# PDL GX

# THEORY OF OPERATION

## for VTECH VT-1421
## and RS 43-1106

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**Revision History**

| Revision No | Description | Page | Effective Date |
|---|---|---|---|
| 1 | Initial Release | All | 20-JAN-99 |

# Table of Contents

# 1 Complete System Description

## 1.1 Introduction

The VT 1421 is a cordless telephone that is based upon the VTECH 900 MHz PDL ADPCM core platform. The complete telephone consists of a miniature form factor handset along with a base unit with integral battery charger. The handset unit uses a retractable antenna whereas the base unit uses an internal antenna for better cosmetics.

This product is intended to address the market segment that is currently using products like our PDL but are looking for a smaller form factor and a stylish product design.

## 1.2 Feature List

### 1.2.1 Basic Features

- Name / number caller ID display with 50 call storage capacity
- 32kbps ADPCM voice coding
- 2 row by 12 character 5x7 dot matrix alpha-numeric LCD display on handset
- 10 channel operation with auto channel selection
- 900 MHz Operation
- 24 bit digital security code for 16.8 million combinations
- DTMF and Pulse dialing
- 20 number/location programmable memory for up to 20 digit phone number
- Automatic search for best available channel
- Low battery detect and warning indicator
- Handset power saving 7 days (less during out-of-range) [1]
- 7.0 Hours continuous talk time [1]
- Volume adjust on handset
- Hearing-aid compatible receiver
- Provisions for spare handset battery pack in the base unit
- Complete battery back-up in case of power failure
- Backlit LCD on the handset
- Auto hang-up when returning the handset to the base cradle.
- Detachable power supply
- Support for handsets with 2.5mm jacks.

[1] Note that this is only when masked ROM is used. Use of external ROM will diminish the talk/standby time.

### 1.2.2 Unique Features

- Use of E2PROM in base unit for permanent memory storage of security code
- Use of E2PROM in the handset for nonvolatile storage of the security code, CID messages and speed dial numbers
- Handset allows for on-the-fly battery replacement
- Fully digital link between handset and base
- Digitally-scrambled voice communication between handset and base has extremely high immunity to noise and interfering signals
- Out-of-range indication while the handset is in use and in standby mode
- Removable battery pack
- Easy answer - When the phone rings simply press any key (except OFF) on the handset to answer when in idle mode.
- A faster charge (.2C) capability will be provided on the base for the handset battery. The unit will automatically switch over to regular trickle charge (.1C) when required.
- The electrical design will support charging in the face up position.
- Ringer muting

