Harris Semiconductor

APPNOTE

Harris Wireless Products

PRISM™ Power Management Modes

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The PRISM™ chip set and reference radio are capable of reduced power operation in many circumstances where communications is not expected for some period of time. These are controlled by the MAC and involve both sleep modes of the baseband processor and power shutdowns of various RF parts of the radio. The degree to which the radio can be put to sleep depends on the time needed for awakening. The deeper the sleep mode, the less power it takes and the longer it takes to awaken. Some of the reasons for the lengthy awakening time are charging of capacitors and settling of oscillators. For the deepest sleep mode, the baseband processor and synthesizer registers will lose their programming and will need to be reloaded.

The power management function has to take into account the need for imminent communications. In IEEE 802.11 networks, in Point Coordination Function operation, the Access Point (AP) will periodically broadcast Beacon frames to implement the Timing Synchronization Function and to inform various nodes of impending traffic. The beacon period is a field of Beacon and Probe Response frames and is in units of kilomicroseconds where 1kμs is 1024μs. There can be 1kμs to 2007kμs in the period, but a typical beacon period is 100kμs. It also uses this message to poll for incoming traffic. If a station determines that it is not needed for upcoming traffic, it can enter a power management mode by informing the AP of this fact using Power Management bits within the Frame Control field of transmitted frames. The station must get a response from the AP acknowledging the mode change before entering it. In a power management mode it can doze until the next poll or until awakened by its own host for outgoing traffic. In an extreme power saving mode, the station is given a listen interval where it can skip a number of beacon periods before it needs to awaken and check one. The PRISM™ radios have the capability to use various doze modes depending on the interval between awakenings. Since the 802.11 only specifies one mode with various sleep times, the MAC needs to decide which PRISM™ sleep mode to use.

One additional factor in power management is the need for staying awake long enough to receive the Beacon frame. If a station is transmitting when the Beacon time arrives, the AP will defer until the medium is clear. This means that the station must stay awake for a period which can be much longer than the Beacon frame itself. This awake period is dependent on the operating mode of the network, but is much shorter than the Beacon interval. Since this occurrence is a random event, the station will stay awake until it hears a Beacon and then resume sleep mode.

PRISM™ radios used in non-802.11 networks or applications can use more of the power management modes than can those constrained by 802.11 network considerations. In particular, the radio can be used in high rate TDMA burst modes to send relatively low average data rates efficiently. In these modes, the radios can have more tightly constrained awakening times and do not need to be awake for as long a period.

The power consumed by the PRISM™ radios is also determined by the traffic patterns. In a typical network with 10 stations per AP, the AP can be assumed to be transmitting at least 80% of the time. This is based on the usual case of transferring programs and graphics from the server to the user with a smaller amount of return traffic. This return traffic will most likely be files sent to printers and files saved to a network hard drive. With this scenario, and the assumption that each user will get an equal share of what's left, the transmit time of each user is about 2%. Thus, the total power consumption can be averaged as 98% receive and 2% transmit. This tends to minimize the impact of the transmit current on the battery life of a laptop. This is further reduced by the power management modes.

