The DETO pin is connected to a passive low-pass filter with a -3 dB cut-off set at about 4.8 kHz. The filtered audio is then passed to an de-emphasis filter where the de-emphasis occurs across the entire audio band (300 Hz to 3400 Hz) at a rate of 6 dB/octave or 20 dB/decade. After de-emphasis, the transmit audio signal is proceeded through level control and the expansion process. The level control, which has a range of about 15 dB, is used to set the transmit audio level at the tip and ring of the telephone line, The transmit level can vary from component tolerances and variations.

After then, the audio is passed to a final stage of amplification. The output of this amplifier is connected to telephone line interface. The output of the DTMF generator circuit is also coupled in at the input to this final stage of amplification.

The transmit audio chain can be disabled at the expander amplifier on chip by a mute command from MCU. This function is used to mute the transmit audio chain when data is being received from the handset so that data noise does not enter the telephone line. When transmitting data from the base to the handset, the mute function is used to disable the receive audio circuits.

2.3.1.2 Receive Direction (telephone line to RF module)

The receive audio signal from the telephone line makes its way through the line interface and the speech circuit before reaching the receive direction audio circuits. From the speech circuit, the audio undergoes a first stage of amplification and light low-pass filtering. Following the amplifier, the receive audio is compressed and fed directly to the pre-emphasis stage. The compressor does a straight 2-to-1 conversion; the dynamic range is reduced by one half. The compressor amplifier is also used to sum in DTMF feedback so that the tones can be heard from the handset' s receiver. Pulse dialling feedback is accomplis hed similarly by summing in the hook switch signal level at the same location.

From the compressor output, the receiver audio signal enters an Tx audio level control circuit. . The level control, as in the transmit direction, has a range of about 15 dB and is used to set the level applied to the RF module. This level control thus sets the FM deviation and is necessary to compensate for component tolerances and variations in the sensitivity of the FM circuits.

Transmit data is resistively combined in after the level control from which point it shares the rest of the audio circuits with the receive audio. However, either only audio or only data will be present at any given time to prevent corruption of the signals. To further minimise the chance of data corruption, the receive audio circuits are disabled after compressor using the mute function as mentioned in above section. Muting this part of the receive audio chain ensures that any noise or signals on the telephone line do not interfere with data transmissions to the handset. The output is then coupled to the RF module's frequency modulator.

2.3.2 Handset

The audio circuits in the handset provide for speech exchange between the audio transducers (ear-piece receiver and microphone) and the RF module that communicates with the base. Figure 2 shows the circuitry for audio processing in the handset.

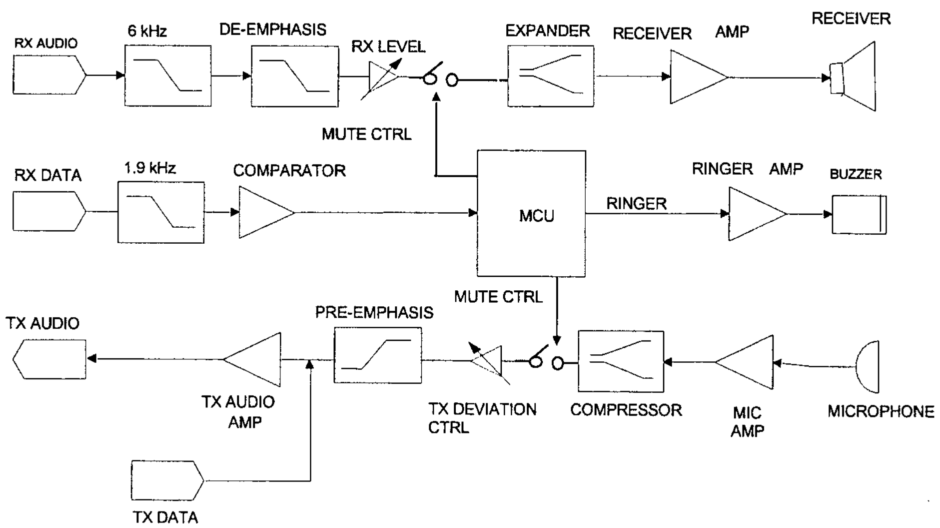

Figure 2. Audio Circuits in Handset

2.3.2.1 Receive Direction (RF module to ear-piece receiver)

The received audio is transmitted from the base to the handset using FM. The FM signal from the base enters the handset RF module where the signal undergoes filtering, down-conversion, and finally demodulation. The baseband audio then leaves the RF module via the demodulator IC (for a deviation of ±50 kHz). From the RF module, the audio is low-pass filtered and directed to both an audio channel and a data channel. The audio undergoes this split in directions because both data and audio share the same circuit.

