Theory of Operation of the

AT&T1430 2.4G HADLc MK1

2.4 GHz Hybrid Analogue Phone with CIDSW

Revision History:

Revision	Description	Page	Effective Date
0	Initial Release	All	

Contents

1 General

The AT&T1430 2.4G HADLc MK1 is based on the VTECH VT9122 ADLC MK4. The AT&T1430 2.4G HADLc MK1 2.4 GHz Hybrid Analogue Phone with CIDCW, is the next generation product of the VT9122 ADLC MK4 line of 900 MHz analog cordless telephones. The AT&T1430 2.4G HADLc MK1 offers essentially similar functionality as the current VT9122 ADLC MK4, but the difference of radio link.

1.1 Hardware

The AT&T1430 2.4G HADLc MK1 consists of a mobile handset and a fixed base unit. The handset contains two printed circuit boards (PCB) - the baseband audio circuit board and a separated radio frequency (RF) circuit board. Both are double sided. The majority of the discrete components on the PCB are surface mount,using formats such as those in the 0603 size and a few of through-hole components.

The base unit electronics are split over two PCBs _two main PCBs (one double sided and one single-sided) for the RF and audio and line interface electronics respectively. The double-sided PCB contains the RF electronics. The single-sided PCB contains the line interface, power management, baseband controller and parts of audio chain circuits, and is comprised of through-hole (line interface) as well as surface-mount components (rest of the circuit). The single-sided PCB and double-sided PCB are connected together via flexible ribbon cable.

1.2 Overview

This document describes the theory of operation of the AT&T1430 2.4G HADLc MK1. Section 2 provides the technical description of the baseband audio module, including telephone line interface, power management circuits, audio circuits, and microcontroller unit (MCU) circuits. Though similar in some cases, there are sufficient differences that the handset and base unit baseband circuitry are described in separate subsections under each functional heading. Section 3 provides the technical description of the RF module, including the antenna circuits, receiver circuits, and transmitter circuits. Unlike the baseband, the handset and base unit RF circuitry are similar, and any differences applicable are highlighted within the description of each functional heading.

2 Baseband Module

The baseband audio module includes circuitry for the telephone line interface (base only), power management function, audio connection, and the microcontroller.

The following sections explain the individual blocks in the baseband module in detail.

2.1 Telephone Line Interface

The AT&T1430 2.4G HADLc MK1 telephone line interface couples audio and line signalling to and from the telephone line while isolating the phone from the telephone line. The interface provides basic operation for the audio and facilitates pulse dialling and ring detection. Isolation is achieved by electronically coupling audio through a pair of transitors. The isolation is necessary for the phone to meet the FCC 1.5 kV high-pot requirement. However, the line interface circuit used in AT&T1430 is without Hi-Pot isolation. In other words, circuit ground has a conduction path to external T&R. Thanks to the special mechanical design to avoid accessibility of metallic parts(like charge contacts) by human fingers, the interface providing protection from high voltage transients and surge currents can be cost down and simpify.

2.1.1 Line Protection and Filtering

The audio signal from the central office or PBX is carried by the telephone line (tip and ring) to the phone jack. The two lines are also used to carry the ring signal (40 - 15 V_{rms}, 15.3 - 68 Hz) and various line signalling (i.e., DTMF, dial tone, etc.)

To overcome AT&T Surge A requirement, 1A fuse is used instead of 250mA. A fuse is installed in the telephone loop to limit the loop current to no greater than 1A. A varistor is used to limit the voltage across the line interface should a high voltage transient appear on the telephone line (i.e., lightning strike). Further high voltage protection (1.5 kV) is afforded by high resistance high power resistors, high voltage capacitors and high voltage transistors.

2.1.3 Ring Detect

The ring signal across the tip and ring is detected by a transitor switching network. Resistors limit the current flow into the transistor and maintain the necessary ringing impedance as specified in EIA-470. The zener diode across the transitor input provides a discharge path for the coupling capacitor during negative ring cycles.

On the output side, a pull-up resistor is used to set the transistor collector current (i.e., sensitivity control) when a ring signal is detected. The output is connected to the MCU where the ring signal is analysed for validity. A typical ringing pattern from the central office is one second "on" and four seconds "off".