The PRISM™ radio can have various circuits powered off depending on the sleep mode. The Baseband processor has additional sleep modes that involve turning off clocks or portions of the circuitry. These are detailed below. First, we will examine the circuits that are drawing power. Figure 1 below shows the radio in the normal receive mode. The transmit sections are in the off state. Circuits shown in the shaded blocks are drawing power by virtue of being powered and clocked. This paper is based on the PRISM™ Reference Radio Schematic, Revision 10, dated December 13, 1996. The implementation of Power Savings Modes may differ for various schematic revisions.
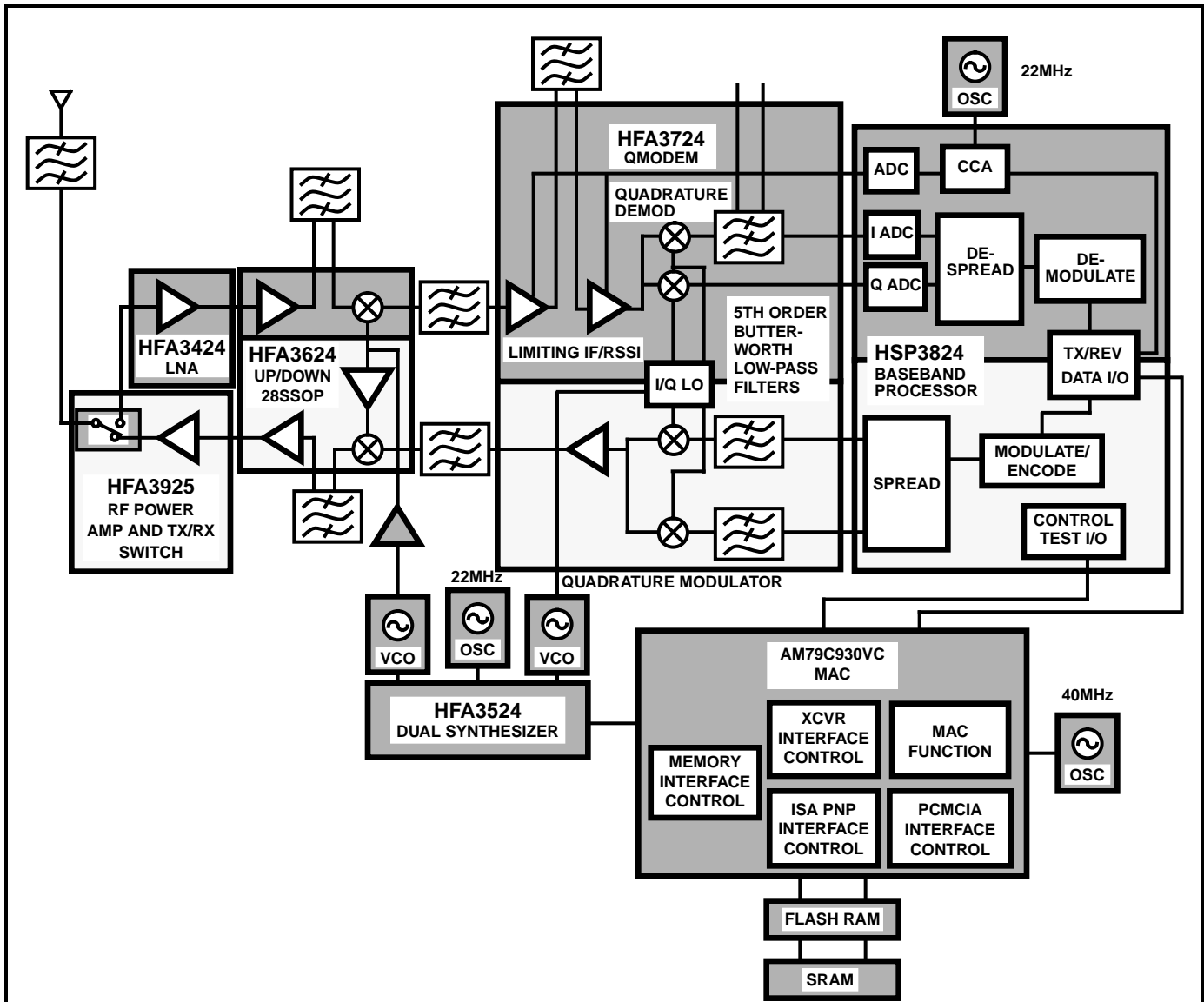
FIGURE 23. PRISM™ PCMCIA REFERENCE RADIO RECEIVE MODE

The power consumption in the various modes are:

TX Current (continuous) 488mA
RX Current (continuous) 287mA
Average Current
   Without Power Saving Modes (Note 2) 290mA
   With Power Saving Modes (Note 3) 60mA
Power Saving Mode 1 (1µs recovery) (Note 1) 190mA
Power Saving Mode 2 (25µs recovery) (Note 1) 70mA
Power Saving Mode 3 (2ms recovery) (Note 1) 60mA
Power Saving Mode 4 (5ms recovery) (Note 1) 30mA

NOTES:

1. Power Savings Mode currents are estimates based on component measurements, estimated power down currents for the AM79C930 and AM29F01055EC, and assuming the removal of the 3 LEDs.