## 1.3 System Block Diagram

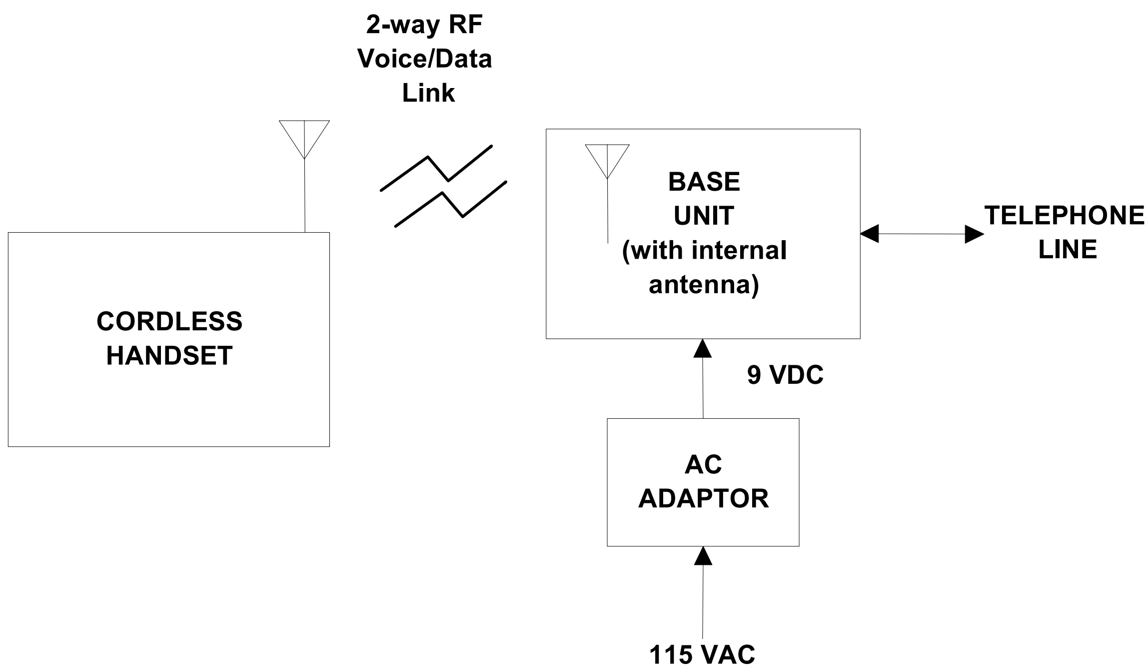


**Figure 1.2 System Block Diagram**

## 1.4 Handset Block Diagram

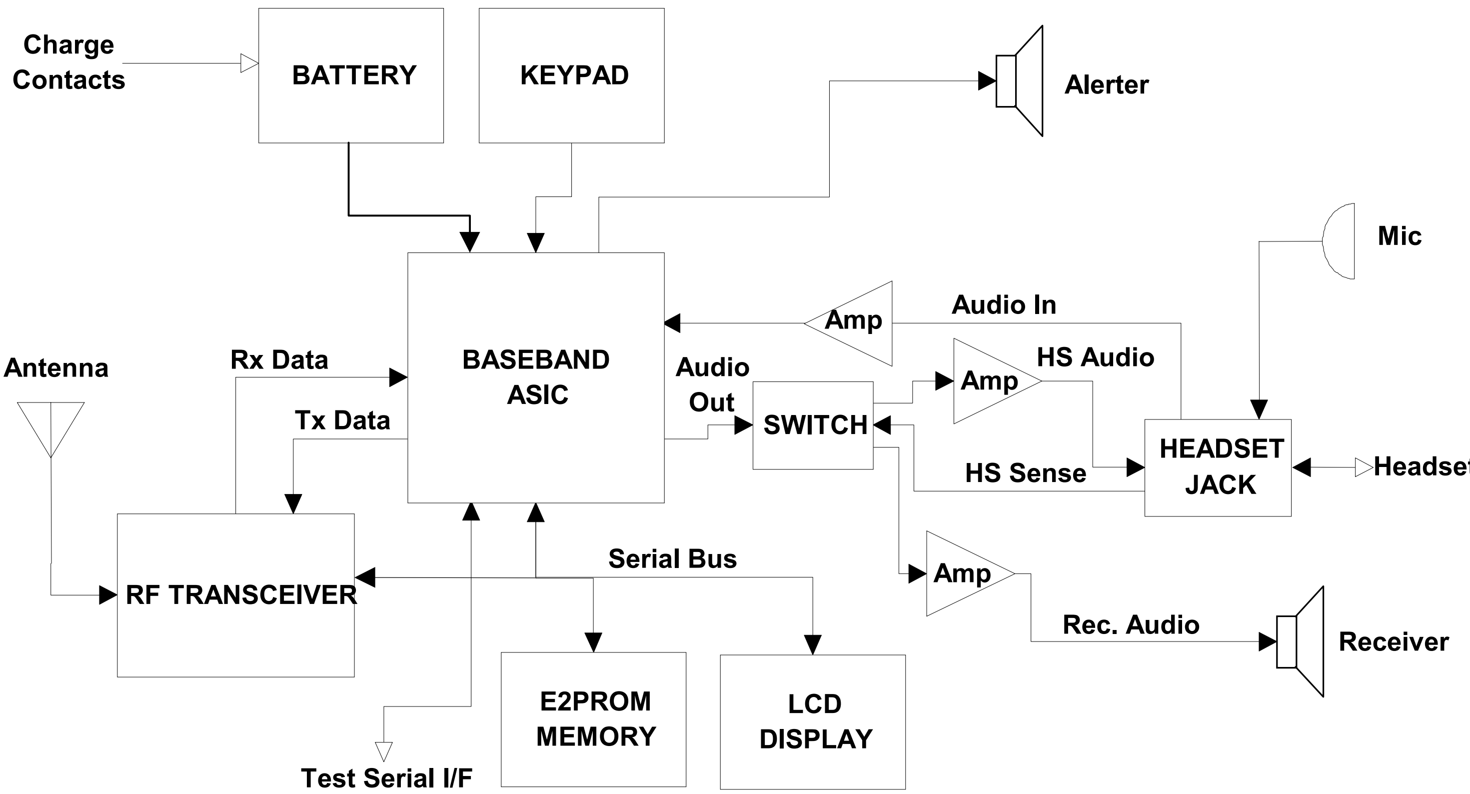


**Figure 1.3 Handset Block Diagram**

## 1.5 Base Block Diagram

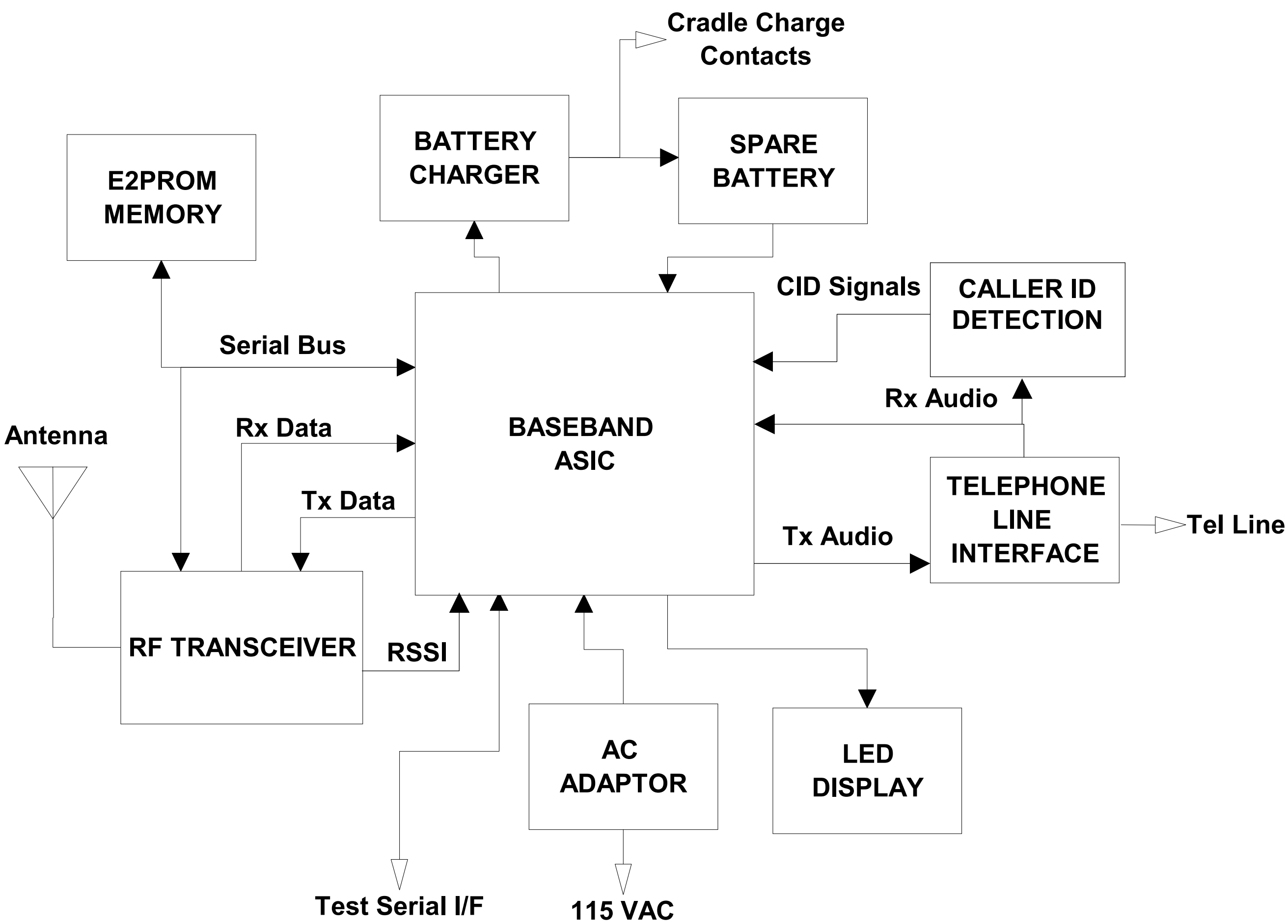


**Figure 1.4 Base Block Diagram**

# 2 RF Section Overview

## 2.1 Introduction

The basic function of the base and handset RF sections is to provide a full duplex wireless link between the handset and base sections of the telephone. This is accomplished by setting up two simultaneous communications links between the handset and base RF boards. The RF receiver and transmitter circuitry essentially provide a link between the microphone and receiver in the handset to the telephone line in the base set. In this way the phone performs exactly as a corded phone, except without the cord.

The frequency at which the handset transmits to the base is centered around 926.55 MHz, and the frequency at which the base transmits to the handset is centered around 903.8 MHz. The data rate which is modulated onto the RF carrier is 48 kbps. On the receiver side, the data is extracted and then converted back into the original audio signal.

It is important to note that the synthesizer / pre-scaler IC only operates up to 500 MHz. The VCO's therefore oscillate at roughly 450 MHz. The 900 MHz signals needed for the transmit and receive sections are generated from the second harmonic of the VCO frequencies.

The following section will outline the transmit frequencies used as well as the corresponding LO frequency which is used for the receiver. This is followed by the Block diagram and a block by block functional description of the modules.

## 2.2 Frequency Tables

This section outlines the RF frequencies and corresponding channel numbers. The handset uses a high side LO while the base uses a low side LO to down-convert the incoming signal.

