



# MX-COM, INC. MiXed Signal ICs

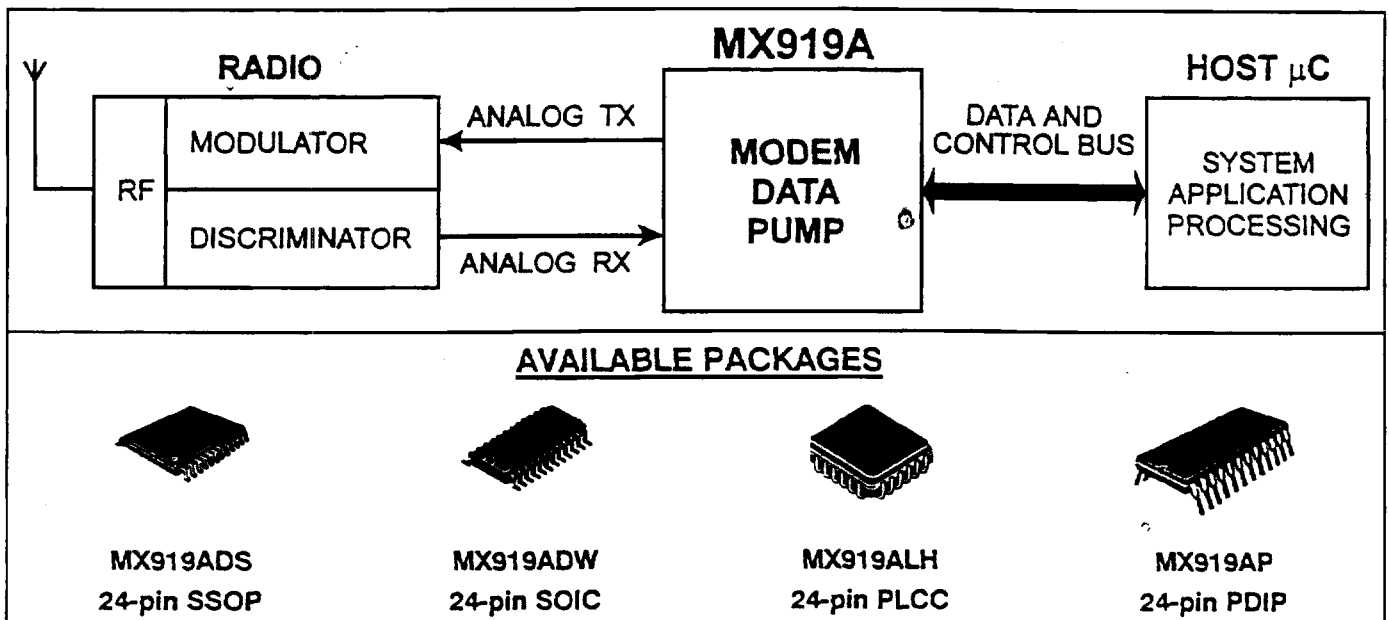
DATA BULLETIN

## MX919A 4-Level FSK Modem Data Pump

Document # 20480151.001 MAY 1996

Advance Information

- 4-Level FSK Modulation
- Half Duplex, 4800 to 19.2k bits/sec
- Full Data Packet Framing
- Increase Channel Bit Rate/Hz
- Flexible Operating Modes
- Host  $\mu$ C Interface
- Low Power 3.3V/5V Operation
- 24-Pin Small Form Package Option



The MX919A is a low voltage CMOS device containing all of the baseband signal processing and Medium Access Control (MAC) protocol functions required for a high performance 4-level FSK Wireless Packet Data Modem. It interfaces with the modem host  $\mu$ C and the radio modulation/demodulation circuits to deliver reliable two-way transfer of the application data over a wireless link.

The MX919A assembles application data received from the host  $\mu$ C, adds forward error correction (FEC) and error detection (CRC) information and interleaves the result for burst-error protection. After automatically adding symbol and frame sync codewords, the data packet is converted into filtered 4-level analog signals for modulating the radio transmitter.

In receive mode, the MX919A performs the reverse function using the analog signals from the receiver discriminator. After error correction and removal of the packet overhead, the recovered application data is supplied to the host  $\mu$ C. CRC detected residual uncorrected data errors will be flagged. A readout of the SNR value during receipt of a packet is also provided.

The MX919A uses data block sizes and FEC/CRC suitable for applications where high speed transfer of data over narrow-band wireless links is required. The device is programmable to operate at standard bit rates from a wide range of Xtal/clock frequencies..

\*CNSMSO18\*

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# 1. Block Diagram

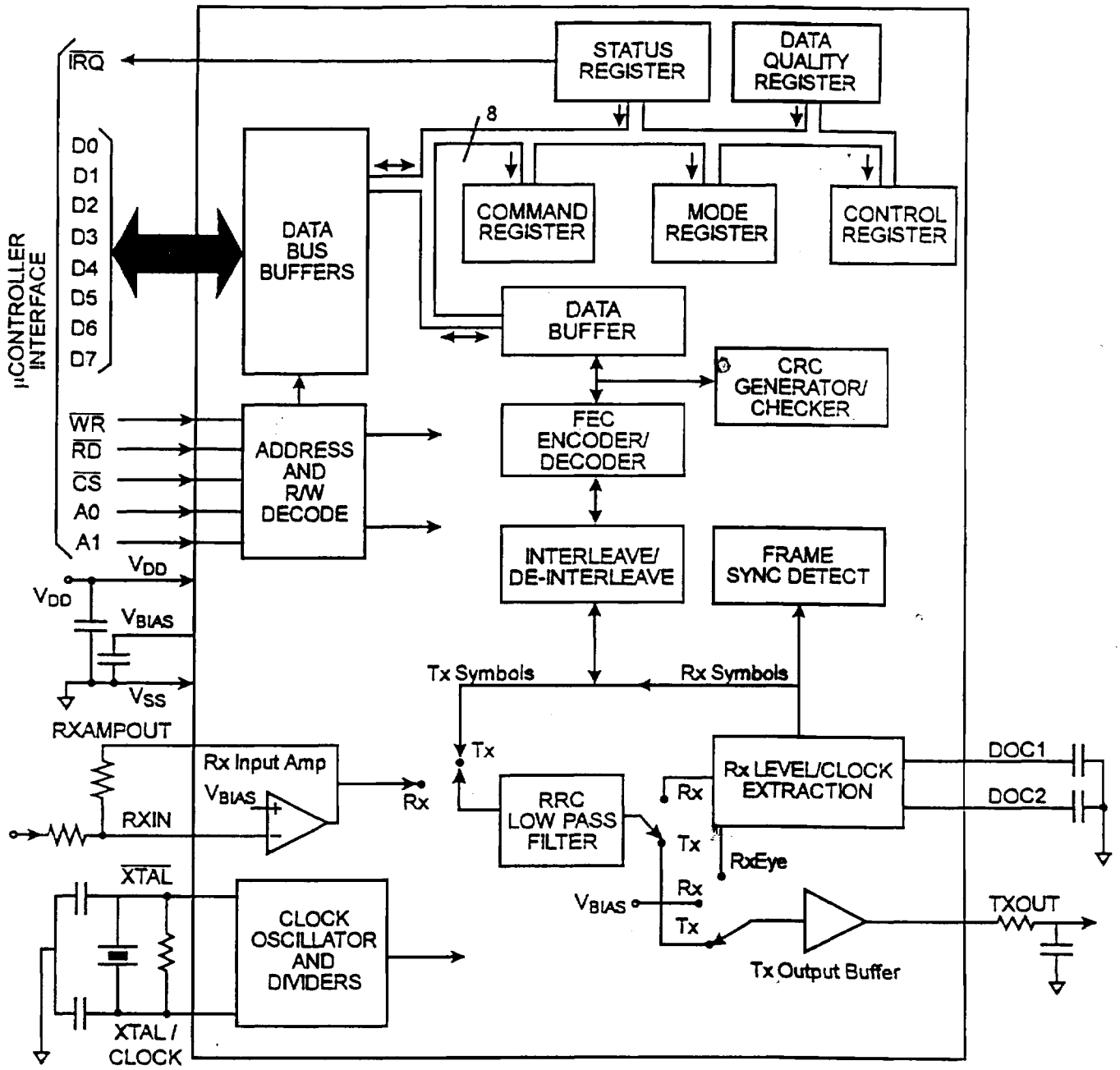


Figure 1: Block Diagram

## 2. Signal List

Pin No.	Signal	Type	Description
1	$\overline{\text{IRQ}}$	output	A 'wire-ORable' output for connection to the host $\mu\text{C}$ 's Interrupt Request input. When active this output has a low impedance pull down to $V_{\text{SS}}$ . It has a high impedance when inactive.
2	D7	BUS	Pins 2-9 (D7-D0) are 8-bit, bi-directional, 3-state $\mu\text{C}$ interface data lines
3	D6	BUS	
4	D5	BUS	
5	D4	BUS	
6	D3	BUS	
7	D2	BUS	
8	D1	BUS	
9	D0	BUS	
10	$\overline{\text{RD}}$	input	Read. An active low logic level input used to control the reading of data from the modem into the host $\mu\text{C}$ .
11	$\overline{\text{WR}}$	input	Write. An active low logic level input used to control the writing of data into the modem from the host $\mu\text{C}$ .
12	$V_{\text{SS}}$	power	Negative supply. (ground).
13	$\overline{\text{CS}}$	input	Chip Select. An active low logic level input to the modem, used to enable a data read or write operation.
14	A0	input	Logic level modem register select input
15	A1	input	Logic level modem register select input
16	$\overline{\text{XTAL}}$	output	Output of the on-chip oscillator.
17	XTAL/CLOCK	input	Input to the on-chip oscillator, for external Xtal circuit or clock.
18	DOC 2	output	Connection to the Rx level measurement circuitry. Should be capacitive coupled to $V_{\text{SS}}$
19	DOC 1	output	Connection to the Rx level measurement circuitry. Should be capacitive coupled to $V_{\text{SS}}$
20	TXOUT	output	Tx signal output from the modem.
21	$V_{\text{BIAS}}$	output	A bias line for the internal circuitry, held at $V_{\text{DD}}/2$ . This pin must be bypassed to $V_{\text{SS}}$ by a capacitor mounted close to the device pins.
22	RXIN	input	Input to the Rx input amplifier.
23	RXAMPOUT	output	Output of the Rx input amplifier.
24	$V_{\text{DD}}$	power	Positive supply. Levels and voltages are dependent upon this supply. This pin should be bypassed to $V_{\text{SS}}$ by a capacitor mounted close to the device pins.