2. Average current calculated with 2% transmit current and 98% receive current without power savings modes.

3. Average radio current with power savings mode is caculated with 2% transmit, 8% receive, and 90% Power Saving Mode 4.

There are six discrete power control lines in the reference radio that come from the MAC. These are shown below along with their MAC pin connections:

PRISM™	MAC NAME	MAC PIN
PA_PE	TXMOD	131
TX_PEbb	TXMOD	131
RX_PEbb	RX_PE	122
RESET	LPFPE	118
RADIO_PE	USER3	002
RX_PE	TXCMD	126
TX_PE	TXCMD	142

Note that RX_PEbb and PA_PE are connected together and of opposite sense. That is, when one is on, the other is off. This makes for a reduction from 7 to 6 control lines.
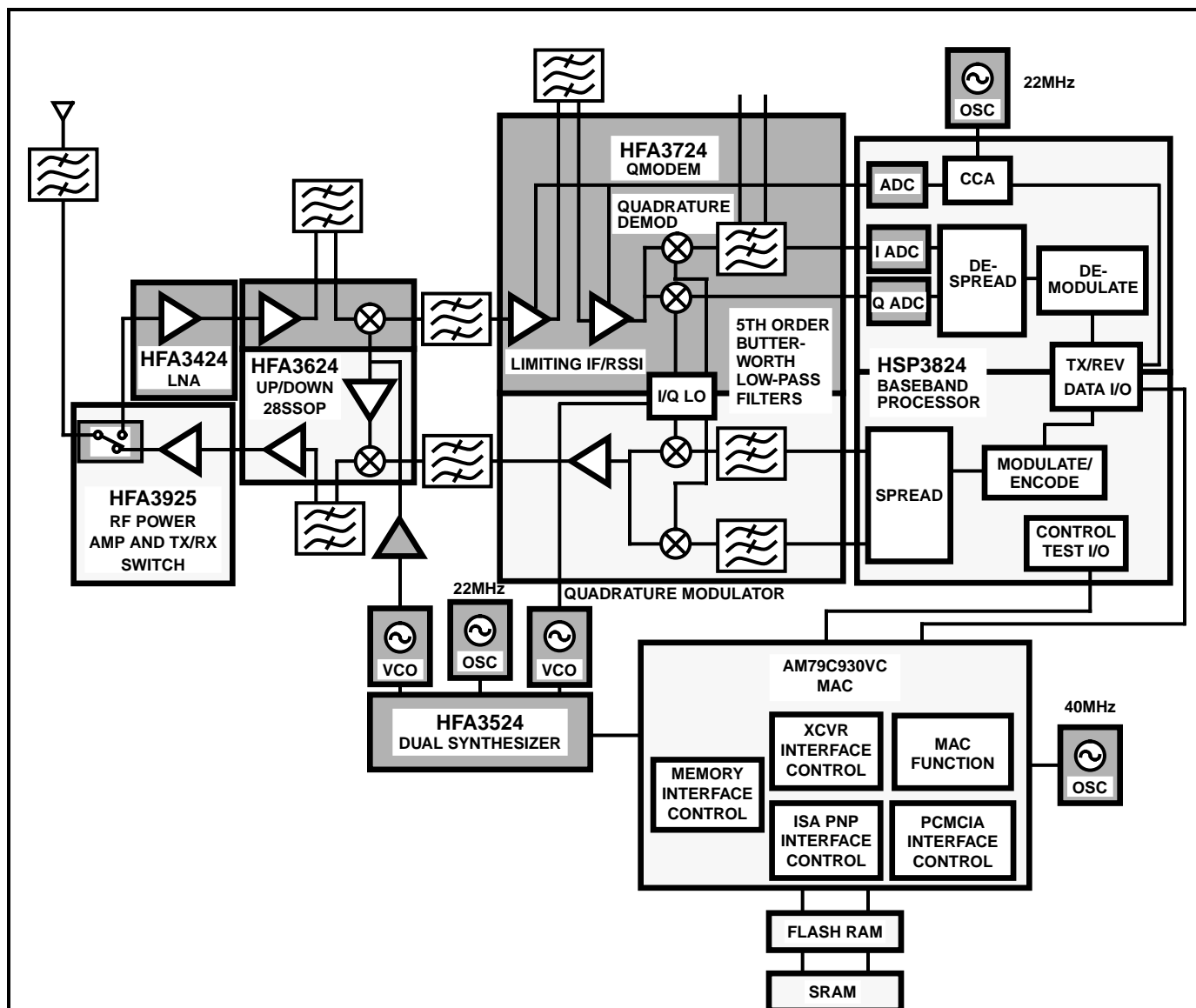
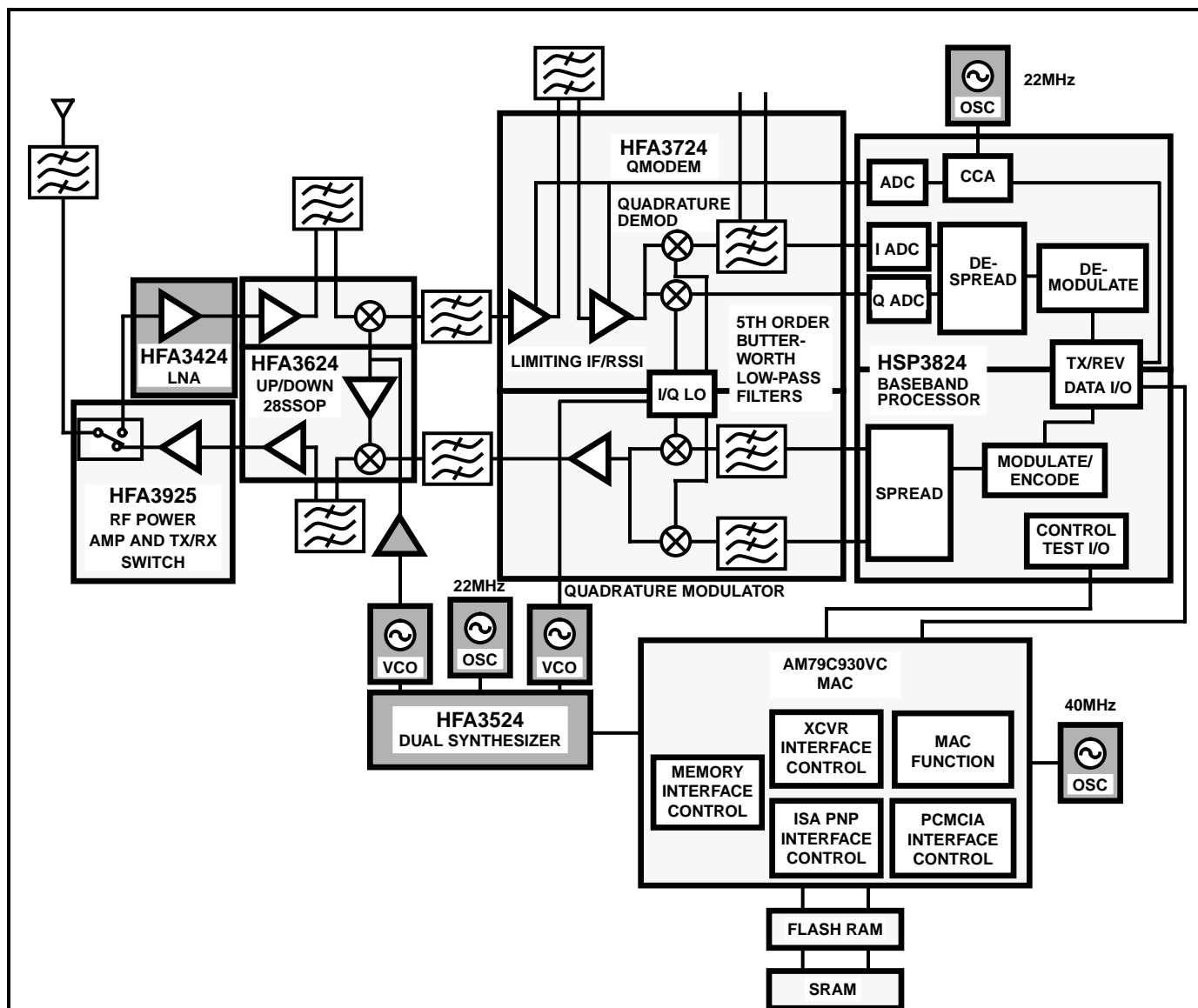NOTE: Dark shading indicates full power, while light shading indicates Sleep Mode.

