

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

PDL MK3

THEORY OF OPERATION

**for SONY
SPP-ID970/1**

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Reference: PRC XXX	Revision: 1	Page: 1 of 21
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TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

Revision History

Revision No	Description	Page	Effective Date
1	Initial Release	All	19-Feb-99



TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

Table of Contents

1	Complete System Description	5
1.1	Introduction.....	5
1.2	Feature List	5
1.3	System Block Diagram	6
1.4	Handset Block Diagram	7
1.5	Base Block Diagram	8
2	RF Section Overview	9
2.1	Introduction.....	9
2.2	Frequency Tables	10
2.2.1	Handset Frequencies	10
2.2.2	Base Frequencies.....	11
2.3	Block Diagram.....	12
3	RF Section Detailed Operation	13
3.1	Antenna Section.....	13
3.1.1	Antenna	13
3.1.2	SAW Duplexer	13
3.2	Receive Section	13
3.2.1	RX Amps and SAW Filter	13
3.2.2	RX Mixer	14
3.2.3	RX VCO and LO Buffer.....	14
3.2.4	RX Synthesizer.....	15
3.2.5	IF Amplifier Stage	15
3.2.6	IF Filtering	15
3.2.7	Mixer, IF Amplifier, FM Demodulator (Temic IC)	15
3.3	Transmit Section.....	16
3.3.1	TX Amp	16
3.3.2	TX VCO	16
3.3.3	TX Synthesizer/PLL	16
4	Baseband Section.....	17

Reference: PRC XXX	Revision: 1	Page: 3 of 21
--------------------	-------------	---------------

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

4.1	General Description.....	17
4.2	Detailed Functional Description	18
4.2.1	Protocol Functions.....	18
4.2.2	Audio Functions	18
4.2.3	System Control Functions.....	18
4.3	Port Pin Assignment And Functions.....	20
4.3.1	Handset Port Pin Assignment	20
4.3.2	Base Port Pin Assignment.....	21

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

1 Complete System Description

1.1 Introduction

This theory of operation covers the basic single line SPP-ID970/1 in the PDL MK3 series. based on the third generation 900 MHz ADPCM core.

1.2 Feature List

- Name / number caller ID display with 50 call storage capacity
- 32kbps ADPCM voice coding
- 2 row by 16 character 5x7 dot matrix alpha-numeric with 7 segment Digits and ICONS on the LCD display on handset
- 30 channel operation with auto channel selection
- 900 MHz Operation
- 24 bit digital security code for 16.8 million combinations
- DTMF and Pulse dialing
- 50 name/number/location programmable memory for up to 32 max 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
- Backlit LCD on the handset
- Auto hang-up when returning the handset to the base cradle.
- Detachable power supply
- Jog Dial for menu navigation
- 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
- 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.