### 3. External Components

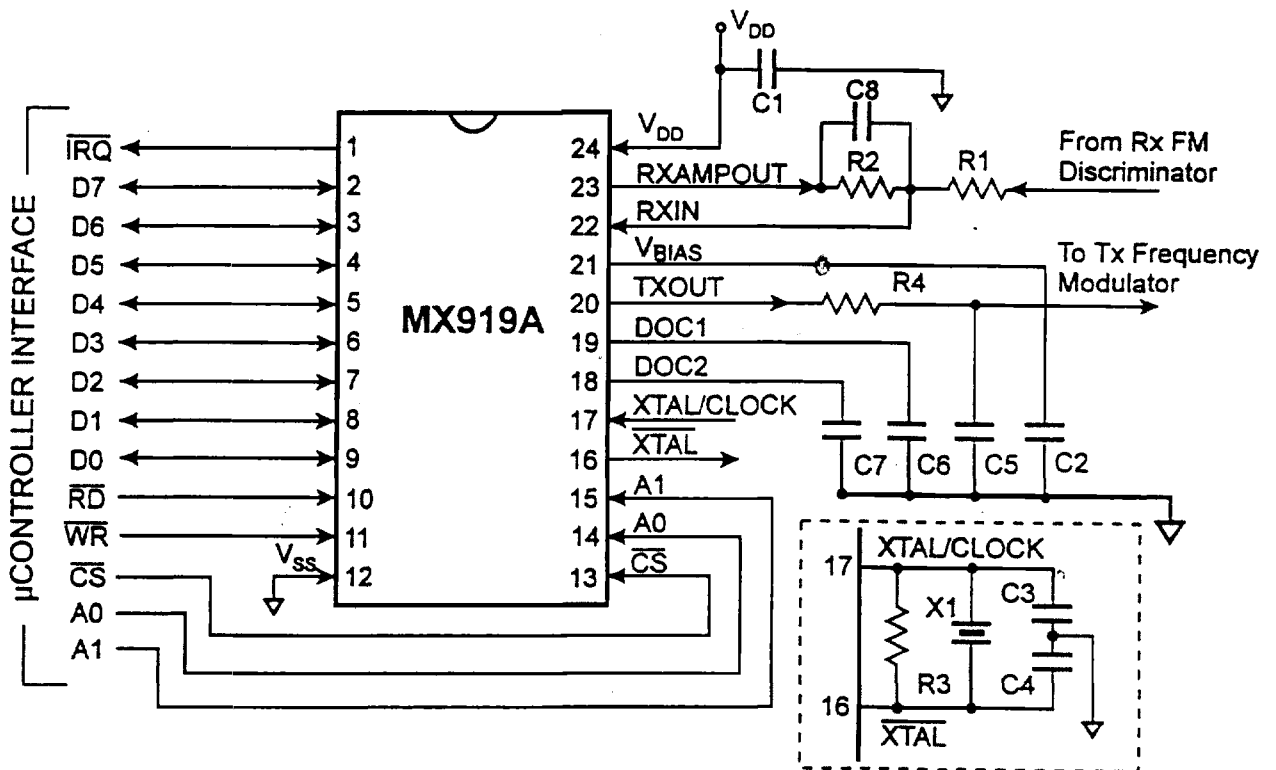


Figure 2: Recommended External Components

Component	Notes	Value	Tolerance
R1	1		±20%
R2		100kΩ	±5%
R3		1MΩ	±20%
R4		100kΩ	±5%
C1		0.1 μF	±20%
C2		0.1 μF	±20%
C3	2		±20%
C4	2		±20%
C5	3		±5%
C6	4		±20%
C7	4		±20%
C8	3		±5%
X1	5		

#### Recommended External Component Notes:

- See Section 4.1.10.
- The values used for C3 and C4 should be suitable for the frequency of the crystal X1. As a guide, values (including stray capacitance) of 33pF at 1MHz falling to 18pF at 10MHz will generally prove suitable. For optimum performance, the crystal frequency tolerance should be ±10ppm or better to allow for use of the Narrow Bandwidth PLL setting (see Section 4.5.3). Tolerances as wide as ±50ppm may be used, but at the cost of slightly reduced BER performance.

3. Values C5 and C8 should equal the following:  $750,000 / \text{symbol rate}$

Symbol Rate	C5 / C8
2400 symbols/second	330pF
4800 symbols/second	150pF
9600 symbols/second	82pF

4. Values C6 and C7 should equal the following:  $50,000 / \text{symbol rate}$

Symbol Rate	C6 / C7
2400 symbols/second	0.022 $\mu$ F
4800 symbols/second	0.01 $\mu$ F
9600 symbols/second	4700pF

5. See Section 4.5.3.

## 4. General Description

### 4.1 Description of Blocks

#### 4.1.1 Data Bus Buffers

Eight bi-directional 3-state logic level buffers between the modem's internal registers and the host  $\mu$ C's data bus lines.

#### 4.1.2 Address and R/W Decode

This block controls the transfer of data bytes between the  $\mu$ C and the modem's internal registers, according to the state of the Write and Read Enable inputs ( $\overline{WR}$  and  $\overline{RD}$ ), the Chip Select input ( $\overline{CS}$ ) and the Register Address inputs A0 and A1.

The Data Bus Buffers, Address and R/W Decode blocks provide a byte-wide parallel  $\mu$ C interface, which can be memory-mapped, as shown in Figure 3

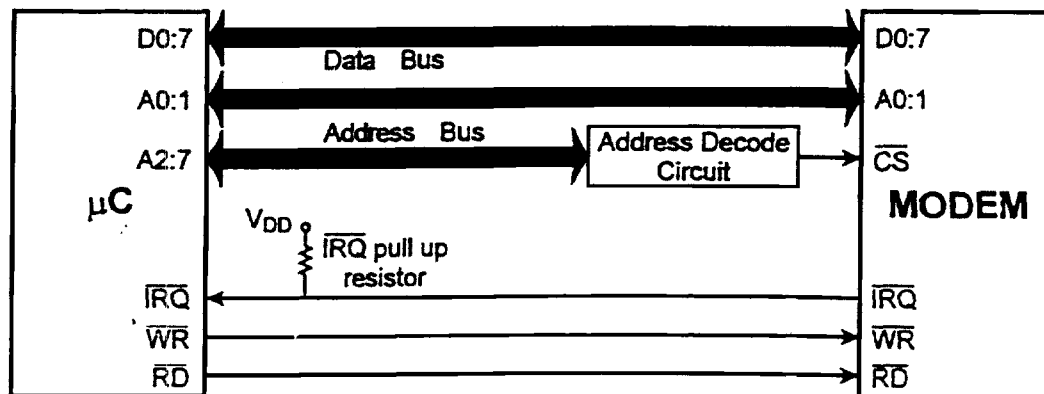


Figure 3: Typical Modem  $\mu$ C connections

#### 4.1.3 Status and Data Quality Registers

Two, 8-bit registers which the  $\mu$ C can read, to determine the status of the modem and the received data quality.

#### 4.1.4 Command, Mode and Control Registers

The values written by the  $\mu$ C to these 8-bit registers control the operation of the modem.

#### 4.1.5 Data Buffer

A 12-byte buffer used to hold receive or transmit data to or from the  $\mu\text{C}$ .

#### 4.1.6 CRC Generator/Checker

A circuit which generates (in transmit mode) or checks (in receive mode) the Cyclic Redundancy Checksum bits, which may be included in the transmitted data blocks so the receive modem can detect transmission errors.

#### 4.1.7 FEC Generator/Checker

In transmit mode, this circuit adds Forward Error Correction bits to the transmitted data, resulting in the conversion of binary data to 4-level symbols. In receive mode, this circuit translates received 4-level symbols to binary data, using the FEC information to correct a large proportion of transmission errors.

#### 4.1.8 Interleave/De-interleave Buffer

This circuit interleaves data symbols within a block before transmission and de-interleaves the received data so that the FEC system is best able to handle short noise bursts or fades.

#### 4.1.9 Frame Sync Detect

This circuit, which is only active in receive mode, is used to look for the 24-symbol Frame Synchronization pattern that is transmitted to mark the start of every frame.

#### 4.1.10 Rx Input Amp

This amplifier allows the received signal input to the modem to be set to the optimum level by suitable selection of the external components R1 and R2. The value of R1 should be calculated to give  $(0.2 \times V_{DD})V_{P-P}$  at the RXAMP OUT pin for a received '...+3 +3 -3 -3 ...' sequence.

A capacitor may be placed in series with R1 if ac coupling of the received signal is desired (see Section 5.4), otherwise the dc level of the received signal should be adjusted so that the signal at the modem's RXAMP OUT pin is centered around  $V_{BIAS}$  ( $V_{DD}/2$ ).

#### 4.1.11 RRC Low Pass Filter

This filter, which is used in both transmit and receive modes, is a linear-phase lowpass filter with a 'Root Raised Cosine' frequency response defined by:

$$\begin{aligned}
 H(f) &= 1 && \text{for } 0 && \leq f < (1-b)/(2T) \\
 &= \text{square root of } \{0.5 [1 - \sin(\pi T (f - 0.5/T)/b)]\} && \text{for } (1-b)/(2T) && \leq f \leq (1+b)/(2T) \\
 &= 0 && \text{for } (1+b)/(2T) && < f
 \end{aligned}$$

where  $b = 0.2$ ,  $T = 1/\text{symbol rate}$

This frequency response is illustrated in Figure 5.

In transmit mode, the 4-level symbols are passed through this filter to eliminate the high frequency components which would otherwise cause interference into adjacent radio channels.

In receive mode, the filter is used to reject HF noise and to equalize the received signal to a form suitable for extracting the 4-level symbols.

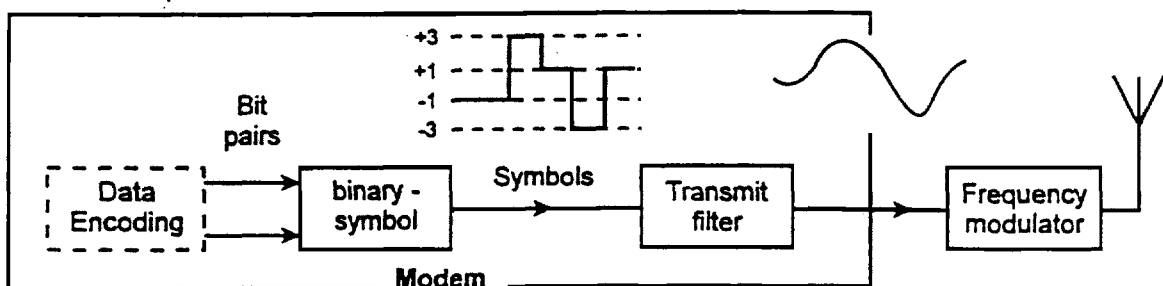


Figure 4: Translation of Binary Data to Filtered 4-Level Symbols in Tx Mode

#### 4.1.12 Tx Output Buffer

This is a unity gain amplifier used in the transmit mode to buffer the output of the Tx low pass filter. In receive mode, the input of this buffer is connected to  $V_{BIAS}$ , unless the RXEYE bit of the Control Register is '1', when it is connected to the received signal. When changing from Rx to Tx mode the input to this buffer will be connected to  $V_{BIAS}$  for 8 symbol times while the RRC filter settles.

Note: The RC low pass filter formed by the external components R4 and C5 between the TXOUT pin and the input to the radio's frequency modulator forms an important part of the transmit signal filtering. These components may form part of any dc level-shifting and gain adjustment circuitry. The value used for C5 should take into account stray circuit capacitance, and its ground connection should be positioned to give maximum attenuation of high frequency noise into the modulator.