FIGURE 24. PRISM™ PCMCIA REFERENCE RADIO POWER SAVING MODE 1

The power down modes of the radio are controlled by the control signals as follows:

- Receiver Power Enable (RX_PE and RX_PEbb) disable the radio receiver functions when inactive.

- Transmit Power Enable (TX_PE and TX_PEbb) disable the radio transmitter functions when inactive.

- Reset puts the Baseband Processor into a standby mode when it is asserted after RX_PEbb goes low.

- Radio Power Enable (RADIO_PE) disables the entire synthesizer section of the radio which includes the 22MHz Voltage Crystal Oscillator, IF and RF VCOs, HFA3524 Synthesizer, LO Buffer, and Regulator U16.

- In addition, the HFA3524 synthesizer can be put into a power down mode via the synthesizer serial control bus.

CONTROL	STATE
PA_PE	LOW
TX_PEbb	LOW
RX_PEbb	LOW
RESET	HIGH
RADIO_PE	HIGH
RX_PE	HIGH
TX_PE	LOW

Power Saving Mode 1 shown in Figure 2 is where RX_PEbb and TX_PEbb are set low to the Baseband Processor (BBP) and the MAC is put in standby mode. This turns off most of the digital logic to save about 100mA of current. Recovery from this mode is 1μs since the previous state of all logic is retained.
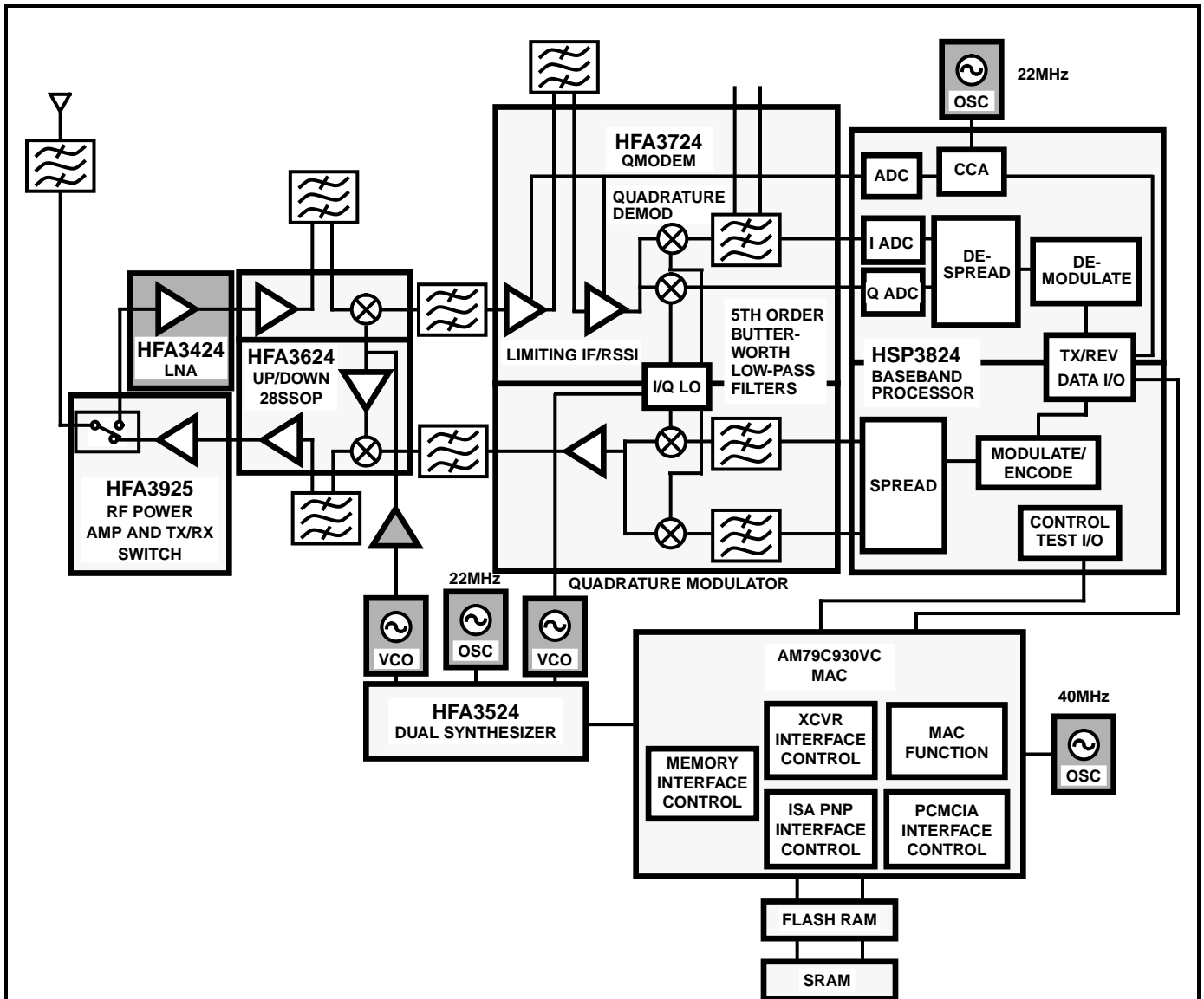
NOTE: Dark shading indicates full power, while light shading indicates Sleep Mode.