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

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

1.3 System Block Diagram

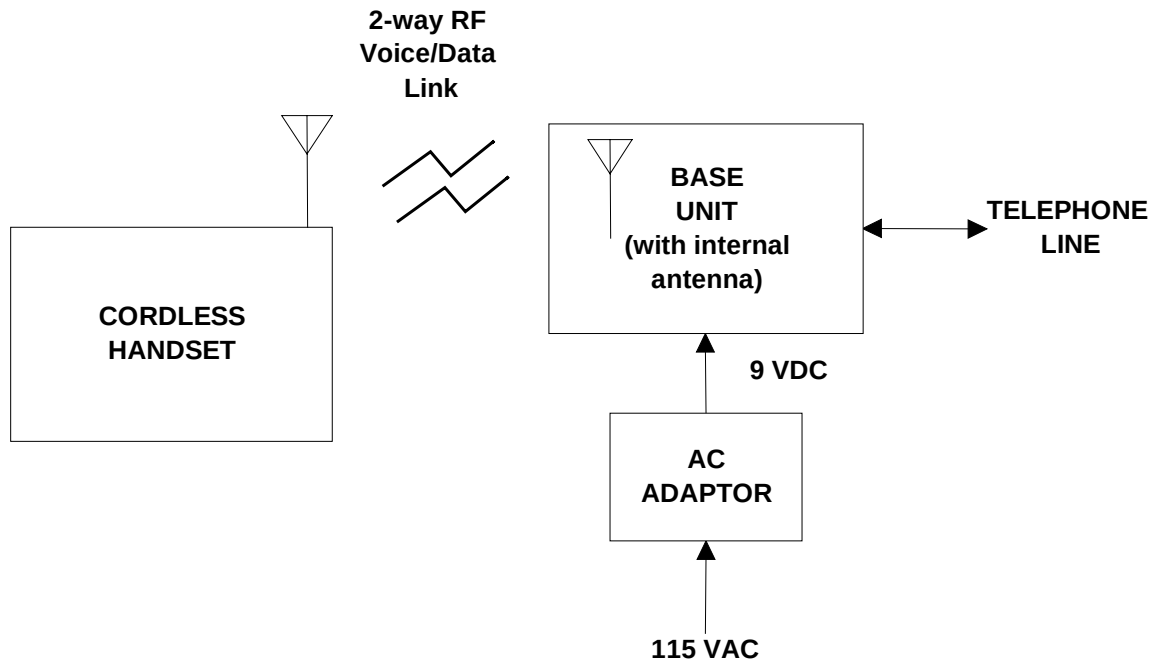


Figure 1.2 System Block Diagram

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

1.4 Handset Block Diagram

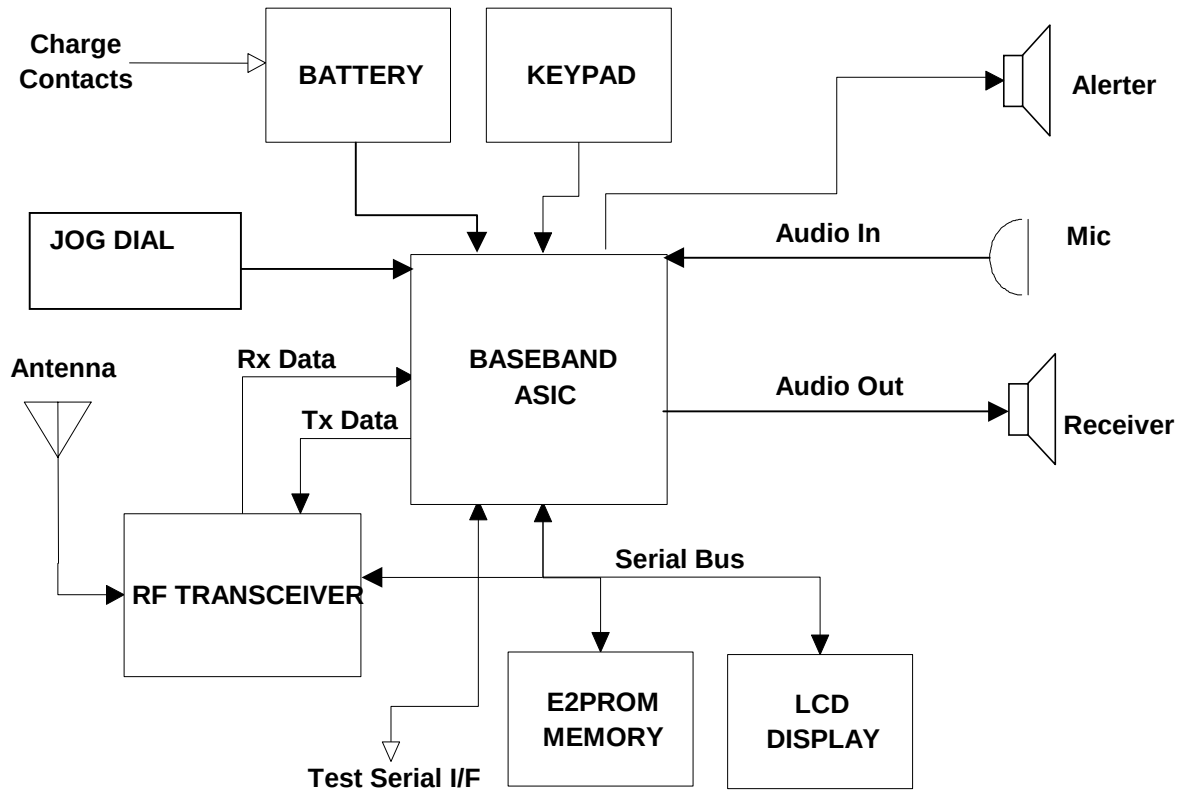


