub>HEX</sub>     |           |           |        |       |       |       |       |       |
| DATA 2                | 0         | 0         | 0      | 0     | 1     | 1     | 1     | 1     |
| 0F <sub>HEX</sub>     |           |           |        |       |       |       |       |       |
| DATA 3                | 1         | 1         | 1      | 1     | 1     | 0     | 0     | 1     |
| F9 <sub>HEX</sub>     |           |           |        |       |       |       |       |       |

| INITIALIZING MODE 0   |           |        |        |        |        |       |       |        |
|-----------------------|-----------|--------|--------|--------|--------|-------|-------|--------|
| WORD/BIT              | D7        | D6     | D5     | D4     | D3     | D2    | D1    | D0     |
| DATA 1                | SOFTLIMIT | SD     | SATD4  | SATD3  | SATD2  | SATD1 | SATD0 | RXSEN4 |
| DATA 2                | RXSEN3    | RXSEN2 | RXSEN1 | RXSEN0 | INPS4  | INPS3 | INPS2 | INPS1  |
| DATA 3                | INPS0     | COMP2  | COMP1  | PDLVC  | DTWIST | EPH0  | 0     | 0      |
| START-UP BIT SETTINGS |           |        |        |        |        |       |       |        |
| DATA 1                | 1         | 0      | 1      | 0      | 0      | 0     | 0     | 1      |
| A1 <sub>HEX</sub>     |           |        |        |        |        |       |       |        |
| DATA 2                | 0         | 0      | 0      | 0      | 1      | 0     | 0     | 0      |
| 08 <sub>HEX</sub>     |           |        |        |        |        |       |       |        |
| DATA 3                | 0         | 1      | 0      | 0      | 1      | 1     | 0     | 0      |
| 4C <sub>HEX</sub>     |           |        |        |        |        |       |       |        |