The DETO pin is connected to a low-pass filter with a -3 dB cut-off set at about 6 kHz. The filtered audio is then passed to a de-emphasis filter where de-emphasis occurs across the entire audio band (300 Hz to 3400 Hz) at a rate of 6 dB/octave or 20 dB/decade. After de-emphasis, the audio undergoes received audio level control and the expansion process. The level control, which has a range of about 15 dB, is used to set tolerances and variations.

After the expander, the audio is passed to a final stage of amplification. A volume control (selectable to "high", "mid", and "low" volume) can be processed through the feedback resistor of this amplifier. This process ensures the compliance of min. 12 dB volume change from the lowest to the highest (FCC Part 15: 68.317).

The receive audio chain can be disabled by a mute command from MCU. This function is used to mute the receive audio chain when data is being received from the base so that data noise is not heard at the receiver. When transmitting data from the handset to the base, the mute function is used to disable the transmit audio circuits.

2.3.2.2 Transmit Direction (microphone to RF module)

In the transmit direction, the speech is picked by an electret condenser microphone and passed into a microphone amplifier stage. The speech or transmit audio undergoes a first stage of amplification and light low-pass filtering. Following the amplifier, the transmit audio is compressed and fed directly to the pre-emphasis stage. The compressor does a straight 2-to-1 conversion; the dynamic range is reduced by one half.

From the compressor output, the transmit audio signal enters a pre-emphasis circuit with an audio level control. The pre-emphasis, like the de-emphasis, is set at a rate of 6 dB/octave or 20 dB/decade throughout the entire audio band (300 Hz to 3400 Hz). The level control, as in the receive direction, has a range of about 15 dB and is used to set the level applied to the RF module. This level control thus sets the FM deviation and is necessary to compensate for component tolerances and sensitivity variations of the FM circuits. Extra range control has been implemented to compensate for microphone variations.

Transmit data is resistively combined in after the pre-amphasis from which point it shares the rest of the audio circuits with the transmit audio. However, either only audio or only data will be present at any given time to prevent corruption of the signals. To further minimise the chance of data corruption, the transmit audio circuits are disabled at the compressor output using the mute command from MCU as mentioned in above section. Muting this part of the transmit audio chain insures that any noise or signals from the microphone do not interfere with data transmissions to the base.

Following the transmit audio level control which programmed by the MCU, the audio goes through another stage of amplification and light low-pass filtering. It is then coupled to the RF module's frequency modulator.

2.4 MCU Circuits

A CMOS 4K x 8-bit microcontroller from Toshiba (TMP87C807U) is used to control all the functions in the base. The B/U MCU can be clocked by the 8-MHz signal which come from the RF chip CLKO pin or clocked by an external seperated 8MHz X'tal The H/S MCU (TMP86CM25F) is clocked by a 8-MHz resonator seperately. The reason why not using the clock which can be provided from the RF chip CLKO pin is for current saving during "sleep" mode.

The base MCU controls such functions as DTMF generation, data communications, telephone signalling detection and ATE interfacing, while the handset MCU controls such functions as data communications, sleep/wake-up sequence, battery maintenance and ATE interfacing.

2.4.1 Base Unit

2.4.1.1 RSSI

When a communication channel is required, the handset searches for a channel that is unoccupied or has a very low-level interference. The H/S MCU does this by using the received signal strength indicator (RSSI) function of the demodulator to determine if a channel is available. The demodulator's RSSI, coupled with its carrier detect, supplies the MCU with a signal whose state indicates the status of a channel. A power threshold is set by the demodulator and when a channel's total power exceeds this threshold, the channel is declared to be occupied.

2.4.1.2 DTMF Generation

To minimise costs, power consumption, and space, the base MCU is used to generate the DTMF tones instead of a dedicated DTMF generator IC. The base MCU generates the tone waveforms by using a 1% R-2R ladder network connected to six of its ports to produce a 6-bit digital-to-analog (D/A) converter. The D/A converter's output is then passed through a low-pass filter to clear the waveforms of high frequency ripple caused by the D/A conversion.