Figure 1.3 Handset Block Diagram

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

1.5 Base Block Diagram

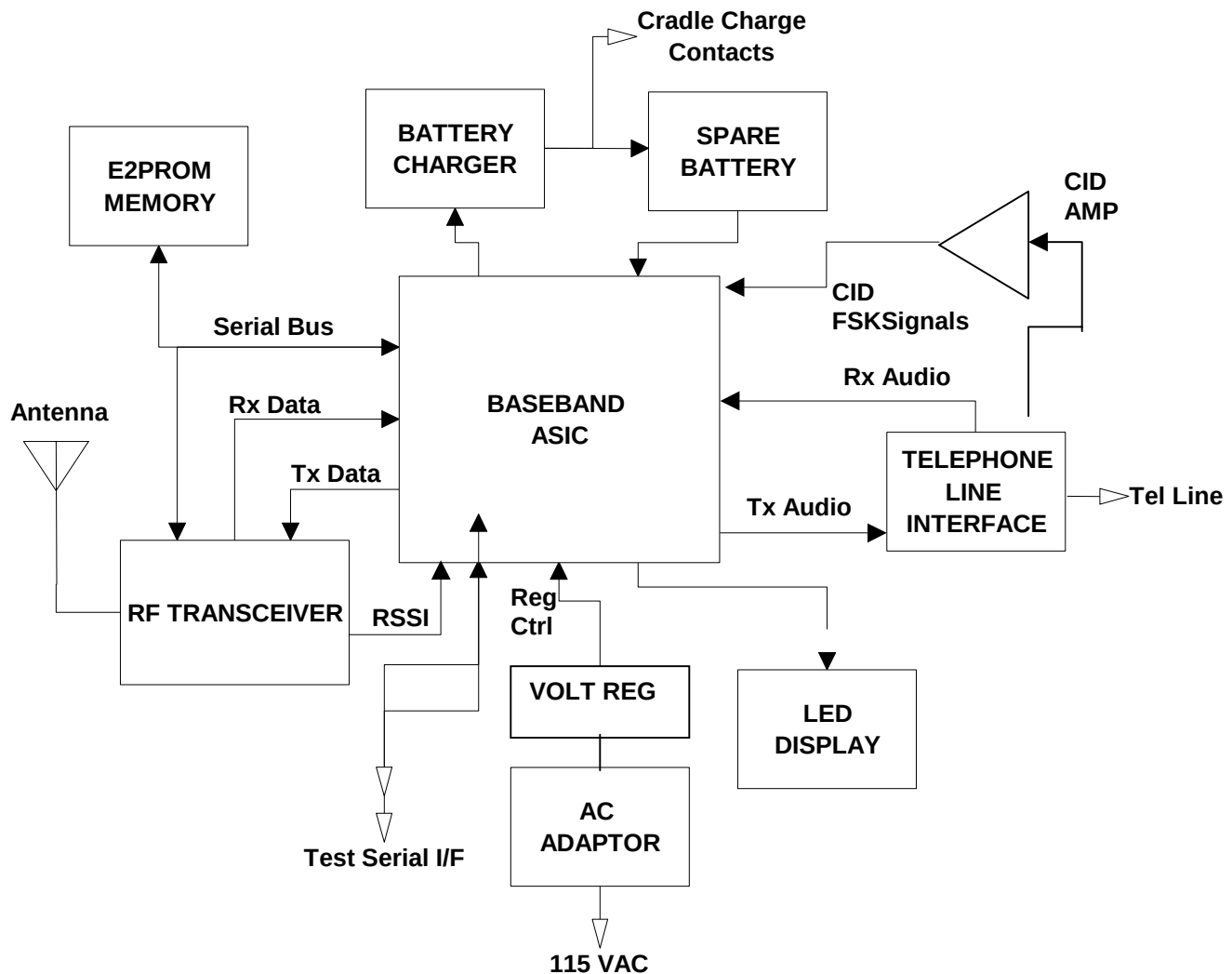


Figure 1.4 Base Block Diagram

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

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.