### 2.2.1 Handset Frequencies

| Channel | Transmit | Receive | RX LO |
|---|---|---|---|
| 1 | 925.05 | 902.3 | 913.0 |
| 2 | 925.35 | 902.6 | 913.3 |
| 3 | 925.65 | 902.9 | 913.6 |
| 4 | 925.95 | 903.2 | 913.9 |
| 5 | 926.25 | 903.5 | 914.2 |
| 6 | 926.55 | 903.8 | 914.5 |
| 7 | 926.85 | 904.1 | 914.8 |
| 8 | 927.15 | 904.4 | 915.1 |
| 9 | 927.45 | 904.7 | 915.4 |
| 10 | 927.75 | 905.0 | 915.7 |

### 2.2.2 Base Frequencies

| Channel | Transmit | Receive | RX LO |
|---|---|---|---|
| 1 | 902.3 | 925.05 | 914.35 |
| 2 | 902.6 | 925.35 | 914.65 |
| 3 | 902.9 | 925.65 | 914.95 |
| 4 | 903.2 | 925.95 | 915.25 |
| 5 | 903.5 | 926.25 | 915.55 |
| 6 | 903.8 | 926.55 | 915.85 |
| 7 | 904.1 | 926.85 | 916.15 |
| 8 | 904.4 | 927.15 | 916.45 |
| 9 | 904.7 | 927.45 | 916.75 |
| 10 | 905.0 | 927.75 | 917.05 |

## 2.3 Block Diagram

Both the handset and base RF sections follow the same block diagram shown below with only minor changes to incorporate the different transmit and receive frequencies.

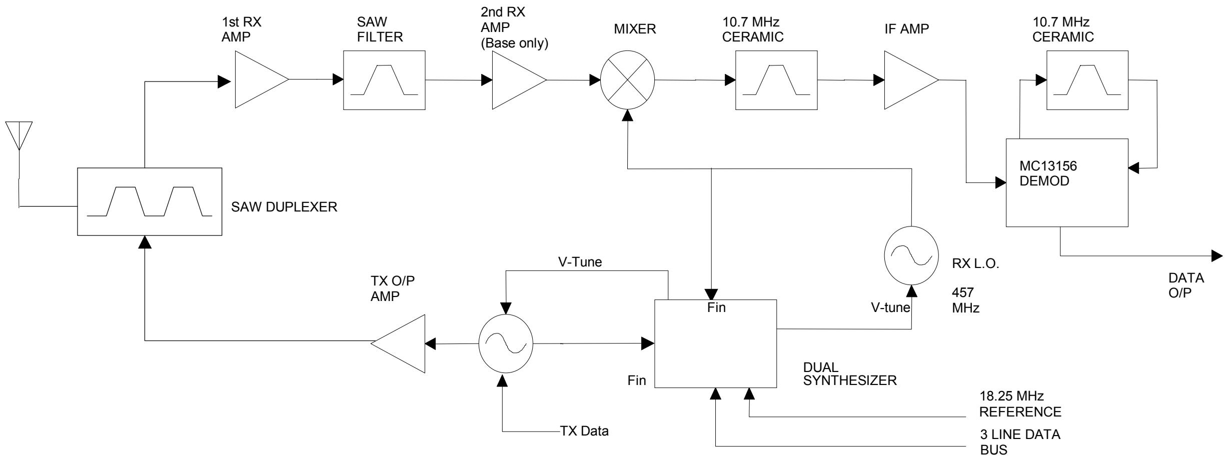


**Figure 2.3 RF Section Block Diagram**

As can be seen by the block diagram, there are several important input/output signals which are necessary for operation of the RF section (this does not include the separate supply lines for both TX and RX sections). An 18.25 MHz reference is present for use in the frequency synthesizers. The accuracy of this 18.25 MHz input will affect the transmit and receive frequencies. In order to ensure proper operation of the RF sections, the 18.25 MHz reference signal must be at least 500 mV in amplitude. Also present is the 3-line serial data bus on which data is transferred to the synthesizers to set both the transmit and receive frequencies.

The modulation input allows digital data to be modulated directly onto the TX carrier. The Data output is the demodulated signal after being filtered and shaped by a comparator. The data is then sent to the AMD ASIC where the original voice signal is reconstructed.

The RF section performs a single down-conversion of the incoming RF signal to 10.7 MHz where it is demodulated and sent to the AMD ASIC. The transmit section directly modulates the carrier.

The following section explains the individual blocks in the RF section in detail. All reference to part numbers correspond to the handset schematic.

# 3 RF Section Detailed Operation

## 3.1 Antenna Section

### 3.1.1 Antenna

The antenna is a device which allows effective conversion of energy from air to the RF circuitry. The antennas used are a retractable 1/2 wave with 2.5 dB gain relative to an isotropic radiator and a fixed 1/4 wave antenna with roughly 0 dB gain relative to an isotropic radiator. The duplexer and filters which follow the antenna, require a 50 ohm match to operate properly. The antenna is roughly matched to 50 ohms and requires a simple microstrip matching network to achieve this. If a network analyzer is attached to the BFA connector after disconnecting the duplexer, the antenna match may be measured. In order to achieve a good 50 ohm match, one must be careful not to obstruct the antenna as any object near the antenna will affect its impedance.

### 3.1.2 SAW Duplexer

The SAW Duplexer consists of two bandpass filters to provide the necessary isolation between transmit and receive sections and to pass the correct frequencies to transmit and receive sections. To ensure that the Duplexer is operating correctly, the match looking into the filters from the BFA connector may be measured. To do this it is necessary to remove the 0 ohm resistor which connects the antenna to the Duplexer. A return loss of approximately 15 dB should be measured for both the TX and RX bands.