As mentioned in previous sections, the DTMF tones are combined in at the input of the last amplifier stage in the transmit direction for transmission onto the telephone line. The transmit audio chain is disabled before the expander during DTMF dialling to stop audio from the RF module from entering the telephone line and interfering with the dialling. Also, the DTMF tone will feedback to handset receiver by sidetone signal path.

2.4.1.3 Data Communications

The data is transmitted between the handset and base at 1000 bps using Manchester Coding format. The two frequencies used in the keying are 500 Hz and 1000 Hz. Logic 0 and logic 1 are represented by falling edge and rising edge of 1kHz data respectively. A separate modem chip is not required in the design since the MCU generates and decides all the data. The level for data transmissions is set to produce about ±50 kHz of deviation.

Received data from the handset is passed form the demodulator IC to undergoes low-pass filtering. The received data is split off to the receive data chain; as mentioned in a previous section. It is shared by both the audio and data, thus requiring a splitting junction . This received data chain consists of low-pass filtering and a comparator to restore the data to its original condition. After conditioning, the data is coupled directly to the MCU for analysis.

2.4.1.4 Reset Circuit

The reset circuit for the base MCU consists of two transistor switch and support components. The circuit is designed to reset the MCU when the power supply drops to about 2.8 VDC and below. This insures that if the power supply drops to a level where logic levels may become indeterminate, the MCU will be reset to a known condition, potentially preventing erroneous operation. In addition to being connected to the reset circuit, the MCU's active low reset line is connected to the power rail via an RC network. This RC network ensures that after a reset, the MCU's reset line is brought back to a logic high cleanly and continuously.

2.4.1.5 EEPROM

An EEPROM 93C46D is used in the base to store all tuning parameters for the RF chip, the current active channel, and the security code so that the information is not lost in the event of a power failure.

2.4.1.6 ATE Interface

ATE test points are available on the base to facilitate testing using automated test equipment (ATE). The ATE uses these test points to access the signals required to complete a base alignment. Connections from the base to its ATE jig are facilitated by a bed of nails. Base to ATE communication is accomplished through a dedicated port on the MCU .

2.4.1.7 LED Indicators

The base features 3 LED indicator to show the base unit when the handset batteries is being charged and In-use mode, New Call and Message.

2.4.2 Handset

2.4.2.1 Data Communications

The data is transmitted between the handset and base at 1000 bps using Manchester Coding format. The two frequencies used in the keying are 500 Hz and 1000 Hz. Logic 0 and logic 1 are represented by falling edge and rising edge of 1 kHz data respectively. A separate modem chip is not required in the design since the MCU generates and decides all the data.

The level for data transmissions are set to produce about ±100 kHz of deviation. This level was determined empirically to provide optimum data sensitivity. In the idle state, the transmit data port on the MCU is set to high impedance.

Received data from the handset is passed form the demodulator output to the data comparator where it undergoes low-pass filtering. After the splitting junction at the demodulator output, this receive data chain consists of low-pass filtering and a comparator to restore the data to its original condition. After conditioning, the data is coupled directly to the MCU for analysis.

2.4.2.2 Keypad Control

The keypad is arranged as a 4 x 6 (row x column) matrix with each row pulled up to V_BAT by a pull-up resistor. When the MCU is ready to accept a key press, columns 0 to 5 are set low. As soon as a key is depressed, the MCU will detect this by sampling the rows (i.e., a row will be pulled low). To determine what column was connected to the row, identifying what key was pressed, the MCU sets all columns high and then sequentially sets them low until the previous detected row is pulled low.

2.4.2.3 Ringer

The ringer used in the handset is basically a magnetic transducer. It takes an electrical signal from the MCU and uses it to create a varying magnetic field to vibrate a metal diaphragm. The vibrating diaphragm, in turn, produces acoustic waves forming sound energy. The ringer draws a large amount of current when it rings and is therefore powered directly from the battery. There are four different ring signals produced by the MCU to provide four distinct ringing tones. Each signal is a combination of two frequencies. The frequencies are listed in the table below.