The signal at the TXOUT pin is centered around  $V_{BIAS}$ . It is approximately  $(0.2 \times V_{DD})V_{P-P}$  for a continuous '+3 +3 -3 -3 ...' pattern.

A capacitor may be placed in series with the input to the frequency modulator if AC coupling is desired, see Section 5.4

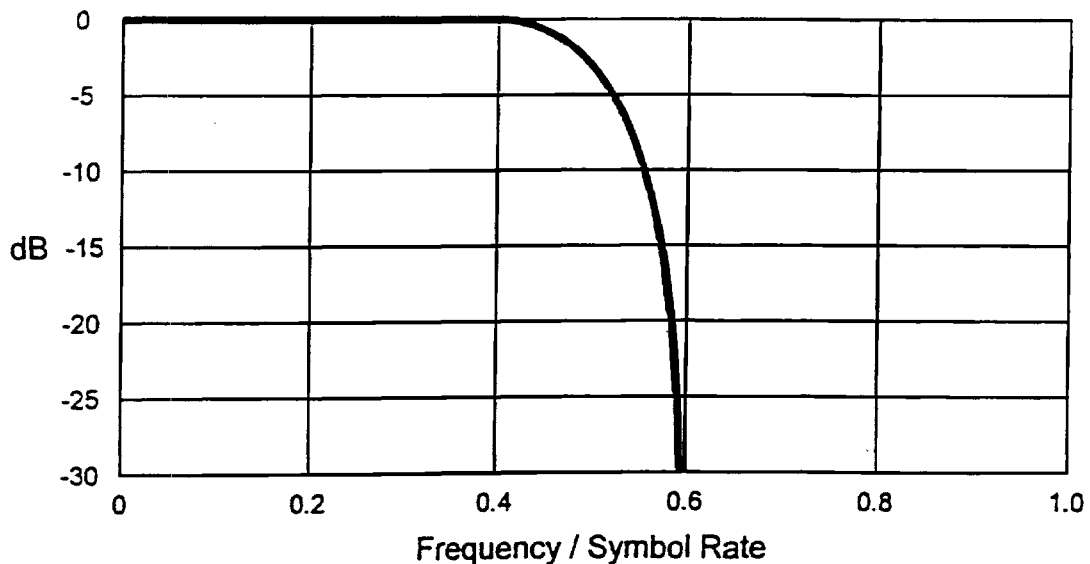


Figure 5: RRC Filter Frequency Response (including the external RC filter R4/C5)

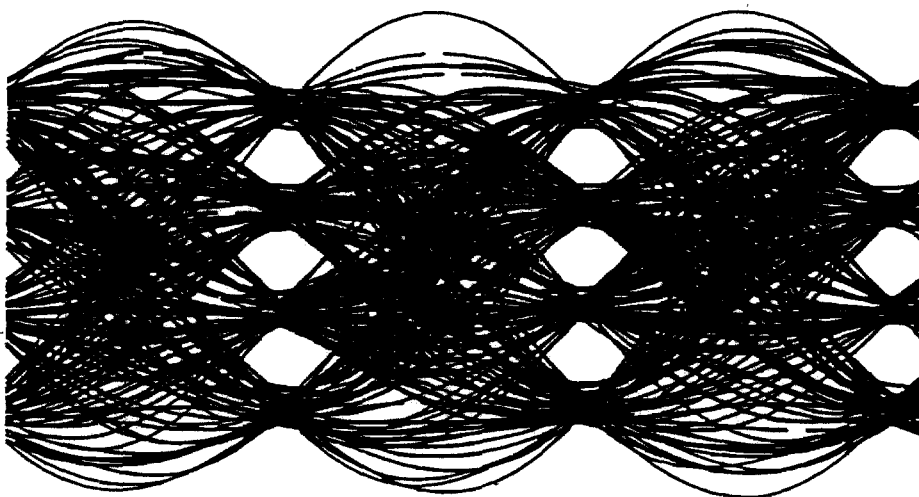


Figure 6: Transmitted Signal Eye Diagram

#### 4.1.13 Rx Level/Clock Extraction

These circuits, which operate only in receive mode, derive a symbol rate clock from the received signal and measures the received signal amplitude and dc offset. This information is then used to extract the received 4-level symbols and also to provide an input to the received Data Quality measuring circuit. The external capacitors C6 and C7 form part of the received signal level measuring circuit.

#### 4.1.14 Clock Oscillator and Dividers

These circuits derive the transmit symbol rate (and the nominal receive symbol rate) by frequency division of a reference frequency which may be generated by the on-chip Xtal oscillator or applied from an external source.

Note: If the on-chip Xtal oscillator is to be used, then the external components X1, C3, C4 and R3 are required. If an external clock source is to be used, then it should be connected to the XTAL/CLOCK input pin, the XTAL pin should be left unconnected, and X1, C3, C4 and R3 not fitted.

### 4.2 Modem - $\mu$ C Interaction

In general, data is transmitted over-air in the form of messages, or 'Frames', consisting of a 'Frame Preamble' followed by one or more formatted data blocks. The Frame Preamble includes a Frame Synchronization pattern designed to allow the receiving modem to identify the start of a frame. The following data blocks are constructed from the 'raw' data using a combination of CRC (cyclic redundancy checksum) generation, Forward Error Correction coding and Interleaving. Details of the message formats handled by the modem are given in Section 4.3 and Figure 7 and Figure 8.

To reduce the processing load on the associated  $\mu$ C, the MX919A modem has been designed to perform as much of the computationally intensive work involved in Frame formatting and de-formatting and when in receive mode, in searching for and synchronizing onto the Frame Preamble. In normal operation the modem will only require servicing by the  $\mu$ C once per received or transmitted block.

Thus, to transmit a block, the controlling  $\mu$ C needs only to load the - unformatted - 'raw' binary data into the modem's Data Block Buffer, instruct the modem to format and transmit that data. The modem will then calculate and add the CRC bits as required, encode the result as 4-level symbols (with Forward Error Correction coding) and interleave the symbols before transmission.

In receive mode, the modem can be instructed to assemble a block's worth of received symbols, de-interleave the symbols, translate them to binary - using the FEC coding to correct as many errors as possible - and check the resulting CRC before placing the received binary data into the Data Block Buffer for the  $\mu$ C to read.

The modem can also handle the transmission and reception of unformatted data - for example: to allow the transmission of Symbol and Frame Synchronization sequences or special test patterns.

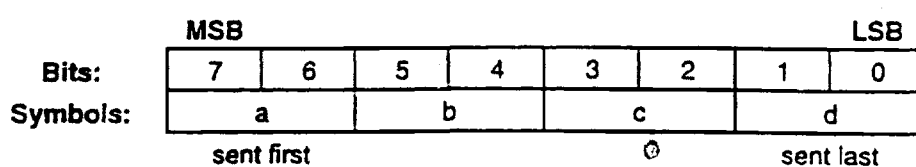
### 4.3 Binary to Symbol Translation

Although, the over-air signal and therefore the signals at the modem TXOUT and RXIN pins, consists of 4-level symbols, the raw data passing between the modem and the  $\mu$ C is in binary form. Translation between binary data and the 4-level symbols is done in one of two ways, depending on the task being performed.

1. Direct: (simplest form) - converts between 2 binary bits and a single symbol.

SYMBOL	MSB	LSB
+3	1	1
+1	1	0
-1	0	0
-3	0	1

This is expanded so an 8-bit byte translates to four symbols for the T4S, T24S and R4S tasks described in Section 4.5.2.



2. FEC (more complicated) - essentially translates groups of 3 binary bits to pairs of 4-level symbols using a Forward Error Correcting coding scheme for the block oriented tasks THB, TIB, TLB, RHB and RILB described in Section 4.5.2.

### 4.4 Frame Structure

Figure 7 shows how an over-air message frame may be constructed from Frame and Symbol Sync patterns, followed by one or more 'Header', 'Intermediate' or 'Last' blocks.

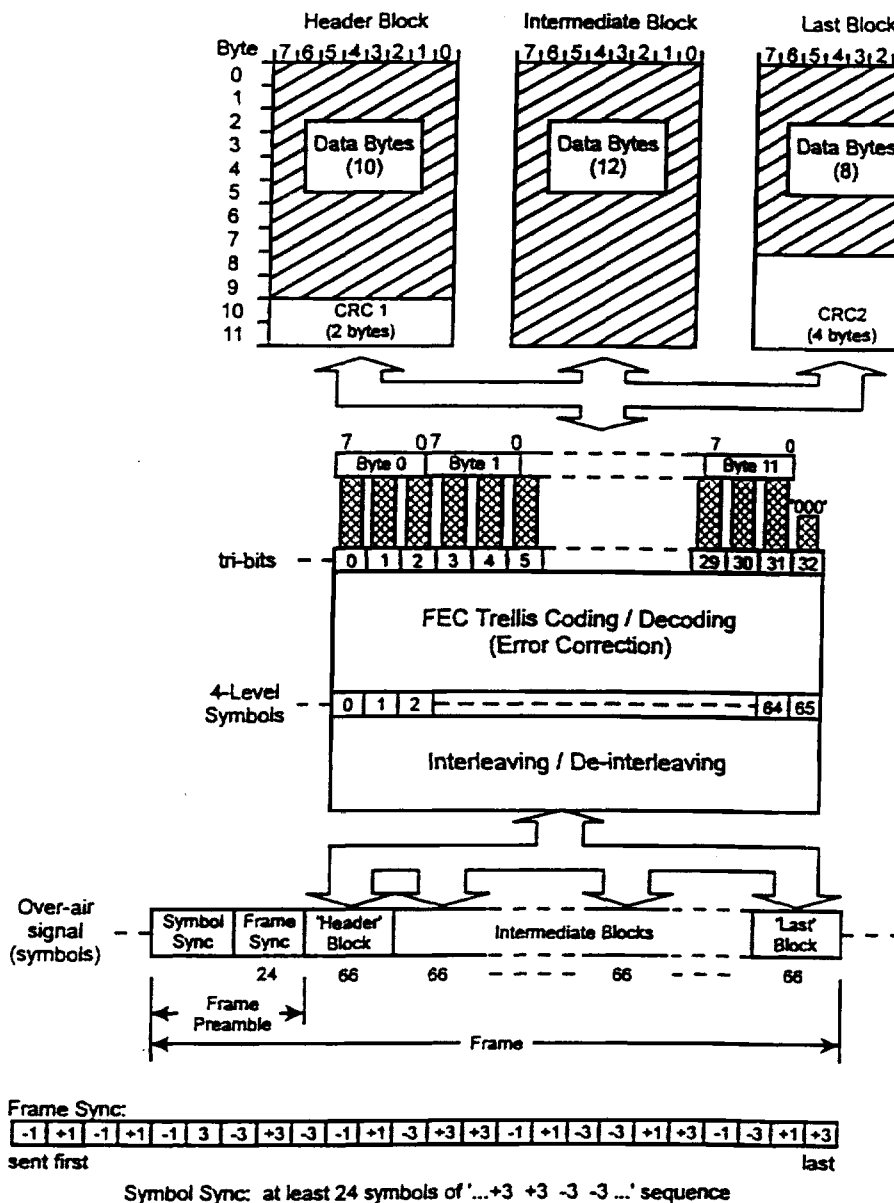


Figure 7: Over-Air Signal Format

The 'Header' block is self-contained, it includes its own checksum (CRC1), and would normally carry information such as the address of the calling and called parties, the number of following blocks in the frame (if any) and miscellaneous control information.