## 3.2 Receive Section

### 3.2.1 RX Amps and SAW Filter

The purpose of the first RX amp is to provide enough gain that the noise figure of the RX section is fixed to as low a value as possible. It must provide a good 50 Ω match to both the RX bandpass filter and the SAW filter. This amplifier must also have good power handling capability due to the limited filtering which precedes it. The design employs a collector inductor to improve the output power capability of the transistor. This form of matching also ensures that the gain of this stage is not too wide band further improving its performance by allowing it to effectively reject signals which are far out of its passband.

Directly following the first RX amp is the SAW filter. This filter is responsible for the bulk of the filtering in the receive section. It provides more than 40dB of image rejection and TX carrier suppression. The insertion loss of this filter is relatively high due to its SAW implementation. It has an insertion loss of less than 5 dB, typically 4 dB. An amplifier is required before this SAW filter to keep the noise figure low. If it were not present, the noise figure of the phone would increase by the 4 dB loss associated with the SAW filter.

The second RX amp provides a limited amount of gain. Its main function is to ensure that the mixer sees a good wideband match. Measuring the RX gain from the BFA connector to the output of this amplifier will produce results as shown in Figure 4 below.

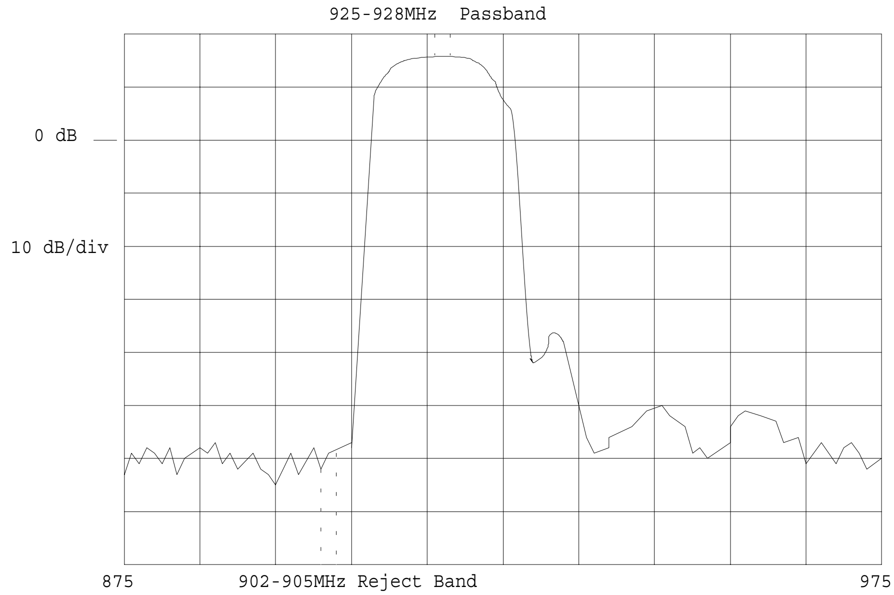


**Figure 3.2.1 RX Front End Response**

### 3.2.2 RX Mixer

The function of the mixer is to combine the incoming signal with a LO signal in order to convert the desired signal to the 10.7 MHz IF frequency. The mixer used for this task is a dual gate FET (NEC 25139). The LO and RF signals are placed on the gates of the FET and the IF signal is coupled off of the drain. The FET provides conversion gain along with adequate power handling characteristics. Both the RF and LO ports are shorted to ground by spiral microstrip inductors on base unit and, spiral microstrip and SMT inductors on the handset. These inductors provide a high impedance at both the RF and LO frequencies while presenting a very low impedance at the IF frequency. The mixer is followed by an emitter follower which converts the high impedance output of the mixer to a 330 ohm output suitable for directly driving the IF ceramic filters. The gain for the pair (mixer and follower) is about 4 dB (50 ohms in, 330 ohms out).

### 3.2.3 RX VCO and LO Buffer

The RX VCO is a Colpitt's type oscillator operating at about 450 MHz with a frequency selective network tuned to about 900 MHz on the collector. The frequency of oscillation is controlled by a varactor diode in the tank circuit connected to the base of the transistor. This diode is connected to the loop voltage from the RX synthesizer. Rough tuning is achieved with a variable chip cap. This capacitor is used to center the tuning voltage to ensure reliable operation over a wide temperature range and also to compensate for variances in component values.

The 450 MHz LO for the PLL is coupled off of the emitter of the VCO transistor. This is lightly coupled to ensure that the VCO is not loaded by the PLL. The 900 MHz RX LO signal for the Mixer is coupled off the collector of the VCO transistor.

### 3.2.4 RX Synthesizer

The PLL and prescaler for both the TX and RX sides are now combined into one IC. The Synthesizer receives channel information from the embedded microprocessor in the AMD ASIC via the serial buss. It also requires a stable 18.25 MHz reference which is also supplied from the AMD ASIC.