FIGURE 25. PRISM™ PCMCIA REFERENCE RADIO POWER SAVING MODE 2

CONTROL	STATE
PA_PE	LOW
TX_PEbb	LOW
RX_PEbb	LOW
RESET	LOW
RADIO_PE	HIGH
RX_PE	LOW
TX_PE	LOW

Figure 3 shows Power Saving Mode 2 that takes 25µs to recover. In this mode, the MAC and BBP clocks are stopped as above which reduces the BBP and MAC power consumption to maintenance levels. Additionally, the RESET and RX_PE lines are set low to put to sleep the BBP ADC section, the 3724 IF to baseband converter and the 3624 RF to IF downconverter.

The AC coupling capacitors must be taken into account when figuring the time it takes to awaken from Power Saving Mode 2. The circuitry in the analog sections has been designed to fast charge these capacitors within 25µs and this sets the minimum awakening time. In this mode the lightly shaded blocks have power but their chip control lines have been set to the power down state.

NOTE: Dark shading indicates full power, while light shading indicates Sleep Mode.

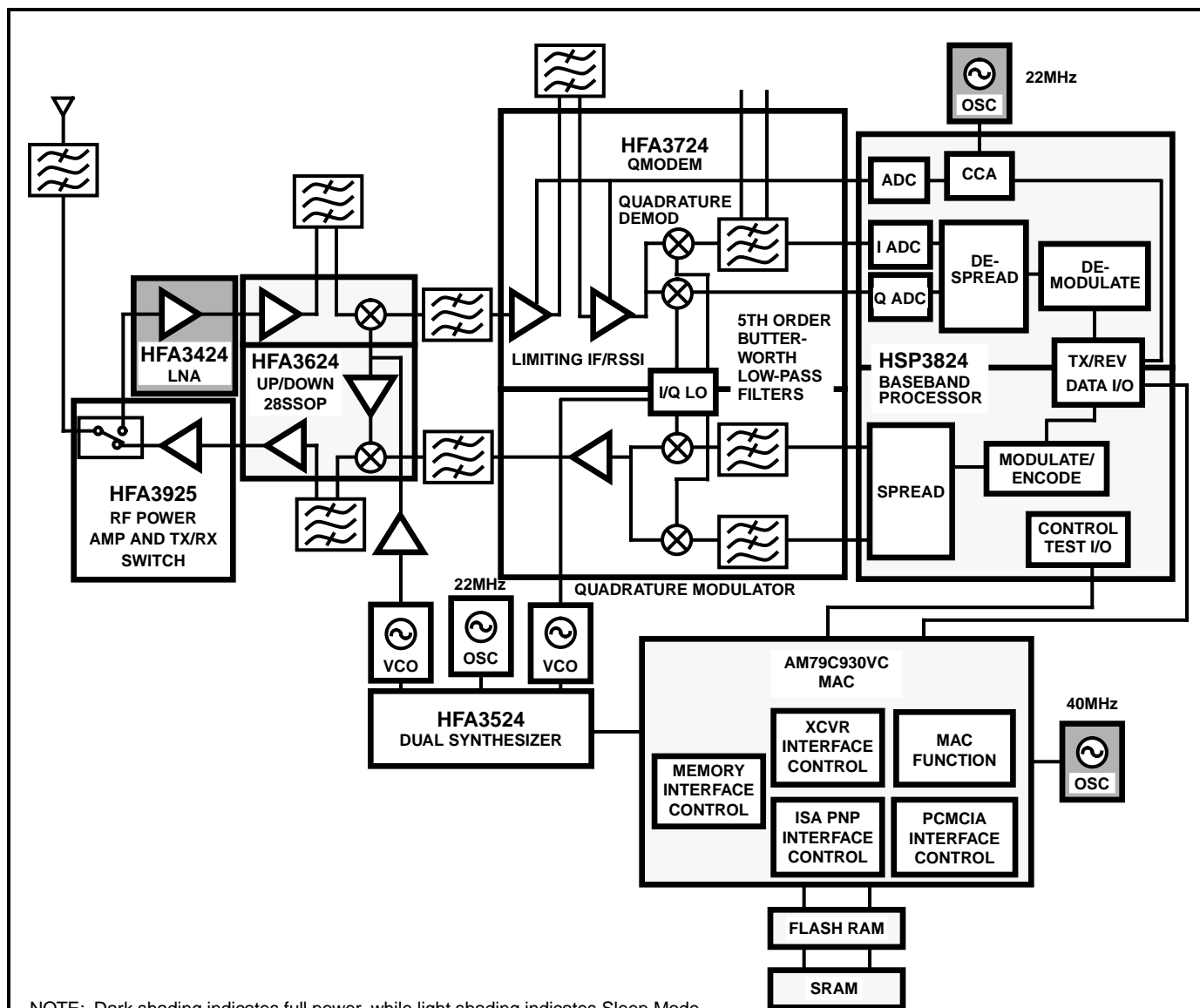**FIGURE 26. PRISM™ PCMCIA REFERENCE RADIO POWER SAVING MODE 3**

CONTROL	STATE
PA_PE	LOW
TX_PEbb	LOW
RX_PEbb	LOW
RESET	LOW
RADIO_PE	HIGH
RX_PE	LOW
TX_PE	LOW

Power Saving Mode 3 saves an additional 10mA.

The synthesizer has a power down mode that can be controlled by sending a serial control message over the control bus. In this mode, the synthesizer powers down its charge pumps and dividers. It retains essential frequency tuning information, but must be restarted via the serial control bus which takes 2ms. See Application Note 9617 for details.