The 'Intermediate' block(s) contain only data, the checksum for all of the data in the 'Intermediate' and 'Last' blocks (CRC2) being contained at the end of the 'Last' block.

This arrangement, while efficient in terms of data capacity, may not be optimum for poor signal-to-noise conditions, since a reception error in any one of the 'Intermediate' or 'Last' blocks would invalidate the whole frame. In such conditions, increased throughput may be obtained by using the 'Header' block format for all blocks of the frame, so blocks that are received correctly can be identified as such, and do not need to be re-transmitted. This, and some other possible frame structures, are shown in Figure 8.

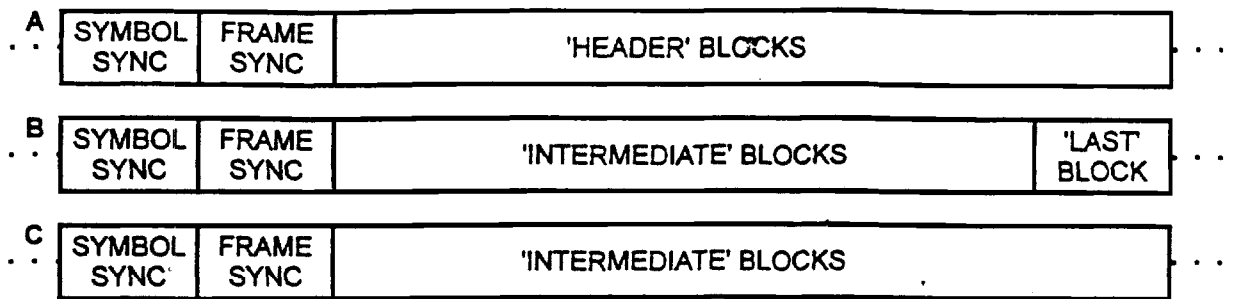


Figure 8: Alternative Frame Structure

The MX919A performs all of the block formatting and de-formatting, the binary data transferred between the modem and its  $\mu$ C is shown by diagonal lines in Figure 7.

#### 4.5 The Programmer's View

To the programmer, the modem appears as 4, write only 8-bit registers, shadowed by 3 read only registers. The individual registers are selected by the A0 and A1 chip inputs:

A1	A0	Write to Modem	Read from Modem
0	0	Data Buffer	Data Buffer
0	1	Command Register	Status Register
1	0	Control Register	Data Quality Register
1	1	Mode Register	not used

Note: There is a minimum time allowance between accesses of the modem's registers, see Section 6.1.

##### 4.5.1 Data Block Buffer

This is a 12-byte read/write buffer used to transfer data (as opposed to command, status, mode, data quality or control information) between the modem and the host  $\mu$ C.

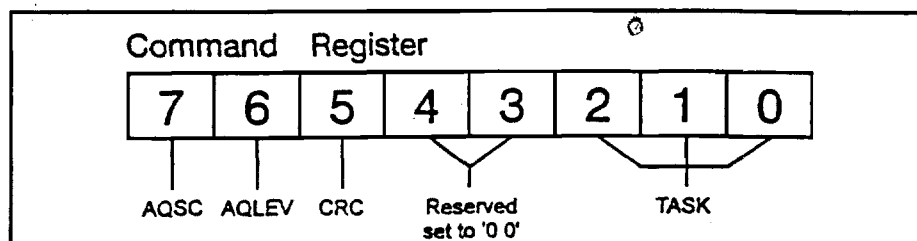
To the  $\mu$ C, the Data Block Buffer appears as a single 8-bit register. The modem ensures that sequential  $\mu$ C read or writes to the buffer are routed to the correct locations within the buffer.

The  $\mu$ C should only access this buffer when the Status Register BFREE (Buffer Free) bit is '1'.

The buffer should only be written to while in Tx mode and read from while in Rx mode. Note that in receive mode the modem will function correctly even if the received data is not read from the Data Buffer by the  $\mu$ C.

##### 4.5.2 Command Register

Writing to this register tells the modem to perform a specific action or actions, depending on the setting of the TASK, AQLEV and AQSC bits.



When there is no action to perform, the modem will be in an 'idle' state. If the modem is in transmit mode the input to the Tx RRC filter will be connected to  $V_{BIAS}$ . In receive mode the modem will continue to measure the received data quality and extract symbols from the received signal, supplying them to the de-interleave buffer, otherwise the received data is ignored.

##### 4.5.2.1 Command Register B7: AQSC - Acquire Symbol Clock

This bit has no effect in transmit mode.

In receive mode, when a byte with the AQSC bit set to '1' is written to the Command Register, and TASK is not set to RESET, it initiates an automatic sequence designed to achieve symbol timing synchronization with the received signal as quickly as possible. This involves setting the Phase Locked Loop of the received bit timing extraction circuits to its widest bandwidth, then gradually reducing the bandwidth as timing synchronization is achieved, until it reaches the 'normal' value set by the PLLBW bits of the Control Register.

Setting this bit to '0' (or changing it from '1' to '0') has no effect, however; the acquisition sequence will be re-started every time a byte written to the Command Register has the AQSC bit set to '1'.

The AQSC bit will normally be set at the same time as a SFS (Search for Frame Sync) or SFSH (Search for Frame Sync plus Header block) task is written to the MX919A, however it may also be used independently to re-establish clock synchronization quickly after a long fade. Alternatively, a SFS or SFSH task may be written to the Command Register with the AQSC bit at '0' if it is known that clock synchronization does not need to be re-established.

#### 4.5.2.2 Command Register B6: AQLEV - Acquire Receive Signal Levels

This bit has no effect in transmit mode.

In receive mode, when a byte with the AQLEV bit set to '1' is written to the Command Register and TASK is not set to RESET, it initiates an automatic sequence designed to measure the amplitude and dc offset of the received signal as rapidly as possible. This sequence involves setting the measurement circuits to respond quickly at first, then gradually increasing their response time, therefore improving the measurement accuracy, until the 'normal' value set by the LEVRES bits of the Control Register is reached.

Setting this bit to '0' (or changing it from '1' to '0') has no effect, however; the acquisition sequence will be re-started every time a byte written to the Command Register has the AQLEV bit set to '1'.

The AQLEV bit will normally be set at the same time as a SFS (Search for Frame Sync) or SFSH (Search for Frame Sync plus Header Block) task is initiated, however it may also be used independently to re-establish signal levels quickly after a long fade. Alternatively, a SFS or SFSH task may be written to the Command Register with the AQLEV bit at '0' if it is known that there is no need to re-establish the received signal levels.

#### 4.5.2.3 Command Register B5: CRC

This bit allows the user to select between two different forms of the CRC1 and CRC2 checksums. When this bit is set to '0' the CRC generators are initialized to 'all ones' as for CCITT X25 CRC calculations. When this bit is set to '1' the CRC generators are initialized to 'all zeros'. Setting this bit to '0' provides compatibility with older 'non A' version of the MX919. Other systems may set this bit as required.

#### 4.5.2.4 Command Register B4, B3

These bits should be set to '0'.

#### 4.5.2.5 Command Register B2, B1, B0: TASK

Operations such as transmitting or receiving a data block are treated by the modem as 'tasks' and are initiated when the  $\mu$ C writes a byte to the Command Register with the TASK bits set to anything other than the 'NULL' code.

The  $\mu$ C should not write a task (other than NULL or RESET) to the Command Register or write to or read from the Data Buffer when the BFREE (Buffer Free) bit of the Status Register is '0'.

Different tasks apply in receive and transmit modes.

When the modem is in transmit mode, all tasks other than NULL or RESET instruct the modem to transmit data from the Data Buffer, formatting it as required. The  $\mu$ C should therefore wait until the BFREE (Buffer Free) bit of the Status Register is '1', before writing the data to the Data Block Buffer, then it should write the desired task to the Command Register. If more than 1 byte needs to be written to the Data Block Buffer, byte number 0 of the block should be written first.

Once the byte containing the desired task has been written to the Command Register, the modem will:

Set the BFREE (Buffer Free) bit of the Status Register to '0'.

Take the data from the Data Block Buffer as quickly as it can - transferring it to the Interleave Buffer for eventual transmission. This operation will start immediately if the modem is 'idle' (i.e. not transmitting data from a previous task), otherwise it will be delayed until there is sufficient room in the Interleave Buffer.

Once all of the data has been transferred from the Data Block Buffer the modem will set the BFREE and IRQ bits of the Status Register to '1', (causing the chip  $\overline{\text{IRQ}}$  output to go low if the IRQEN bit of the Mode Register has been set to '1') to tell the  $\mu$ C that it may write new data and the next task to the modem.

This lets the  $\mu$ C write a task and the associated data to the modem while the modem is still transmitting the data from the previous task.

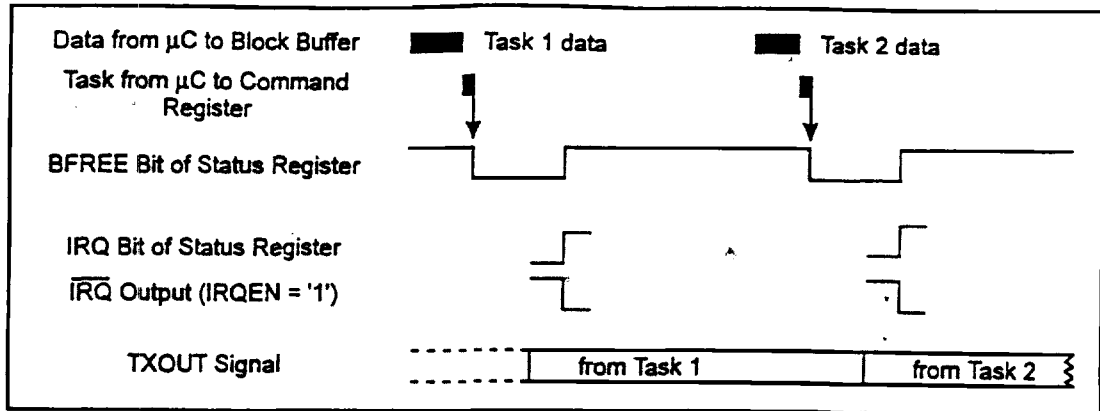


Figure 9: Transmit Task Overlapping

When the modem is in receive mode, the µC should wait until the BFREE bit of the Status Register is '1', then write the desired task to the Command Register.

Once the byte containing the desired task has been written to the Command Register, the modem will:

Set the BFREE bit of the Status Register to '0'.

Wait until enough received symbols are in the De-interleave Buffer.