A passive loop filter is employed to connect the synthesizer to the VCO. This tuning voltage may be observed from test point RX_LOOP_V on the bottom side of the PCB. The loop filter cutoff frequency is set to about 1 kHz to allow relatively fast power-up times.

### 3.2.5 IF Amplifier Stage

There is only one stage of discrete IF amplification. Transistor Q8 on the base (Q5 on handset) is used as an amplifier with 330 ohms input and output impedance. The rest of the IF gain is provided by the FM demod IC discussed below.

### 3.2.6 IF Filtering

The choice of 10.7 MHz as an IF frequency, allows the use of relatively inexpensive filters. Two ceramic filters are used to achieve the desired adjacent channel suppression. Two different bandwidth filters are used, 230 kHz and 150 kHz, so that any shifting in the passband does not narrow the bandwidth excessively.

### 3.2.7 Demodulator, Data Comparator, Mute Comparator

This RF section uses a MC13156 FSK demodulator. It incorporates all three of the above functions into a single IC.

The Quadrature voltage may be observed form test point DATA_OUT on the handset or QUAD_VOLT on the base. This voltage should nominally be 1.2 V when a signal is center tuned.

The data stream which comes out of the demodulator has a peak to peak amplitude of approx. 0.5V. In order to be of use it is first filtered and converted to a digital (0 to 5V) signal by using a comparator inside the IC.

## 3.3 Transmit Section

### 3.3.1 TX Amp

There is one transistor which provide the necessary gain for the transmit section. Transistor Q1 amplifies the signal from the TX VCO. The output power is set such that we guarantee less then 50mV/meter radiated field strength measured at 3 meters.

### 3.3.2 TX VCO

The basic operation of the TX VCO is the same as the RX VCO, except for one detail. The TX VCO is also FSK modulated by the transmit data through a second varactor in the tank (25kHz peak to peak). The data is first filtered and then the amplitude is set via a precision resistor divider (R119/R120 on handset and R27/R179 on base) to set the deviation of the data modulation.

### 3.3.3 TX Synthesizer/PLL

The TX PLL is combined into one IC with the RX PLL. See above. The loop filter cutoff frequency is about 100 Hz. This allows the data modulation to include frequencies down to about 100 Hz. The power-up time of the TX PLL is not critical.

# 4 Baseband Section

## 4.1 General Description

The AMD ASIC is a custom designed IC based on the core platform of the AMD CT2 baseband chipset. This custom modification contracted by VTech removes the protocol blocks associated with the CT2 TDD architecture and replaces it with a VTech proprietary FDD protocol block.

The AMD ASIC performs virtually all the non-RF functions. The base and handset ASIC's are identical with the exception of the ROM code which will be masked into the ASIC prior to mass production.