In addition to setting the seven control lines for Mode 4, one must insure that a low state is programmed on 5 digital lines from the MAC. These digital control paths may cause voltages to be fed through inactive devices and cause undesirable currents to flow. Ensure that the following lines are at a low state in Power Saving Mode 4.

CONTROL	MAC PIN #
Synth L/E	3
Synth CLK	101
Synth Data	102
Sel 0	132
Sel 1	141

NOTE: Dark shading indicates full power, while light shading indicates Sleep Mode.

FIGURE 27. PRISM™ PCMCIA REFERENCE RADIO POWER SAVING MODE 4

CONTROL	STATE
PA_PE	LOW
TX_PEbb	LOW
RX_PEbb	LOW
RESET	LOW
RADIO_PE	LOW
RX_PE	LOW
TX_PE	LOW

Power Saving Mode 4, shown in Figure 5, powers down most of the radio in addition to the above. This is done by bringing RADIO_PE low. This turns off the synthesizer voltage regulator, which causes the synthesizer and its crystal oscillator to power off. In addition, the RF and IF VCOs and the LO Buffer are powered off. The only circuits left with power are the MAC, BBP, RF/IF converter, and 2 crystal oscillators. With the synthesizer unpowered, it looses its frequency tuning register information. This plus the long settling times of the synthesizer VCOs and crystal oscillators, makes it take 5ms to bring it back up. The MAC and BBP are still powered to maintain register values, but much of the circuitry is static. The MAC oscillator is left running to allow it to respond when the sleep mode changes. The HFA3824 crystal oscillator is still running, although its output is disabled. The HFA3624 is left powered although it is in an inactive mode.