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

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
2	925.2	902.45	913.15
3	925.35	902.6	913.3
4	925.5	902.75	913.45
5	925.65	902.9	913.6
6	925.8	903.05	913.75
7	925.95	903.2	913.9
8	926.1	903.35	914.05
9	926.25	903.5	914.2
10	926.4	903.65	914.35
11	926.55	903.8	914.5
12	926.7	903.95	914.65
13	926.85	904.1	914.8
14	927	904.25	914.95
15	927.15	904.4	915.1
16	927.3	904.55	915.25
17	927.45	904.7	915.4
18	927.6	904.85	915.55
19	927.75	905	915.7
20	923.1	904.85	915.55
21	923.25	905	915.7
22	923.4	905.15	915.85
23	923.55	905.3	916
24	923.7	905.45	916.15
25	923.85	905.6	916.3
26	924	905.75	916.45
27	924.15	905.9	916.6
28	924.3	906.05	916.75
29	924.45	906.2	916.9
30	924.6	906.35	917.05

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

2.2.2 Base Frequencies

Channel	Transmit	Receive	RX LO
1	902.3	925.05	914.35
2	902.45	925.2	914.5
3	902.6	925.35	914.65
4	902.75	925.5	914.8
5	902.9	925.65	914.95
6	903.05	925.8	915.1
7	903.2	925.95	915.25
8	903.35	926.1	915.4
9	903.5	926.25	915.55
10	903.65	926.4	915.7
11	903.8	926.55	915.85
12	903.95	926.7	916
13	904.1	926.85	916.15
14	904.25	927	916.3
15	904.4	927.15	916.45
16	904.55	927.3	916.6
17	904.7	927.45	916.75
18	904.85	927.6	916.9
19	905	927.75	917.05
20	905.15	923.1	912.4
21	905.3	923.25	912.55
22	905.45	923.4	912.7
23	905.6	923.55	912.85
24	905.75	923.7	913
25	905.9	923.85	913.15
26	906.05	924	913.3
27	906.2	924.15	913.45
28	906.35	924.3	913.6
29	906.5	924.45	913.75
30	906.65	924.6	913.9

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

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.

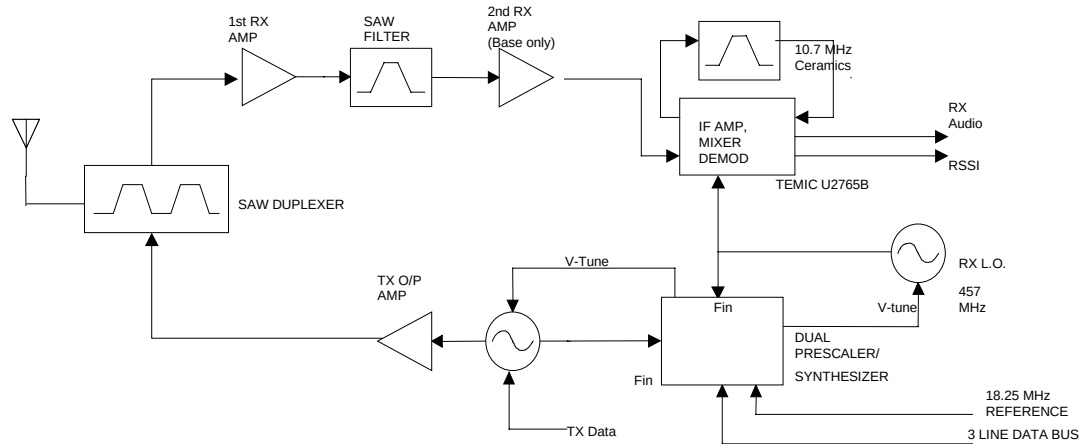


Figure 2.3 RF Section Block Diagram

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 synchronous data bus on which data is transferred to the synthesizers to set both the transmit and receive frequencies.