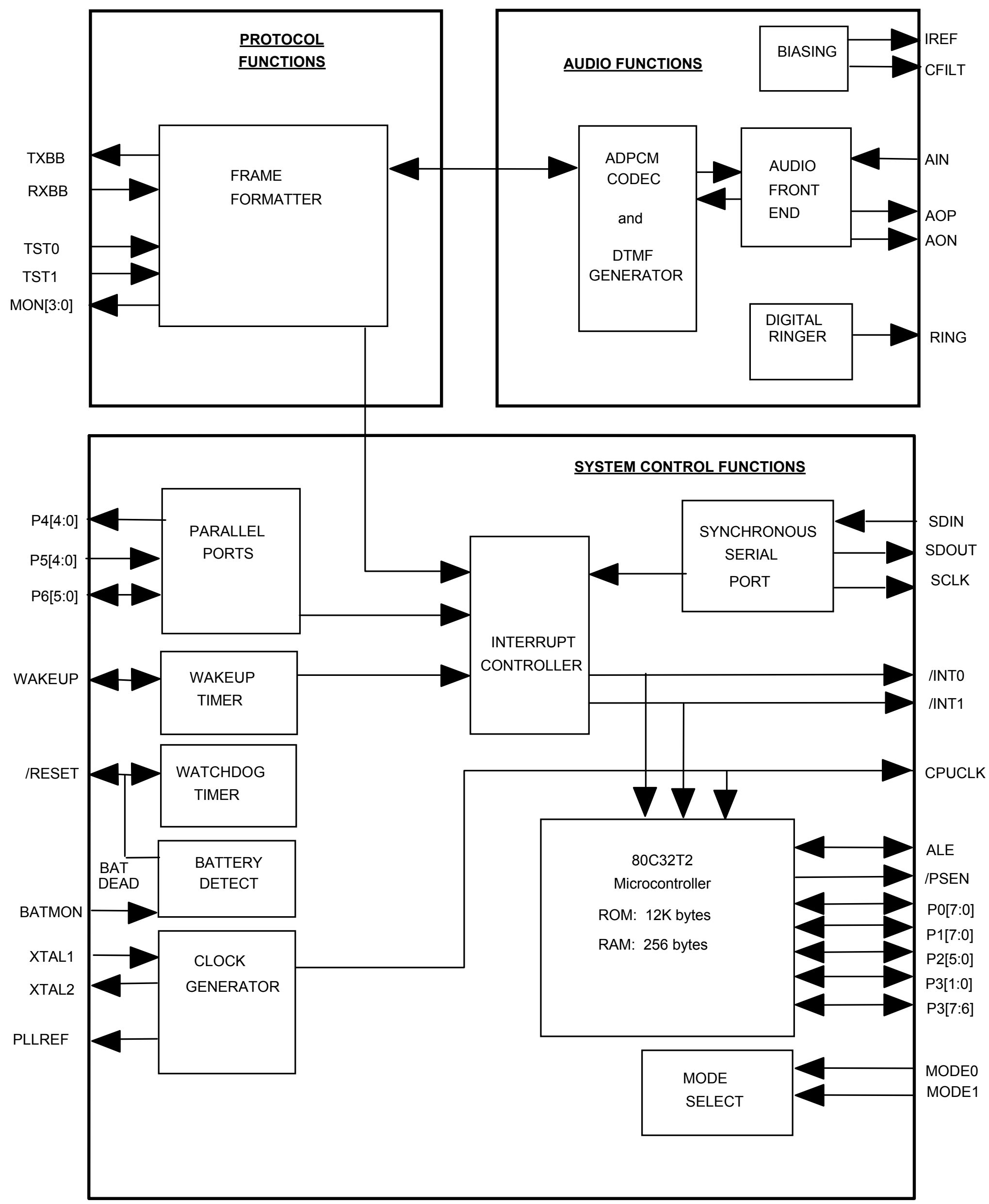


**Figure 4.1 AMD ASIC - Internal Structure Diagram**

## 4.2 Detailed Functional Description

The principle components are:

### 4.2.1 Protocol Functions

The protocol block conducts a signaling and a voice channel in the transmit and receive directions. All data I/O are CMOS levels.

### 4.2.2 Audio Functions

1) **CODEC.** The CODEC transcodes analog voice signals and 32 kbps ADPCM data.
2) **Audio Front End.** The audio front end connects the analog voice I/O pins to the CODEC.
3) **Tone Ringer.** The tone ringer produces digital square-wave ringing tone signals for output on the RING pin.
4) **Biasing.** The biasing circuits establish precision currents and voltage references to support audio and battery detection analog operations.
5) **DTMF Generator.** The DTMF generator produces digitally-generated tones for DTMF dialing and call progress tones.

### 4.2.3 System Control Functions

1) **Microcontroller.** An 8-bit 80C32T2 microcontroller executes the program and controls the protocol logic and other hardware configuration. It includes 16 Kbytes of mask-programmable ROM and 256 bytes of RAM. It also includes an asynchronous serial port.
2) **Synchronous Serial Port.** The serial port provides a synchronous serial link to devices such as RF synthesizers, serial EEPROMs, etc.
3) **Peripheral Ports.** The peripheral ports are for general purpose I/O functions. One port is designed such that any change of state generates an interrupt for the key scanning function.
4) **Battery Level Detector.** The battery level detector reports the low battery condition to prevent misoperation when batteries are low. It also emits a dead battery control signal which can be used to hold the device in a disabled, low power state and a high level detection for battery charging control.
5) **Watchdog Timer.** The watchdog timer protects the system from errant software by periodically issuing a reset unless serviced by software.
6) **Wakeup Timer.** The wakeup timer is a multivibrator controlled by external passive components to effect a low power periodic wakeup for call detection.
7) **Interrupt Controller.** The interrupt controller structures the various interrupts for manageable service by the microcontroller.
8) **Clock Generator.** The clock generator creates required internal timing signals from the crystal operating at 18.25 MHz. It also generates a PLL reference at the crystal frequency.
9) **Address decoder.** The address decoder generates strobes accessing selected address spaces in the device.