Decode them as needed, and transfer the resulting binary data to the Data Block Buffer

Then the modem will set the BFREE and IRQ bits of the Status Register to '1', (causing the  $\overline{\text{IRQ}}$  output to go low if the IRQEN bit of the Mode Register has been set to '1') to tell the µC that it may read from the Data Block Buffer and write the next task to the modem. If more than 1 byte is contained in the buffer, byte number 0 of the data will be read out first.

In this way the µC can read data and write a new task to the modem while the received symbols needed for this new task are being received and stored in the De-interleave Buffer.

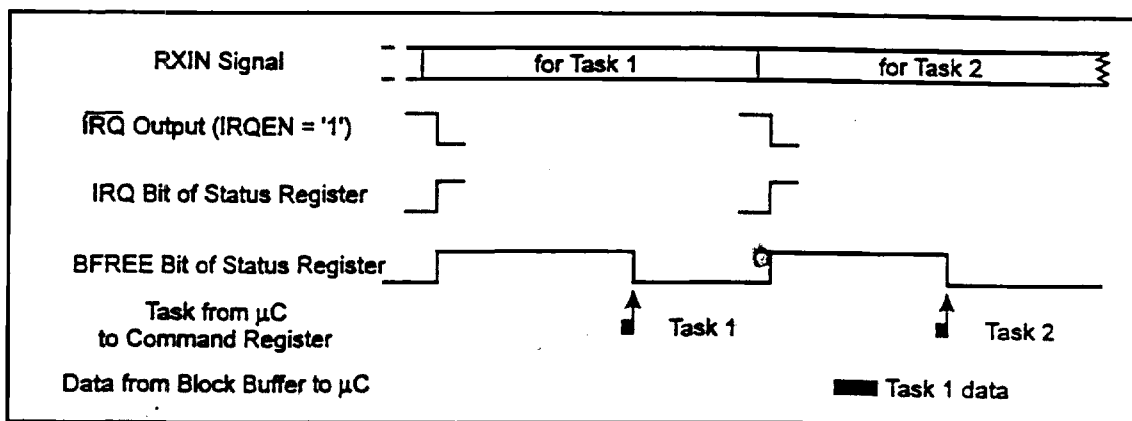


Figure 10: Receive Task Overlapping

Detailed timings for the various tasks are provide in Figure 11 and Figure 12.

**MX919A Modem Tasks:**

B2	B1	B0	Receive Mode		Transmit Mode	
0	0	0	NULL		NULL	
0	0	1	SFSH	Search for FS + Header	T24S	Transmit 24 symbols
0	1	0	RHB	Read Header Block	THB	Transmit Header Block
0	1	1	RILB	Read Intermediate or Last Block	TIB	Transmit Intermediate Block
1	0	0	SFS	Search for Frame Sync	TLB	Transmit Last Block
1	0	1	R4S	Read 4 symbols	T4S	Transmit 4 symbols
1	1	0	NULL		NULL	
1	1	1	RESET	Cancel any current action	RESET	Cancel any current action

**4.5.2.6 NULL: No effect**

This 'task' is provided so an AQSC or AQLEV command can be initiated without loading a new task.

**4.5.2.7 SFSH: Search for Frame Sync plus Header Block**

This task causes the modem to search the received signal for a valid 24-symbol Frame Sync sequence followed by Header Block which has a correct CRC1 checksum.

The task continues until a valid Frame Sync plus Header Block has been found.

The search consists of two stages:

First of all the modem will attempt to match the incoming symbols against the 24-symbol Frame Synchronization pattern to within the tolerance defined by the FSTOL bits of the Control Register.

Once a match has been found, the modem will read in the next 66 symbols as if they were a 'Header' block, decoding the symbols and checking the CRC1 checksum. If this is incorrect, the modem will resume the search, looking for a fresh Frame Sync pattern.

If the received CRC1 is correct, the 10 decoded data bytes will be placed into the Data Block Buffer, the BFREE and IRQ bits of the Status Register will be set to '1' and the CRCERR bit cleared to '0'.

On detecting that the BFREE bit of the Status Register has gone to '1', the  $\mu$ C should read the 10 bytes from the Data Block Buffer and then write the next task to the modem's Command Register.

**4.5.2.8 RHB: Read Header Block**

This task causes the modem to read the next 66 symbols as a 'Header' Block, decoding them, placing the resulting 10 data bytes and the 2 received CRC1 bytes into the Data Block Buffer, and setting the BFREE and IRQ bits of the Status Register to '1'. When the task is complete it indicates that the  $\mu$ C may read the data from the Data Block Buffer and write the next task to the modem's Command Register.

The CRCERR bit of the Status Register will be set to '1' or '0' depending on the validity of the received CRC1 checksum bytes.

**4.5.2.9 RILB: Read 'Intermediate' or 'Last' Block**

This task causes the modem to read the next 66 symbols as an 'Intermediate' or 'Last' block (the  $\mu$ C should be able to tell from the 'Header' block how many blocks are in the frame and when to expect the 'Last' block).

In each case, it will decode the 66 symbols and place the resulting 12 bytes into the Data Block Buffer, setting the BFREE and IRQ bits of the Status Register to '1' when the task is complete.

If an 'Intermediate' block is received then the  $\mu$ C should read out all 12 bytes from the Data Block Buffer and ignore the CRCERR bit of the Status Register, for a 'Last' block the  $\mu$ C need only read the first 8 bytes from the Data Block Buffer, and the CRCERR bit in the Status Register will reflect the validity of the received CRC2 checksum.

**4.5.2.10 SFS: Search for Frame Sync**

This task causes the modem to search the received signal for a 24-symbol sequence which matches the Frame Synchronization pattern to within the tolerance defined by the FSTOL bits of the Mode Register.

When a match is found the modem will set the BFREE and IRQ bits of the Status Register to '1' to indicate to the  $\mu$ C that it should write the next task to the Command Register.

**4.5.2.11 R4S: Read 4 Symbols**

This task causes the modem to read the next 4 symbols and translate them directly (without de-interleaving or FEC) to an 8-bit byte which is placed into the Data Block Buffer. The BFREE and IRQ bits of the Status Register is then set to '1' to indicate that the  $\mu$ C may read the data byte from the Data Block Buffer and write the next task to the Command Register.

This task is intended for special tests and channel monitoring - perhaps preceded by SFS task.

#### 4.5.2.12 T24S: Transmit 24 Symbols

This task, which is intended to facilitate the transmission of Symbol and Frame Sync patterns as well as special test sequences, takes 6 bytes of data from the Data Block Buffer and transmits them as 24 4-level symbols without any CRC or FEC.

Byte 0 of the Data Block Buffer is sent first, byte 5 last.

Once the modem has read the data bytes from the Data Block Buffer, the BFREE and IRQ bits of the Status Register will be set to '1', indicating to the  $\mu$ C that it may write the data and command byte for the next task to the modem.

The tables below show what data needs to be written to the Data Block Buffer to transmit the MX919A Symbol and Frame Sync sequences:

'Symbol Sync'				Values written to Data Block Buffer		
Symbols					Binary	Hex
+3	+3	-3	-3	Byte 0:	11110101	F5
+3	+3	-3	-3	Byte 1:	11110101	F5
+3	+3	-3	-3	Byte 2:	11110101	F5
+3	+3	-3	-3	Byte 3:	11110101	F5
+3	+3	-3	-3	Byte 4:	11110101	F5
+3	+3	-3	-3	Byte 5:	11110101	F5

'Frame Sync'				Values written to Data Block Buffer		
Symbols					Binary	Hex
-1	+1	-1	+1	Byte 0:	00100010	22
-1	+3	-3	+3	Byte 1:	00110111	37
-3	-1	+1	-3	Byte 2:	01001001	49
+3	+3	-1	+1	Byte 3:	11110010	F2
-3	-3	+1	+3	Byte 4:	01011011	5B
-1	-3	+1	+3	Byte 5:	00011011	1B

#### 4.5.2.13 THB: Transmit Header Block

This task takes 10 bytes of data (Address and Control) from the Data Block Buffer, calculates and appends the 2-byte CRC1 checksum, translates the result to 4-level symbols (with FEC), interleaves the symbols and transmits the result as a formatted 'Header' Block.

Once the modem has read the data bytes from the Data Block Buffer, the BFREE and IRQ bits of the Status Register will be set to '1'.

#### 4.5.2.14 TIB: Transmit Intermediate Block

This task takes 12 bytes of data from the Data Block Buffer, updates the 4-byte CRC2 checksum for inclusion in the 'Last' block, translates the 12 data bytes to 4-level symbols (with FEC), interleaves the symbols and transmits the result as a formatted 'Intermediate' Block.

Once the modem has read the data bytes from the Data Block Buffer, the BFREE and IRQ bits of the Status Register will be set to '1'.

#### 4.5.2.15 TLB: Transmit Last Block

This task takes 8 bytes of data from the Data Block Buffer, updates and appends the 4-byte CRC2 checksum, translates the resulting 12 bytes to 4-level symbols (with FEC), interleaves the symbols and transmits the result as a formatted 'Last' Block.

Once the modem has read the data bytes from the Data Block Buffer, the BFREE and IRQ bits of the Status Register will be set to '1'.

#### 4.5.2.16 T4S: Transmit 4 Symbols

This command is similar to T24S but takes only one byte from the Data Block Buffer, transmitting it as four 4-level symbols.

**4.5.2.17 RESET: Stop any current action**

This 'task' takes effect immediately, and terminates any current action (task, AQSC or AQLEV) the modem may be performing and sets the BFREE bit of the Status Register to '1', without setting the IRQ bit. It should be used when V<sub>DD</sub> is applied, to set the modem into a known state.

Note: Due to delays in the transmit filter, it will take several symbol times for any change to appear at the TXOUT pin.