2.1.4 Pulse Dialling or Off-Hook Switch

For pulse dialling (8 - 11 pps, 58 - 64% break, interval 53 - 80 ms), transitor networks are used to make and break the telephone line loop. In order for the phone to function normally irrespective of the polarity of the tip and ring, a diode bridge is used to ensure the potential on the emitter of the dialington pair with respect to its collector. One of the transitor input is connected to the MCU from which the required state of the dialington pairs is controlled. For pulse dialling, the dialington pairs are simply pulsed off and on at the appropriate rate. To set the phone off-hook, the dialington pairs are activated which closes the telephone loop.

2.1.5 Speech Circuit

To minimize cost, a speech network IC is not used in the AT&T1430 2.4G HADLc MK1 design. Instead, transitors with supporting hardwares are used to provide all the speech network functions. The speech circuit provides line impedance matching and sidetone cancellation.

Matching (or return loss) is optimised when the termination impedance equals the source impedance. The effective impedance looking into the AT&T1430 2.4G HADLc MK1 is a combination of all the components' impedance in the line interface. This effective impedance was derived empirically by fine tuning the resistor across the audio transformer's secondary. The speech circuit matches a line impedance of 600 Ω (EIA-470: 4.5.2.3) while the transmit, receive and sidetone frequency responses are set with a 900 Ω line impedance (EIA-470:4.1.11 - 4.1.3).

The telephone line to audio signal conversion (or vice versa) is accomplished by transmitting audio to dialingtons pairs via a transmit amplifier , and a receive amplifier receives audio directly from the dialington pairs output line.

Sidetone cancellation is accomplished by taking transmit audio (the sidetone) and resistively combining it with out-of-phase transmit audio. In a real-world situation, the match between the line interface and the telephone line is not perfect. This slight mismatch results in some transmit audio being enter into the receive direction. The sidetone cancellation signal in AT&T1430 2.4G HADLc MK1 is created by combining the transmit audio signal from another output of the transmit amplifier which are inherently 180° out-of-phase (i.e., the sidetone source), then feed to the receive path.

2.1.6 FSK, CAS & Stuttered Dialtone Detection

The detection of FSK, CAS & Stuttered dialtone is done by the NEWAVE SP0001 chip. The chip works on 3.579545MHz clock source. An external crystal is used as reference.

As CAS sign appears in the presence of voices form the near end, so CAS signal must be sidetone compensated. In the schematics, after the sidetone tone compensation network, the CAS_IN signal passes to the GS2 AMP. Note that the sidetone network optimises compensation at around 2.5kHz before CAS tone is combined by 2.1kHz and 2.7kHz tones. Besides providing gain, the GS2 AMP also rejects signals outside CAS tone frequency to enhance CAS tone detection.
Summary: Gain(T&R → GS2) = 0dB @ 2.5kHz

Since FSK signals may appear during on-hook and they will not appear with the presence of near-end voice, hence GS1 AMP is use, which does not have any sidetone compensation.

Also as GS2 AMP has a low frequency cut-off at about 1500Hz (in order to enhance CAS detection), stuttered dialtone (dual tone of around 300Hz and 400Hz) must be detected through GS1 AMP. Hence this amplifier must have a flat frequency response from 300 to 2.5kHz.
Summary: Gain(T&R → GS2) = 0dB @1kHz.

Unlike PCC318, the NEWAVE CID chip does not provide MEI detection hardware. Hence we must use external Op-Amp to monitor the T&R DC condition. This Op-Amp stage is a standard DC differential amplifier configuration, with a gain of 0.165. Using two series 10Mohm resistors can further reduce the on-hook DC leakage current.

The following table shows the detailed DC voltage to define different line conditions :

T&R DC voltage	Line Condition
>20V	Normal
<20V	Extension in-use
<2.1V	No line
DC drop > 0.5V	Parallel phone pick-up

2.2 Power Management

2.2.1 Base Unit

AT&T1430 2.4G HADLc MK1 base power circuits consist of DC power regulation and charging circuits for the handset. The base unit operates on a regulated 5 VDC power supply. The power is supplied to the regulator via a UL-approved 9 VDC, 400 mA power adapter. During normal operation, the base unit draws about 97 mA of current (with an additional 130 mA when the handset is in the cradles).