In the transmit direction, modulation input allows digital data to be modulated directly onto the TX carrier.

In the receive direction, 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 Data output is the demodulated signal which is sent to the ASIC to be filtered and shaped by an internal data slicer. The reconstructed data represents the original voice which can then be processed by the DSP in the ASIC..

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

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

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.

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

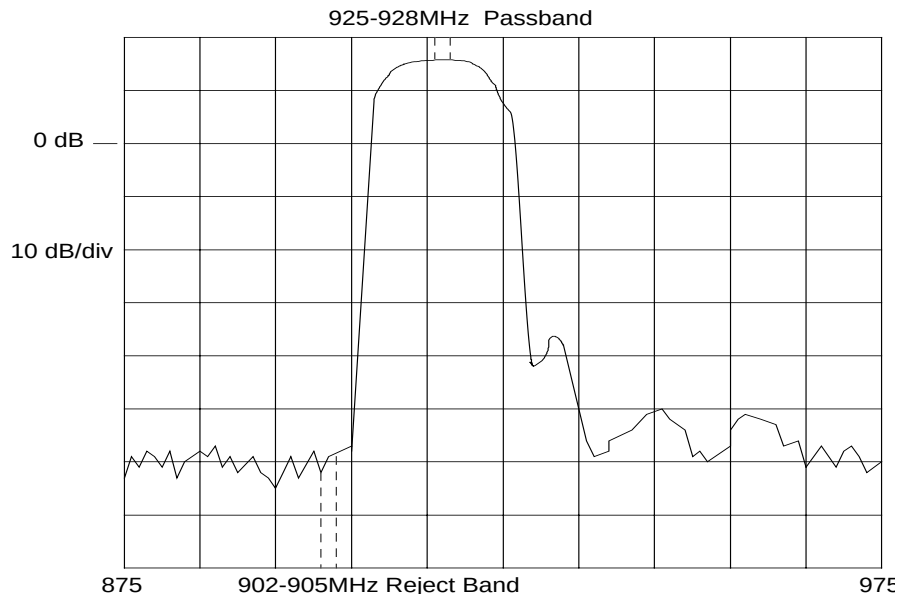


Figure 3.2.1 RX Front End Response

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.



TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

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 Mixer, IF Amplifier, FM Demodulator (Temic IC)

The RF design uses an integrated solution that provides a number of different receiver functions on a single silicon chip. The Temic U2765B IC combines a, mixer down-converter, IF amplifier and FM demodulator onto one device.

3.2.7.1 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 intermediate frequency (IF). The LO and RF signals are coupled onto pins 26 and 3 respectively on the Temic IC. The mixer output is coupled off of the Temic IC by a 10.7 MHz transformer to a 10.7 MHz ceramic IF filter before it is injected into limiter 1 within the Temic IC. The output of limiter 1 is coupled off of the Temic IC into another 10.7 MHz ceramic IF filter.

3.2.7.2 IF Amplifier Stage

There is a two-stage limiting amplifier integrated with the Temic IC. Both of the limiters require external 10.7 MHz ceramic IF filters.

3.2.7.3 Demodulator

The quadrature circuit is made up one inductor, one resistor, and two capacitors. One of the two capacitors is a variable capacitor that allows tuning of the circuit. The quadrature voltage may be observed at the ATE test point connector. This voltage should nominally be 1.2 V for both the base and handset when a signal is centre tuned.

The recovered audio signal from the demodulator has a peak-to-peak amplitude of approximately 0.31 V (for 50 kHz peak-to-peak modulation). One path from the recovered audio port is filtered through a low-pass data filter and passed back into the baseband module.

3.2.7.4 RSSI Comparator

The U2765B provides an RSSI voltage that is proportional to the input signal level that is then sent to the ASIC A/D pin.

Reference: PRC XXX	Revision: 1	Page: 15 of 21
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TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

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.

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

4 Baseband Section

4.1 General Description

The AMD 79C493 ASIC is a custom designed IC, which consists of a VTech proprietary FDD protocol block plus a unique baseband architecture

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.