**Task Timing**

		Task	Time (symbol times)
t1	Modem in idle state. Time from writing first task to application of first transmit bit to Tx RRC filter	Any	1 to 2
t2	Time from application of first symbol of the task to the Tx RRC filter until BFREE goes to a logic '1'	T24S	5
		THB/TIB/TLB	16
		T4S	0
t3	Time to transmit all symbols of the task	T24S	24
		THB/TIB/TLB	66
		T4S	4
t4	Max time allowed from BFREE going to a logic '1' (high) for next task (and data) to be written to modem	T24S	18
		THB/TIB/TLB	49
		T4S	3
t5	Time to receive all symbols of task	SFS	24 (minimum)
		SFSH	90 (minimum)
		RHB/RILB	66
		R4S	4
t6	Maximum time between first symbol of task entering the de-interleave circuit and the task being written to modem	SFS	21
		SFSH	21
		RHB/RILB	49
		R4S	3
t7	Maximum time from the last bit of the task entering the de-interleave circuit to BFREE going to a logic '1' (high)	Any	1

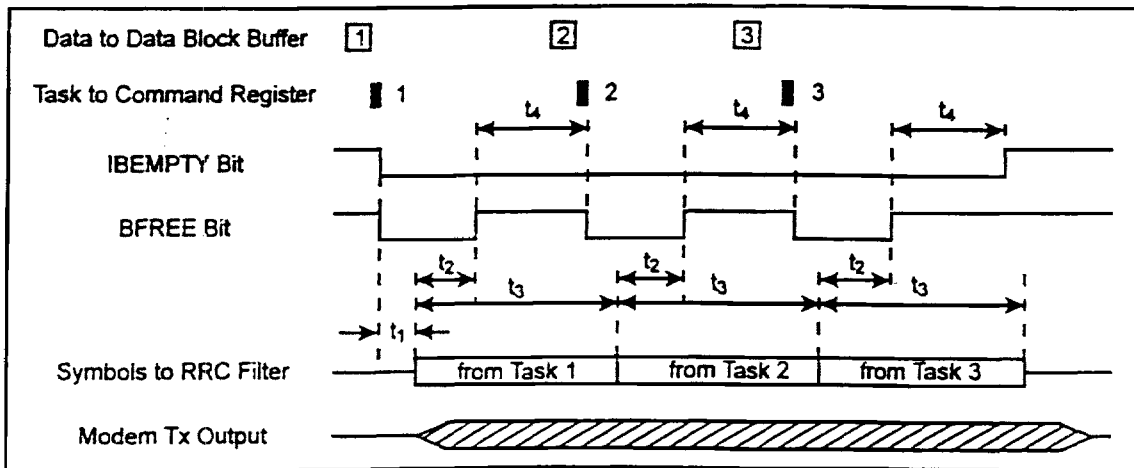


Figure 11: Transmit Task Timing Diagram

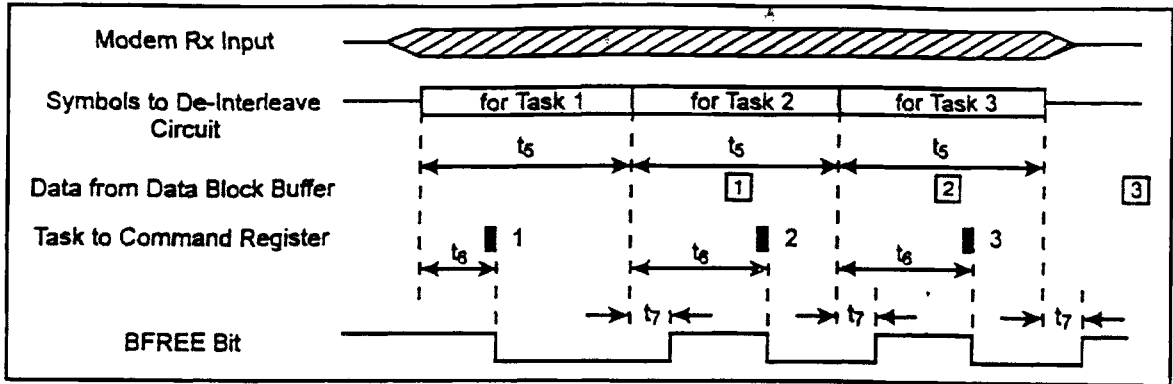


Figure 12: Receive Task Timing Diagram

4.5.2.18 RRC Filter Delay

The previous task timing figures are based on the signal at the input to the RRC filter (in transmit mode) or the input to the de-interleave buffer (in receive mode). There is an additional delay of about 8 symbol times through to the RRC filter in both transmit and receive modes, as illustrated below:

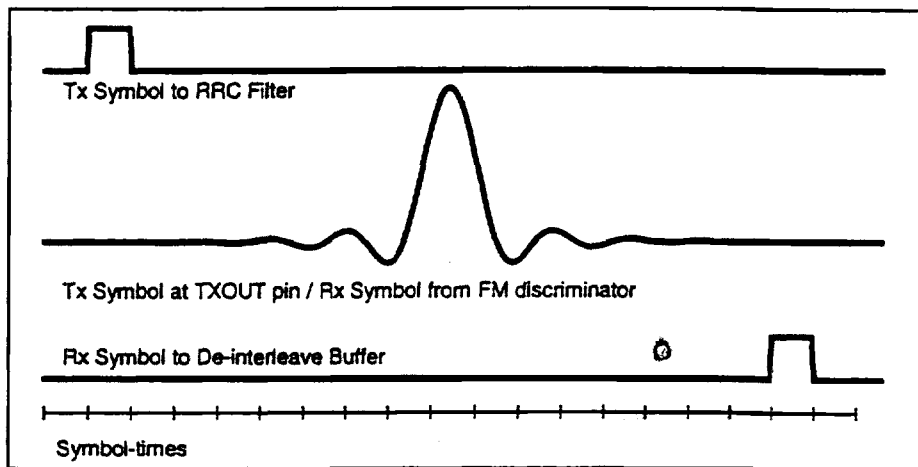
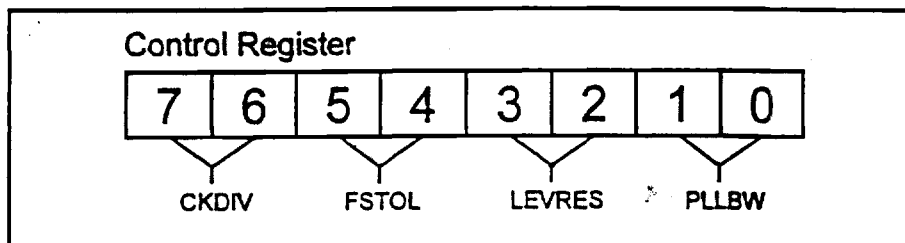


Figure 13: RRC Low Pass Filter Delay

4.5.3 Control Register

This 8-bit write-only register controls the modem's symbol rate, the response times of the receive clock extraction and signal level measurement circuits and the Frame Sync pattern recognition tolerance.



4.5.3.1 Control Register B7, B6: CKDIV - Clock Division Ratio

These bits control a frequency divider driven from the clock signal present at the XTAL pin, therefore determining the nominal symbol rate. The table below shows how symbol rates of 2400/4800/9600 symbols/sec may be obtained from common Xtal frequencies:

B7	B6	Division Ratio: Xtal Frequency/Symbol Rate	Xtal Frequency (MHz)		
			2.4576	4.9152	9.8304
0	0	512	4800	9600	
0	1	1024	2400	4800	9600
1	0	2048		2400	4800
1	1	4096			2400

Note: Device operation is not guaranteed below 2400 or above 9600 symbols/sec.

#### 4.5.3.2 Control Register B5, B4: FSTOL - Frame Sync Tolerance

These two bits have no effect in transmit mode. In receive mode, they define the maximum number of mismatches allowed during a search for the Frame Sync pattern:

B5	B4	Mismatches allowed
0	0	0
0	1	2
1	0	4
1	1	6

Note: A single 'mismatch' is defined as the difference between two adjacent symbol levels, thus if the symbol '+1' were expected, then received symbol values of '+3' and '-1' would count as 1 mismatch, a received symbol value of '-3' would count as 2 mismatches.

#### 4.5.3.3 Control Register B3, B2: LEVRES - Level Measurement Modes

These two bits have no effect in transmit mode. In receive mode they set the 'normal' operating mode of the Rx signal amplitude and dc offset measuring circuits. This setting will be temporarily overridden by the automatic sequencing of an AQLEV command.

B3	B2	Mode
0	0	Hold
0	1	Slow Peak Detect
1	0	Lossy Peak Detect
1	1	Clamp

For most applications these two bits should be set to 'Slow Peak Detect' mode, in which the peak positive and peak negative excursions of the received signal (after filtering) are measured to establish the amplitude and dc offset of the signal. The decay time-constant of the peak rectifier circuits used in this mode is approximately 750 symbol times.

The 'Hold' setting freezes the stored values of the current amplitude and offset measurements which may be used to improve performance during short fades or while the radio is switched from receive mode for the transmission of a short acknowledgment. It should be noted, that the measured amplitude and offset values are stored on the external capacitors C7 and C8 and will decay gradually when the 'Hold' setting is chosen, the discharge time-constant being approximately 750 symbol times.

The 'Lossy Peak Detect' setting is similar to 'Slow Peak Detect' except the decay time-constant of the peak detectors are reduced to approximately 25 symbol times to provide a faster response to signal changes at the expense of reduced BER performance. This mode is used by the automatic Level Measurement acquisition sequence but may also be useful in non-standard systems.

The 'Clamp' setting is primarily intended for use by the automatic Level Measurement Acquisition Sequence as described in Section 5.3, but may also be useful in non-standard systems. In this mode, the DOC1 and DOC2 pins are connected directly to the output of the circuit that normally drives the peak detectors.

#### 4.5.3.4 Control Register B1, B0: PLLBW - Phase-Locked Loop Modes

These two bits have no effect in transmit mode. In receive mode, they set the 'normal' bandwidth of the Rx clock extraction Phase Locked Loop circuit. This setting will be temporarily overridden by the automatic sequencing of an AQSC command.

B1	B0	PLL Mode	Working Bandwidth ( $\pm$ ppm)
0	0	Hold	-
0	1	Narrow Bandwidth	20
1	0	Medium Bandwidth	100
1	1	Wide Bandwidth	650

Note: 'Working Bandwidths' are the maximum difference between the actual received symbol rate and the nominal rate determined by the tolerance of the modem's Xtal frequency, to provide minimal degradation of a reasonably random received signal.

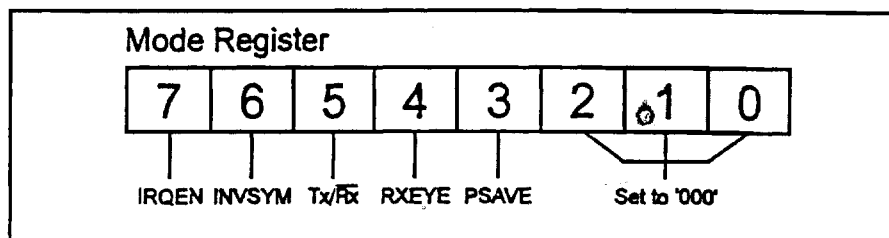
The minimum bandwidth consistent with the transmit and receive modem symbol rate tolerances should be chosen, i.e. if the Xtals used with both modems have accuracies within  $\pm 50$ ppm, then the PLLBW bits should be set to '10' ('Medium Bandwidth'). However, to allow the PLL to settle quickly, it is recommended that when very close tolerance Xtals are used, then the PLLBW bits should be set to 'Medium' whenever an AQSC is triggered, and only changed to 'Narrow' about 200 symbol times later.

The 'Wide Bandwidth' setting is intended for message acquisition in systems where the  $\mu$ C cannot detect the start of a received message, as it allows the modem to respond rapidly to fresh messages and recover rapidly after a fade without  $\mu$ C intervention - although at the cost of reduced Bit Error Rate vs Signal to Noise performance.

The 'Hold' setting disables the PLL feedback loop. It may be used during signal fades.

#### 4.5.4 Mode Register

The contents of this 8-bit write only register, control the basic operating modes of the modem:



##### 4.5.4.1 Mode Register B7: IRQEN - $\overline{\text{IRQ}}$ Output Enable

When this bit is set to '1', the  $\overline{\text{IRQ}}$  chip output pin is pulled low ( $V_{SS}$ ) when the IRQ bit of the Status Register is a '1'.