Ring Tone Number	Frequency #1 (Hz)	Frequency #2 (Hz)
1	2500	1250
2	2500	625
3	1250	625
4	625	313

Table 1. MCU Ringer Tone Frequencies

The MCU ringing tones are coupled to the ringer via transistors. These transistors are biased to insure that ringer output is consistent from handset to handset.

2.4.2.4 ATE Interface

ATE test points are available on the handset to facilitate testing using automated test equipment (ATE). The ATE uses these test points to access the signals required to complete a handset alignment. Connections from the handset to its ATE jig uses a single 8-pin header. Handset to ATE communication is accomplished through a dedicated port on the MCU.

2.4.2.5 LED Indicators

The handset features two sets of LED indicators that is used to luminate the LCD in dark environment.

3 RF Module

The basic function of the radio frequency (RF) circuits on both handset and base is to provide a full duplex wireless link between the handset and base units of the telephone. This is accomplished by setting up two simultaneous communications links between the handset and base RF modules. The RF receiver and transmitter circuitries essentially provide a link between the microphone and speaker in the handset to the telephone line in the base. In this way, the phone performs exactly as a corded phone, except without the cord.

The frequency at which the handset (operating at 3.6V) transmits to the base is centred around 914.85 MHz, and the frequency at which the base (operating at 5V) transmits to the handset is centred around 2414MHz. The AT&T1430 2.4G HADLc MK1 uses a wideband FM scheme to directly modulate audio signals onto the RF carriers.

The following tables outline the frequencies and corresponding channel numbers used by the RF. The handset uses a high-side local oscillator (LO) while the base uses a low-side LO to down-convert the incoming signal.

Channel #	Transmit Frequency (MHz)	Receive Frequency (GHz)	Rx LO Frequency (GHz)
0	9.12750	2.41115	2.39885
1	9.12900	2.41140	2.39910
2	9.13050	2.41165	2.39935
3	9.13200	2.41190	2.39960
4	9.13350	2.41215	2.39985
5	9.13500	2.41240	2.40010
6	9.13650	2.41265	2.40035
7	9.13800	2.41290	2.40060
8	9.13950	2.41315	2.40085
9	9.14100	2.41340	2.40110
10	9.14250	2.41365	2.40135
11	9.14400	2.41390	2.40160
12	9.14550	2.41415	2.40185
13	9.14700	2.41440	2.40210

Channel #	Transmit Frequency (MHz)	Receive Frequency (GHz)	Rx LO Frequency (GHz)
14	9.14850	2.41465	2.40235
15	9.15000	2.41490	2.40260
16	9.15150	2.41515	2.40285
17	9.15300	2.41540	2.40310
18	9.15450	2.41565	2.40335
19	9.15600	2.41590	2.40360
20	9.15750	2.41615	2.40385
21	9.15900	2.41640	2.40410
22	9.16050	2.41665	2.40435
23	9.16200	2.41690	2.40460
24	9.16350	2.41715	2.40485
25	9.16500	2.41740	2.40510
26	9.16650	2.41765	2.40535
27	9.16800	2.41790	2.40560
28	9.16950	2.41815	2.40585
29	9.17100	2.41840	2.40610

Table 2. Handset Frequencies

Channel #	Transmit Frequency (GHz)	Receive Frequency (MHz)	Rx LO Frequency (GHz)
0	2.41115	9.12750	9.2345
1	2.41140	9.12900	9.2360
2	2.41165	9.13050	9.2375
3	2.41190	9.13200	9.2390
4	2.41215	9.13350	9.2405
5	2.41240	9.13500	9.2420
6	2.41265	9.13650	9.2435
7	2.41290	9.13800	9.2450
8	2.41315	9.13950	9.2465
9	2.41340	9.14100	9.2480
10	2.41365	9.14250	9.2495
11	2.41390	9.14400	9.2510
12	2.41415	9.14550	9.2525
13	2.41440	9.14700	9.2540
14	2.41465	9.14850	9.2555
15	2.41490	9.15000	9.2570
16	2.41515	9.15150	9.2585
17	2.41540	9.15300	9.2600
18	2.41565	9.15450	9.2615
19	2.41590	9.15600	9.2630
20	2.41615	9.15750	9.2645
21	2.41640	9.15900	9.2660
22	2.41665	9.16050	9.2675
23	2.41690	9.16200	9.2690
24	2.41715	9.16350	9.2705
25	2.41740	9.16500	9.2720
26	2.41765	9.16650	9.2735