Although this version of the reference radio is not connected for it, one additional mode is available and that is to turn off power to the remaining circuits except the MAC. This mode requires the MAC to spend 1ms to program the BBP registers but this is well within the 5ms time it takes for the oscillators to stabilize.

If the MAC is also powered down to where it is not able to respond to traffic on the PCMCIA Bus, it will miss access on the Bus to which it must respond within 12μs. Circuitry can be added to give a response to the host that the card is not available.

It can be assumed that the power consumption rises as soon as the awakening is started, but the power saving mode can be transitioned slowly back to the fully awake state. With this staging process, it is feasible to enter a given power saving mode whenever the sleep duration is at least as long as the time it will take to awaken. This is of course dependent on the MAC having sufficient processor time to perform the staged awakening.

Figure 6 graphically shows the awakening process. If in PS Mode 4, the awakening process is started at T- 5ms where T is the time the radio needs to be awake and receiving. First, RADIO_PE is brought high which transitions the radio to PS Mode 3. There, the synthesizer can be programmed while the various oscillators start up and settle. Then, at T-2ms, the synthesizer is brought out of its standby state. At T-25µs the RX_PE and RESET lines are brought high. Finally, at T-1µs, the RX_PEbb line is brought high to enable the demodulation functions. There will be short (10µs) bursts of power here and there while the MAC programs the synthesizer or awakens other circuits.
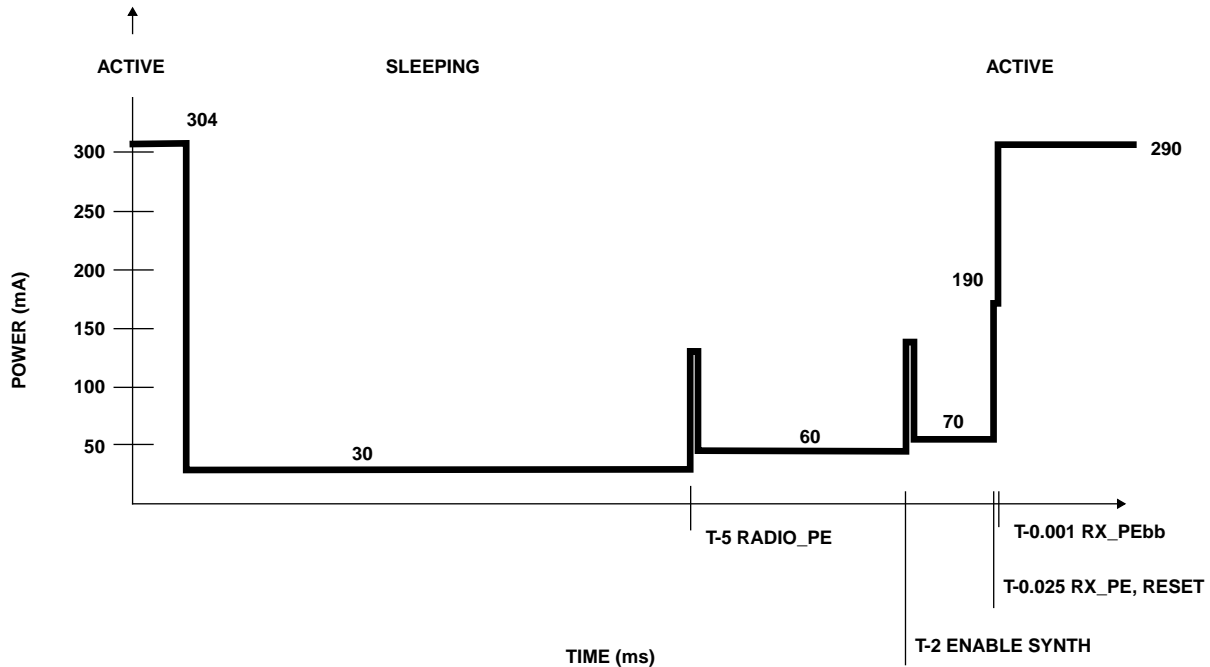

FIGURE 28. POWER RAMP UP

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