##### 4.5.4.2 Mode Register B6: INVSYM - Invert Symbols

This bit controls the polarity of the transmitted and received symbol voltages.

B6	Symbol	Signal at TXOUT	Signal at RXAMPOUT
0	'+3'	Above $V_{BIAS}$	Below $V_{BIAS}$
	'-3'	Below $V_{BIAS}$	Above $V_{BIAS}$
1	'+3'	Below $V_{BIAS}$	Above $V_{BIAS}$
	'-3'	Above $V_{BIAS}$	Below $V_{BIAS}$

##### 4.5.4.3 Mode Register B5: TX/ $\overline{\text{RX}}$ - Tx/Rx Mode

Setting this bit to '1' places the modem into the Transmit mode, clearing it to '0' puts the modem into the Receive mode.

Note: Changing between receive and transmit modes will cancel any current task.

##### 4.5.4.4 Mode Register B4: RXEYE - Show Rx Eye

This bit should normally be set to '0'. Setting it to '1' when the modem is in receive mode configures the modem for a special test mode, in which the input of the Tx output buffer is connected to the Rx Symbol/Clock extraction circuit at a point which carries the equalized receive signal. This may be monitored with an oscilloscope (at the TXOUT pin itself), to assess the quality of the complete radio channel including the Tx and Rx modem filters, the Tx modulator and the Rx IF filters and FM demodulator.

The resulting eye diagram (for reasonably random data) should ideally be as shown in the following Figure 14, with 4 'crisp' and equally spaced crossing points.

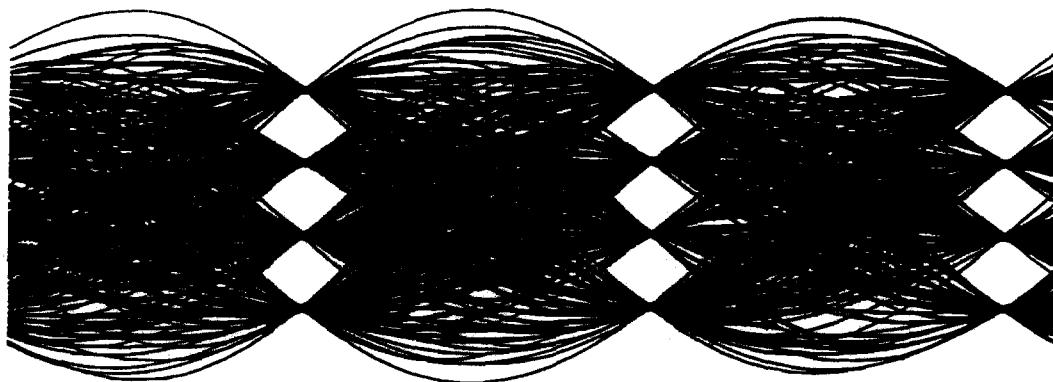


Figure 14: Ideal 'RXEYE' Signal

#### 4.5.4.5 Mode Register B3: PSAVE - Powersave

When this bit is a '1', the modem will be in a 'powersave' mode in which the internal filters, the Rx Symbol & Clock extraction circuits and the Tx output buffer will be disabled, and the TXOUT pin will be connected to the  $V_{BIAS}$  through a high value resistance. The Xtal clock oscillator, Rx input amplifier and the  $\mu C$  interface logic will continue to operate.

Setting the PSAVE bit to '0' restores power to all of the chip circuitry.

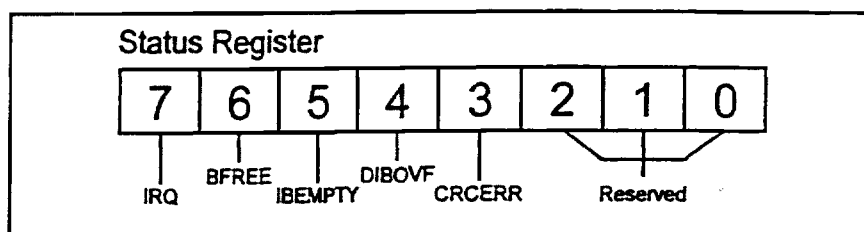
Note: The internal filters, and therefore the TXOUT pin, in transmit mode will take approximately 20 symbol-times to settle after the PSAVE bit has gone from '1' to '0'.

#### 4.5.4.6 Mode Register B2, B1, B0

These bits should be set to '000'.

#### 4.5.5 Status Register

This register may be read by the  $\mu C$  to determine the current state of the modem.



##### 4.5.5.1 Status Register B7: IRQ - Interrupt Request

This bit is set to '1' by:

The Status Register BFREE bit going from '0' to '1', unless this is caused by a RESET task or by a change to the Mode Register TX/RX bit.

The Status Register IBEMPTY bit going from '0' to '1', unless this is caused by a RESET task or by changing the Mode Register TX/RX bit.

The Status Register DIBOVF bit going from '0' to '1'.

The IRQ bit is cleared to '0' immediately after a read of the Status Register.

If the IRQEN bit of the Mode Register is '1', then the chip  $\overline{IRQ}$  output will be pulled low ( $V_{SS}$ ) when the IRQ bit is set to '1', and will go high impedance when the Status Register is read.

##### 4.5.5.2 Status Register B6: BFREE - Data Block Buffer Free

This bit reflects the availability of the Data Block Buffer and is cleared to '0' when a task other than NULL or RESET is written to the Command Register.

In transmit mode, the BFREE bit will be set to '1' (also setting the Status Register IRQ bit to '1') by the modem when the modem is ready for the  $\mu C$  to write new data to the Data Block Buffer and the next task to the Command Register.

In receive mode, the BFREE bit is set to '1' (also setting the Status Register IRQ bit to '1') by the modem when it has completed a task and any data associated with that task has been placed into the Data Block Buffer. The  $\mu\text{C}$  may then read that data and write the next task to the Command Register.

The BFREE bit is also set to '1' - but without setting the IRQ bit - by a RESET task or when the Mode Register TX/ $\overline{\text{RX}}$  bit is changed.

#### 4.5.5.3 Status Register B5: IBEMPTY - Interleave Buffer Empty

In transmit mode, this bit will be set to '1' - also setting the IRQ bit - when less than two symbols remain in the Interleave Buffer. Any transmit task written to the modem after this bit goes to '1' will be too late to avoid a gap in the transmit output signal.

The bit is also set to '1' by a RESET task or by a change of the Mode Register TX/ $\overline{\text{RX}}$  bit, but in these cases the IRQ bit will not be set.

The bit is cleared to '0' within one symbol time after a task other than NULL or RESET is written to the Command Register.

Note: When the modem is in transmit mode and the Interleave Buffer is empty, a mid level (half-way between '+1' and '-1') signal will be sent to the RRC filter.

In receive mode this bit will be '0'.

#### 4.5.5.4 Status Register B4: DIBOVF - De-Interleave Buffer Overflow

In receive mode this bit will be set to '1' - also setting the IRQ bit - when a RHB, RILB or R4S task is written to the Command Register too late to allow continuous reception.

The bit is cleared to '0' immediately after reading the Status Register, by writing a RESET task to the Command Register or by changing the TX/ $\overline{\text{RX}}$  bit of the Mode Register.

In transmit mode this bit will be '0'.

#### 4.5.5.5 Status Register B3: CRCERR - CRC Checksum Error

In receive mode this bit will be updated at the end of a SFSH, RHB or RILB task to reflect the result of the receive CRC check. '0' indicates that the CRC was received correctly, '1' indicates an error.

Note: This bit should be ignored when an 'Intermediate' block (which does not have an integral CRC) is received.

The bit is cleared to '0' by a RESET task, or by changing the TX/ $\overline{\text{RX}}$  bit of the Mode Register. In transmit mode this bit is '0'.

#### 4.5.5.6 Status Register B2, B1, B0

These bits are reserved for future use.

#### 4.5.6 Data Quality Register

In receive mode, the MX919A continually measures the 'quality' of the received signal, by comparing the actual received waveform over the previous 64 symbol times against an internally generated 'ideal'.

The result is placed into bits 3-7 of the Data Quality Register for the  $\mu\text{C}$  to read at any time, bits 0-2 being always set to '0'. Figure 15 shows how the value (0-255) read from the Data Quality Register varies with received signal-to-noise ratio:

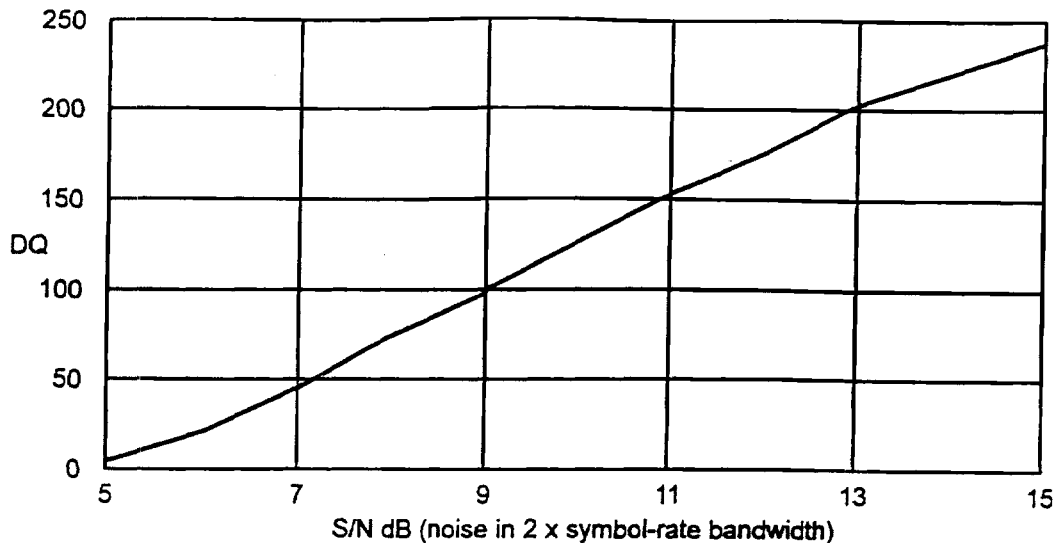


Figure 15: Typical Data Quality Reading vs S/N

In transmit mode and for 64 symbol times after enabling receive mode or after starting an AQSC or AQLEV sequence the value in the Data Quality Register will be invalid.

## 4.6 CRC, FEC and Interleaving

### 4.6.1 Cyclic Redundancy Codes

#### 4.6.1.1 CRC1

This is a sixteen-bit CRC check code contained in bytes 10 and 11 of the Header Block. It is calculated by the modem from the first 80 bits of the block ( Bytes 0 to 9 inclusive) using the generator polynomial:

$$x^{16} + x^{12} + x^5 + 1$$

#### 4.6.1.2 CRC2

This is a thirty-two-bit CRC check code contained in bytes 8 to 11 of the 'Last' Block. It is calculated by the modem from all of the data and pad bytes in the Intermediate Blocks and in the first 8 bytes of the Last Block using the generator polynomial:

$$x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x^1 + 1$$

Note: In receive mode the CRC2 checksum circuits are initialized on completion of any task other than NULL or RILB. In transmit mode the CRC2 checksum circuits are initialized on completion of any task other than NULL, TIB or TLB.