## 4.3 Port Pin Assignment And Functions

### 4.3.1 Handset Port Pin Assignment

| Port # | Functional Description | Direction | Logic | Internal Pull Up Status | External Pull Up |
|---|---|---|---|---|---|
| P0.0-7 | ADDRESS/DATA BUS | | TRI-STATE | | |
| P1.0 | NOT USED | OUTPUT | LOW | DISABLED | |
| P1.1 | LCD CHIP SELECT | OUTPUT | ACTIVE LOW | ENABLED | |
| P1.2 | LCD A0 | OUTPUT | TWO STATE | ENABLED | |
| P1.3 | AUDIO OUT ENABLE | OUTPUT | ACTIVE LOW | ENABLED | 10K |
| P1.4 | HEADSET SENSE | INPUT | ACTIVE HIGH | DISABLED | 300K |
| P1.5 | RINGER LOW | OUTPUT | ACTIVE LOW | ENABLED | |
| P1.6 | BACKLIGHT | OUTPUT | ACTIVE LOW | ENABLED | |
| P1.7 | ON CRADLE | INPUT | ACTIVE LOW | DISABLED | 470K |
| P2.0 | ADDRESS BUS | | | | |
| P3.0 | ATE DATA RX | INPUT | | DISABLED | |
| P3.1 | ATE DATA TX | OUTPUT | | ENABLED | |
| P4.0 | KEYPAD COL 0 | OUTPUT | ACTIVE LOW | ALWAYS ENABLED | |
| P4.1 | KEYPAD COL 1 | OUTPUT | ACTIVE LOW | ALWAYS ENABLED | |
| P4.2 | KEYPAD COL 2 | OUTPUT | ACTIVE LOW | ALWAYS ENABLED | |
| P4.3 | KEYPAD COL 3 | OUTPUT | ACTIVE LOW | ALWAYS ENABLED | |
| P4.4 | KEYPAD COL 4 | OUTPUT | ACTIVE LOW | ALWAYS ENABLED | |
| P5.0 | KEYPAD ROW 0 | INPUT | | ALWAYS ENABLED 550K | |
| P5.1 | KEYPAD ROW 1 | INPUT | | ALWAYS ENABLED 550K | |
| P5.2 | KEYPAD ROW 2 | INPUT | | ALWAYS ENABLED 550K | |
| P5.3 | KEYPAD ROW 3 | INPUT | | ALWAYS ENABLED 550K | |
| P5.4 | KEYPAD ROW 4 | INPUT | | ALWAYS ENABLED 550K | |
| P6.0 | EEPROM CHIP SELECT | OUTPUT | ACTIVE HIGH | DISABLE | 10K Pull Down |
| P6.1 | DATA MON | INPUT | ACTIVE HIGH | DISABLE | |
| P6.2 | RX ENABLE | OUTPUT | ACTIVE LOW | DISABLE | |
| P6.3 | TX ENABLE | OUTPUT | ACTIVE LOW | DISABLE | |
| P6.4 | PLL ENABLE | OUTPUT | ACTIVE HIGH | DISABLE | |

### 4.3.2 Base Port Pin Assignment

| Port # | Functional Description | Direction | Logic | Internal Pull Up Status | External Pull Up |
|---|---|---|---|---|---|
| P0.0-7 | ADDR/DATA BUS | | | | |
| P1.0 | ON CRADLE | INPUT | ACTIVE LOW | DISABLE | 10K |
| P1.1 | FSK ENABLE | OUTPUT | ACTIVE HIGH | ENABLED | |
| P1.2 | ATE ENABLE | INPUT | ACTIVE HIGH | DISABLE | 4K7 P/D |
| P1.3 | POTS MODE | INPUT | ACTIVE LOW | DISABLE | 47K |
| P1.4 | HOOK SWITCH | OUTPUT | ACTIVE LOW | ENABLED | |
| P1.5 | CAS DETECT | INPUT | ACTIVE HIGH | DISABLE | On CID IC |
| P1.6 | PAGE KEY | INPUT | ACTIVE HIGH | DISABLE | 10K Pull Down |
| P1.7 | RING DETECT | INPUT | PULSE | DISABLE | From OP AMP |
| P2.0 | ADDRESS BUS | | | | |
| P3.0 | ATE DATA RX | INPUT | | DISABLE | |
| P3.1 | ATE DATA TX | OUTPUT | | ENABLED | |
| P4.0 | NEW CALLS LED | OUTPUT | ACTIVE LOW | ALWAYS ENABLED | |
| P4.1 | VMWI LED | OUTPUT | ACTIVE LOW | ALWAYS ENABLED | |
| P4.2 | IN USE LED | OUTPUT | ACTIVE LOW | ALWAYS ENABLED | |
| P4.3 | POWER LED | OUTPUT | ACTIVE LOW | ALWAYS ENABLED | |
| P4.4 | CHARGE LED | OUTPUT | ACTIVE LOW | ALWAYS ENABLED | |
| P5.0 | NO LINE | INPUT | ACTIVE HIGH | ALWAYS ENABLED 550K? | |
| P5.1 | NOT USED | INPUT | | ALWAYS ENABLED 550K? | |
| P5.2 | PARALLEL SET DETECT | INPUT | ACTIVE HIGH | ALWAYS ENABLED 550K? | |
| P5.3 | CID CARRIER DETECT | INPUT | ACTIVE LOW | ALWAYS ENABLED 550K? | |
| P5.4 | RF TEST TX PWR SWITCH | INPUT | | ALWAYS ENABLED 550K? | |
| P6.0 | EEPROM CHIP SELECT | OUTPUT | ACTIVE HIGH | DISABLE | 10K Pull Down |
| P6.1 | PLL ENABLE | OUTPUT | ACTIVE HIGH | DISABLE | |
| P6.2 | FAST CHARGE | OUTPUT | ACTIVE HIGH | ENABLED | |
| P6.3 | TX ENABLE | OUTPUT | ACTIVE LOW | DISABLE | |
| P6.4 | DATA MON | INPUT | ACTIVE HIGH | DISABLE | |
| P6.5 | RSSI | INPUT | | DISABLE | |