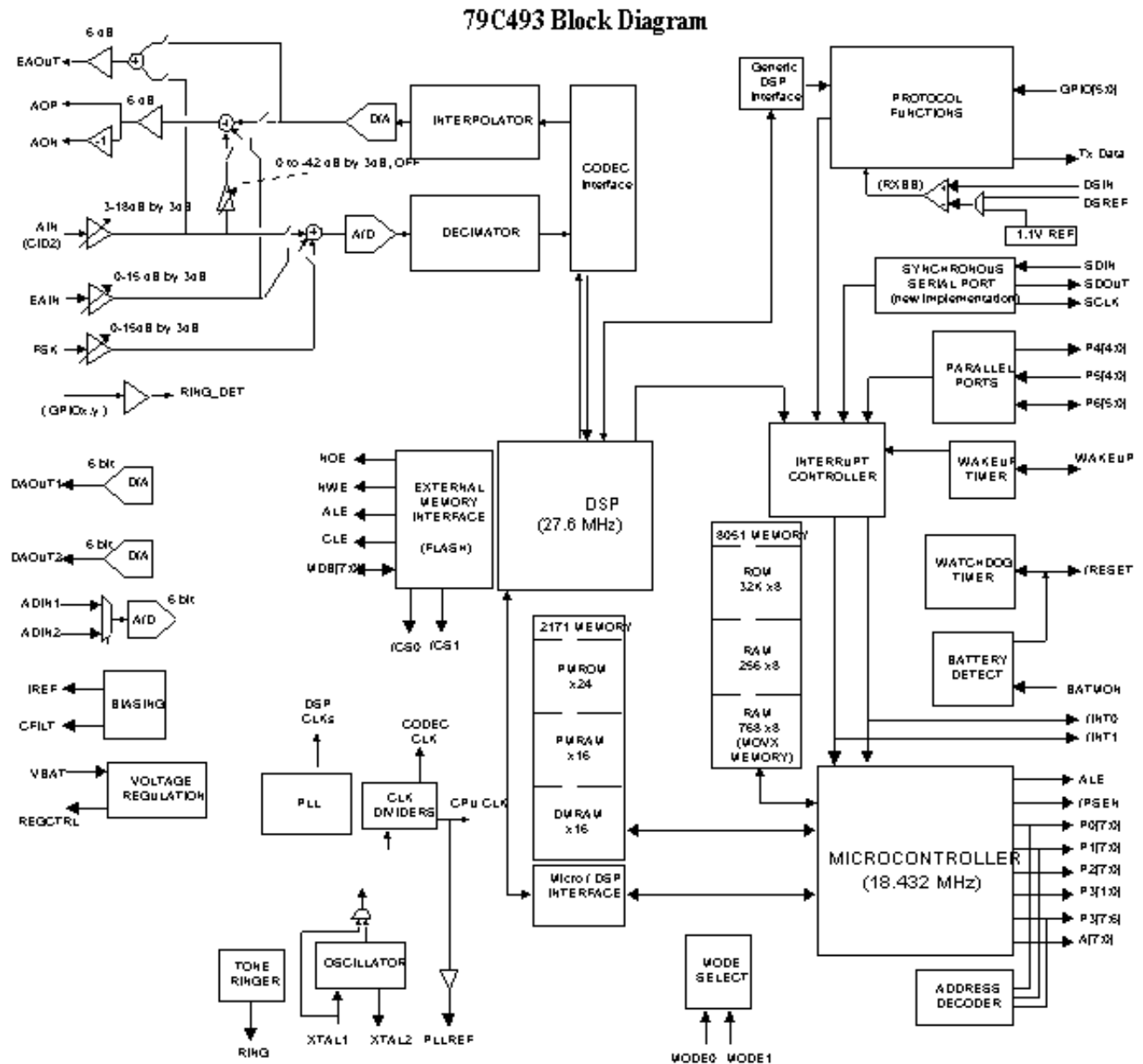


Figure 4.1 ASIC - Internal Structure Diagram

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

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 amplitude controllable 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 32 Kbytes of mask-programmable ROM and a total of 1K 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. This is a different serial port function from that in the Am79C490 and Am79C491.
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. **Regulator Control:** The regulator control function controls an external bipolar transistor to implement a regulating function to provide a steady voltage to the rest of the system.
5. **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.
6. **Watchdog Timer:** The watchdog timer protects the system from errant software by periodically issuing a reset unless serviced by software.
7. **Wakeup Timer:** The wakeup timer is a multivibrator controlled by external passive components to effect a low power periodic wakeup for call detection.
8. **Interrupt Controller:** The interrupt controller structures the various interrupts for

Reference: PRC XXX	Revision: 1	Page: 18 of 21
---------------------------	--------------------	-----------------------



TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

manageable service by the microcontroller.