2.2.1.1 Power Supply

DC power is supplied to the base via a UL-approved AC-to-DC power adapter rated at 9 VDC, 400 mA. The power from the adapter is then regulated down to 5 VDC. Filter capacitors are connected to both sides of the 5 VDC regulator to ensure AC variations are eliminated from the power lines. All circuits except for the Tx RF chain are powered at all times. The Tx RF chain is controlled by the MCU by programming the RF chip and is turned on when communications with the handset is required. The Tx_PWR is switched off when the Tx RF chain is not needed to minimise the use of the RF spectrum space during the idle state.

2.2.1.2 Handset Charge Circuit

To reduce costs by keeping circuits simple, the handset charge circuit is designed to supply a charging current to a cradled handset regardless of whether the battery is fully charged or not. This current varies with the charge on the battery and is limited to 0.1 C or 10% of the battery capacity by a limiting resistor. The charge circuit is supplied directly from the 9 VDC, 400 mA power adapter which insures that power is available to charge the handset battery.

In the AT&T1430 2.4G HADLc MK1, the handset battery has a capacity of 1300 mAHr, thus the maximum charging current is set to approximately 130 mA. The specification of 0.1 C allows a battery to be constantly charged without damaging the battery. The handset charge circuit components have been selected to withstand shorting the charge contacts on the cradle. The handset charge circuit also provides a signal to the MCU for cradle detection.

2.2.1.3 ESD Protection

The charge contacts for the handset are vulnerable to electro-static discharge (ESD) because they are exposed to the outside world. Since the contacts are connected directly to the base circuits, ESD can damage some of the base internal circuits if no protection is implemented. Therefore, a number of measures have been taken to protect internal circuits from ESD damage.

Charge contact have LC filtering on them to bypass ESD. Low voltage spare gaps (arc at ~500 V based on 1 kV/mm electric discharge through air) are also implanted in the PCB layout between charge contacts and a special ESD ground. This ESD ground channels any ESD discharge directly to the telephone line and AC adapter, preventing discharges from entering the main circuits.

2.2.2 Handset

The AT&T1430 2.4G HADLc MK1 handset power is supplied by a three-cell battery with a nominal voltage of 3.6 VDC. This voltage will direct apply to all circuit including the RF circuit part. The variation on the performance can fall within the tolerance.

In order to achieve a long standby time, the handset conserves power by "sleeping" when not in use and occasionally "waking up". In the "sleep" condition, the handset supplies power only to those circuits deemed essential for proper operation such as the MCU and memory. The RF chip will be programmed to " Inactive" mode and all operation will stop including the oscillator circuit. In the "wakeup" condition the handset powers the RF chip to "Rxmode" that allow it to receive data. This function is necessary to detect if the base requires the handset to act on a condition such as an incoming call. With this sleep/wake-up sequence, handset is able to achieve a six-day stand-by time. To reduce the cost, external wake-up circuit are insteaded by entering "Ideal mode" or "Normal mode" that under MCU control.

2.2.2.1 Battery Maintenance and Low Voltage Detection

The battery is recharged via a cradle contact on the base. The handset has a corresponding charge contact at the bottom of the handset chassis. The charge contact is protected from a short to ground by a diode placed in line with the battery connection. The diode prevents the battery from discharging from the charge contact. Protection from ESD is afforded by a bypass capacitor installed at the charge contact.

When the battery voltage drops below the minimum working voltage of the MCU, the phone will not function properly again if the MCU is not properly reset. Therefore, circuits have been implemented to insure that the battery has sufficient charge for proper operation. The reset pin of MCU will be released till the battery voltage charge back to the min. operating voltage.