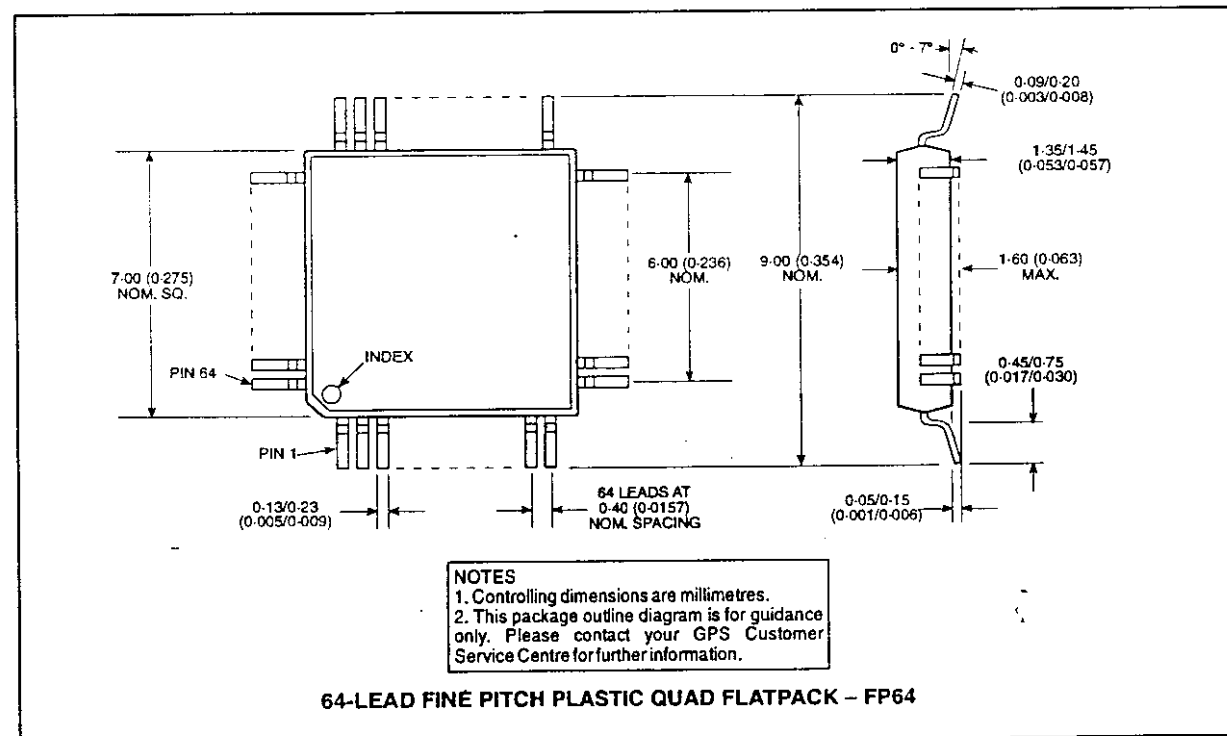
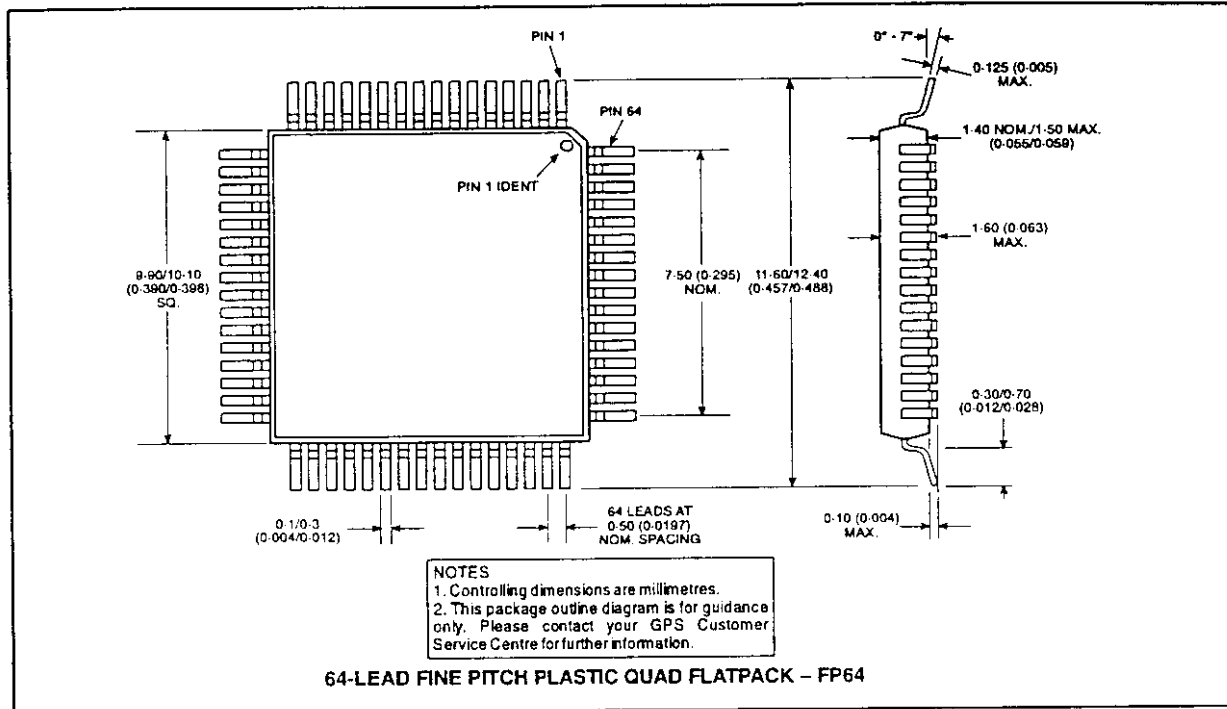
| INITIALIZING MODE 1          |       |        |        |       |        |        |        |        |
|------------------------------|-------|--------|--------|-------|--------|--------|--------|--------|
| WORD/BIT                     | D7    | D6     | D5     | D4    | D3     | D2     | D1     | D0     |
| DATA 1                       | EARS3 | EARS2  | EARS1  | EARS0 | AUDEV3 | AUDEV2 | AUDEV1 | AUDEV0 |
| DATA 2                       | DATD3 | DATD2  | DATD1  | DATD0 | TXSEN3 | TXSEN2 | TXSEN1 | TXSEN0 |
| DATA 3                       | TACS  | DATAF1 | DATAF0 | SATS  | TEST1  | TEST0  | 1      | 0      |
| START-UP BIT SETTINGS (TACS) |       |        |        |       |        |        |        |        |
| DATA 1                       | 1     | 0      | 0      | 0     | 1      | 0      | 0      | 0      |
| 88 <sub>HEX</sub>            |       |        |        |       |        |        |        |        |
| DATA 2                       | 1     | 0      | 0      | 0     | 1      | 0      | 0      | 0      |
| 88 <sub>HEX</sub>            |       |        |        |       |        |        |        |        |
| DATA 3                       | 1     | 1      | 0      | 0     | 0      | 0      | 1      | 0      |
| C2 <sub>HEX</sub>            |       |        |        |       |        |        |        |        |

| HANDSFREE             |      |      |      |      |      |      |     |     |
|-----------------------|------|------|------|------|------|------|-----|-----|
| WORD/BIT              | D7   | D6   | D5   | D4   | D3   | D2   | D1  | D0  |
| DATA 1                | X    | X    | X    | X    | X    | 0    | 0   | 0   |
| DATA 2                | - 0  | X    | AMPS | X    | X    | MIG  | HFS | HFP |
| DATA 3                | RHF2 | RHF1 | RHF0 | THF2 | THF1 | THF0 | 1   | 1   |
| START-UP BIT SETTINGS |      |      |      |      |      |      |     |     |
| DATA 1                | X    | X    | X    | X    | X    | 0    | 0   | 0   |
| 00 <sub>HEX</sub>     |      |      |      |      |      |      |     |     |
| DATA 2                | 0    | X    | 0    | X    | X    | 0    | 0   | 1   |
| 01 <sub>HEX</sub>     |      |      |      |      |      |      |     |     |
| DATA 3                | 0    | 0    | 0    | 0    | 0    | 0    | 1   | 1   |
| 03 <sub>HEX</sub>     |      |      |      |      |      |      |     |     |

Table 25 Control Messages

**PACKAGE DETAILS**

Dimensions are shown thus: mm (in). For further package information, please contact your local Customer Service Centre.



## ACE9040

### ORDERING INFORMATION

Industrial temperature range

TQFP 64 lead 10 x 10 mm, 0.5 mm pitch

ACE9040/IG/FP1N - devices shipped in trays and dry packed

ACE9040/IG/FP1Q - tape mounted and dry packed

TQFP 64 lead 7 x 7 mm, 0.4 mm pitch

ACE9040/IG/FP2N - devices shipped in trays and dry packed

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Fax: (01793) 518411

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