9. **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.
10. **Address decoder:** The address decoder generates strobes accessing selected address spaces in the device.

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

4.3 Port Pin Assignment And Functions

4.3.1 Handset Port Pin Assignment

Port #	Functional Description	Direction	Logic
P0.0-7	ADDRESS/DATA BUS		TRI-STATE
P1.0	\On Cradle	OUTPUT	ACTIVE LOW
P1.1	\Backlighting	OUTPUT	ACTIVE LOW
P1.2	\Jog Dial A	OUTPUT	ACTIVE LOW
P1.3	\Jog Dial B	OUTPUT	ACTIVE LOW
P1.4	\Jog Dial SW2	INPUT	ACTIVE LOW
P1.5	LCD_E	OUTPUT	ACTIVE HIGH
P1.6	LCD_R/W	OUTPUT	
P1.7	LCD_RS	INPUT	ACTIVE HIGH
P2.0	ADDRESS BUS		TRI-STATE
P3.0	ATE DATA RX	INPUT	
P3.1	ATE DATA TX	OUTPUT	
P4.0	Keypad Output	OUTPUT	ACTIVE LOW
P4.1	Keypad Output	OUTPUT	ACTIVE LOW
P4.2	Keypad Output	OUTPUT	ACTIVE LOW
P4.3	Keypad Output	OUTPUT	ACTIVE LOW
P4.4	Keypad Output	OUTPUT	ACTIVE LOW
P5.0	Keypad Input	INPUT	
P5.1	Keypad Input	INPUT	
P5.2	Keypad Input	INPUT	
P5.3	Keypad Input	INPUT	
P5.4	Keypad Input	INPUT	
P6.0	LCD_DB4	OUTPUT	
P6.1	LCD_DB5	OUTPUT	
P6.2	LCD_DB6	OUTPUT	
P6.3	LCD_DB7	OUTPUT	
P6.4			
P6.5			
GPIO.0			
GPIO.1			
GPIO.2	PLL EN	OUTPUT	ACTIVE HIGH
GPIO.3	\TX EN	OUTPUT	ACTIVE HIGH
GPIO.4	\RX EN	OUTPUT	ACTIVE HIGH
GPIO.5	EE CS	OUTPUT	ACTIVE HIGH

TITLE	PDL MK3 Theory Of Operation
MODEL	SPP-ID970/1

4.3.2 Base Port Pin Assignment

Port #	Functional Description	Direction	Logic
P0.0-7	ADDR/DATA BUS		
P1.0	\Ring Detect	INPUT	ACTIVE LOW
P1.1	\Hook Sw	OUTPUT	ACTIVE LOW
P1.2	\Pots Mode	INPUT	ACTIVE LOW
P1.3	\On Cradle	INPUT	ACTIVE LOW
P1.4	Fast Charge	OUTPUT	ACTIVE HIGH
P1.5			
P1.6			
P1.7			
P2.0	ADDRESS BUS		
P3.0	ATE DATA RX	INPUT	
P3.1	ATE DATA TX	OUTPUT	
P4.0	Page Key Output	OUTPUT	ACTIVE LOW
P4.1			
P4.2			
P4.3			
P4.4			
P5.0			
P5.1			
P5.2			
P5.3			
P5.4	Page Key Input	INPUT	
P6.0	\In Use/Line LED	OUTPUT	ACTIVE LOW
P6.1	\Charge LED	OUTPUT	ACTIVE LOW
P6.2	\Message LED	OUTPUT	ACTIVE LOW
P6.3	\New Call LED	OUTPUT	ACTIVE LOW
P6.4			
P6.5			