About the function of low voltage detection, the RF chip can provide an internal reference to which battery charge is compared and the detection voltage are programmable by MCU. In AT&T1430 2.4G HADLc MK1, two level of voltage will be detected. If the battery voltage drops below 3.3 VDC, the low battery detect pin in chip will be activated to inform the MCU and causes the MCU to notify the user by producing an audible tone and flashing the LED. Then, MCU will change the detection voltage to 2.9V to noticfy the MCU stop all the operation before the voltage drop below the operation voltage of the RF chip. The detection voltage will change back to 3.3V once the on-cradle signal detected. The typical hysteresis of the comparator is 18mV.

2.3 Audio Circuits

Audio circuits are necessary to condition speech for RF transmission and reception. The conditioning includes amplification, filtering, pre-emphasis / de-emphasis and compression / expansion, all of which ensures that the speech is received and transmitted with maximum clarity and legibility.

Pre-emphasis/de-emphasis is used to improve signal-to-noise ratio (SNR) which is, as a consequence of frequency or phase modulation, degraded at high audio frequencies. Compression/expansion is also used to improve the perceived SNR by reducing the noise vulnerability of low-level signals. The compression process amplifies low level signals more than it does for high level signals. Thus, by compressing the dynamic range of the audio before transmission, noise picked up during transmission has less of an effect on the low-level signals.

After receiving the transmission, the expansion process maintains this improved SNR while restoring the low level signals back to their original levels.

The audio circuits are implemented by using the compressor and expander inside the combo chip. It provides compression/expansion, amplification and muting all in a clean, simple way.

2.3.1 Base Unit

The audio circuits in the base provide for speech exchange between the telephone line interface and the RF module that communicates with the handset. Figure 1 shows the circuitry for audio processing in the base unit.

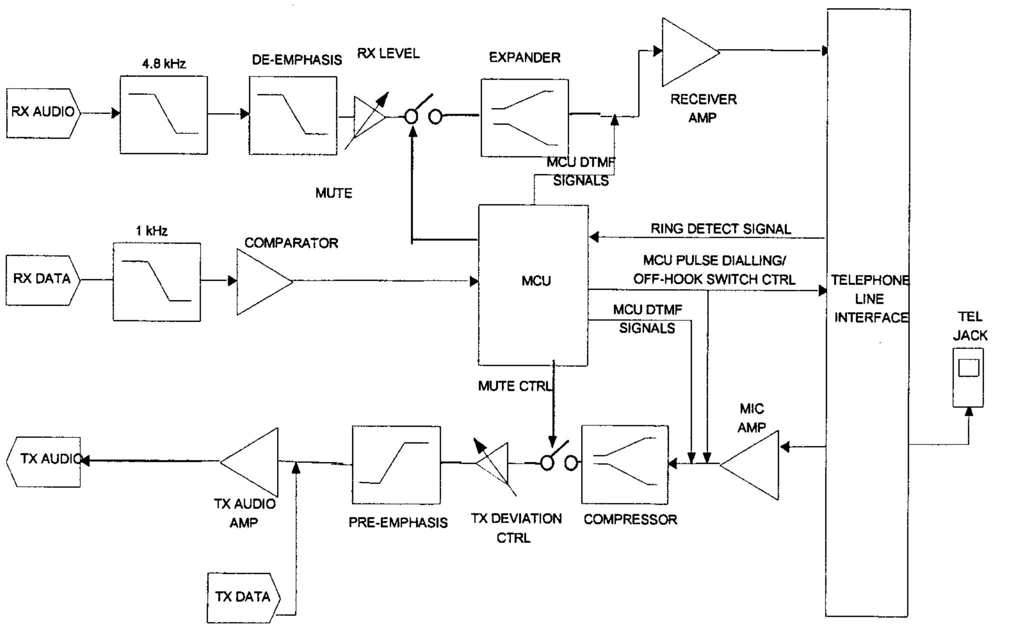

Figure 1. Audio Circuits in Base Unit

2.3.1.1 Transmit Direction (RF module to telephone line)

The transmit audio is transmitted from the handset to the base using frequency modulation (FM). The FM signal from the handset enters the base RF module, where the signal undergoes filtering, down-conversion, and finally demodulation. The baseband audio then leaves the RF module via the demodulator (for a deviation of ±25 kHz).