#### 4.6.1.3 Forward Error Correction

In transmit mode, the MX919A uses a Trellis Encoder to translate the 96 bits (12 bytes) of a 'Header', 'Intermediate' or 'Last' Block into a 66-symbol sequence which includes FEC information.

In receive mode, the MX919A decodes the received 66 symbols of a block into 96 bits of binary data using a 'Soft Decision' Viterbi algorithm to perform decoding and error correction.

#### 4.6.1.4 Interleaving

The 66 symbols of a 'Header', 'Intermediate' or 'Last' block are interleaved by the modem before transmission to provide protection against the effects of noise bursts and short fades.

In receive mode, the MX919A de-interleaves the received symbols prior to decoding.

## 5. Application

### 5.1 Transmit Frame Example

The operations needed to transmit a single Frame consisting of Symbol and Frame Sync sequences, and one each Header, Intermediate and Last blocks are provided below:

1. Ensure that the Control Register has been loaded with a suitable CKDIV value, that the IRQEN and bits of the Mode Register are '1', the RXEYE and PSAVE bits are '0' and the INVSYM bit is set appropriately.
2. Read the Status Register to ensure that the BFREE bit is '1', then write 6 Symbol Sync bytes to the Data Block Buffer and a T24S task to the Command Register.
3. Wait for an interrupt from the modem, read the Status Register; the IRQ and BFREE bits should be '1' and the IBEMPTY bit should be '0'.
4. Write 6 Frame Sync bytes to the Data Block Buffer and a T24S task to the Command Register.
5. Wait for an interrupt from the modem, read the Status Register; the IRQ and BFREE bits should be '1' and the IBEMPTY bit should be '0'.
6. Write 10 Header Block bytes to the Data Block Buffer and a THB task to the Command Register.
7. Wait for an interrupt from the modem, read the Status Register; the IRQ and BFREE bits should be '1' and the IBEMPTY bit should be '0'.
8. Write 12 Intermediate Block bytes to the Data Block Buffer and a TIB task to the Command Register.
9. Wait for an interrupt from the modem, read the Status Register; the IRQ and BFREE bits should be '1' and the IBEMPTY bit should be '0'.
10. Write 8 Last Block bytes to the Data Block Buffer and a TLB task to the Command Register.
11. Wait for an interrupt from the modem, read the Status Register; the IRQ and BFREE bits should be '1' and the IBEMPTY bit should be '0'.
12. Wait for another interrupt from the modem, read the Status Register; the IRQ, BFREE and IBEMPTY bits should be '1'.

Note: The final symbol of the frame will start to appear approximately 2 symbol times after the Status Register IBEMPTY bit goes to '1'; a further 16 symbol times should be allowed for the symbol to pass completely through the RRC filter.

Figure 16 and Figure 17 illustrate the host  $\mu$ C routines needed to send a single Frame consisting of Symbol and Frame Sync patterns, a Header block, and any number of Intermediate blocks and one Last Block. It is assumed that the Tx Interrupt Service Routine Figure 17 is called when the MX919A  $\overline{\text{IRQ}}$  output line goes low.

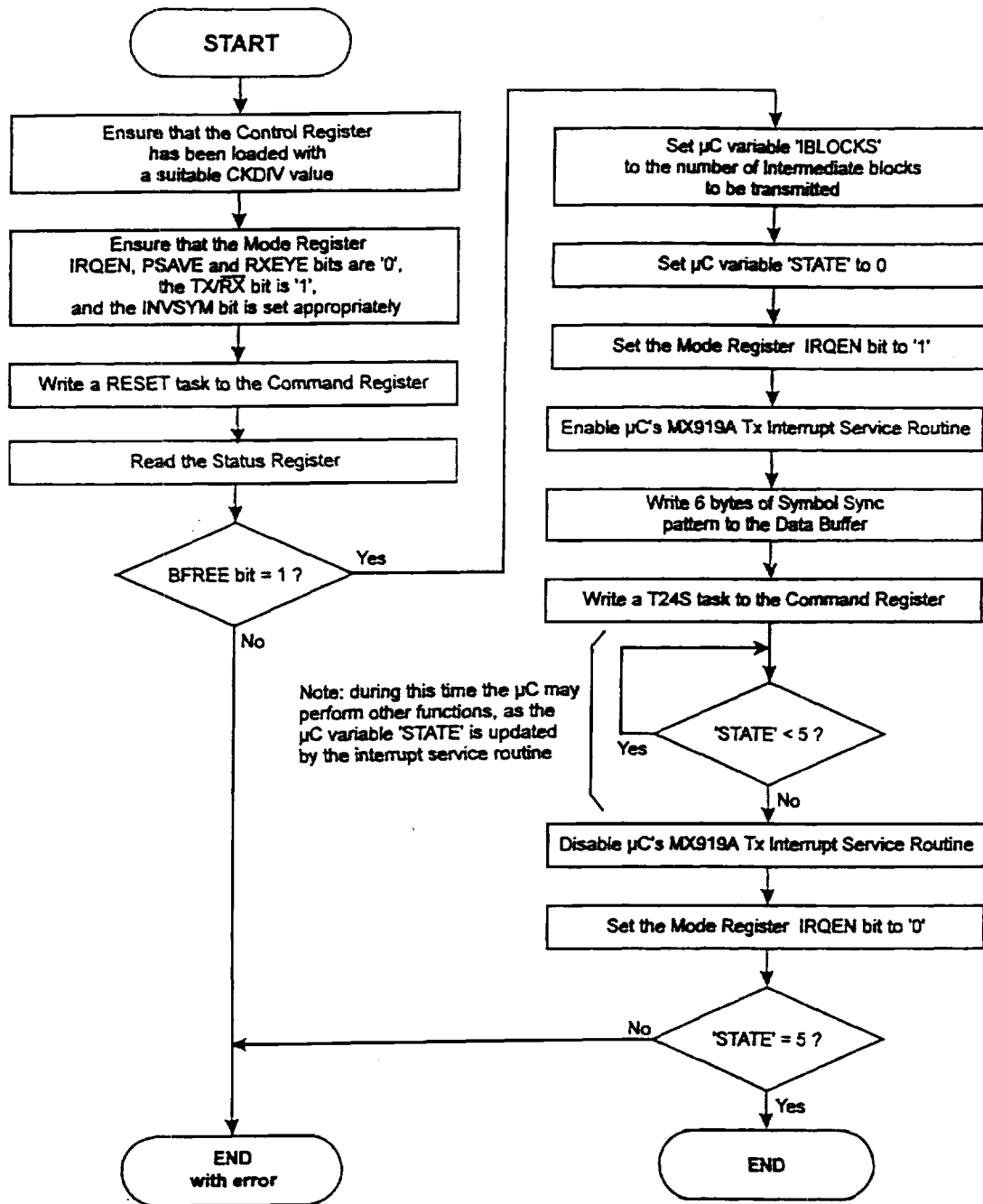
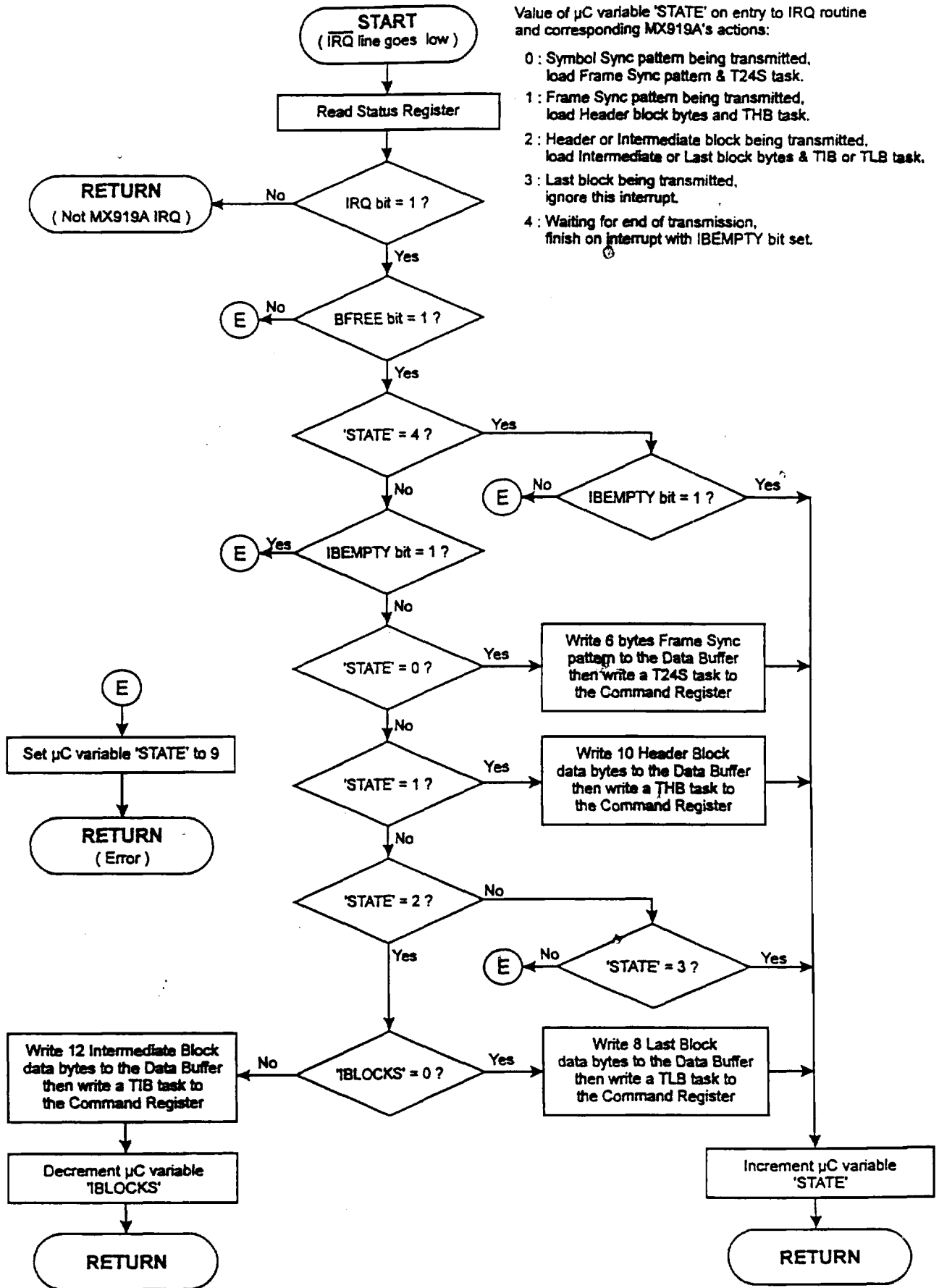


Figure 16: Transmit Frame Example Flowchart, Main Program

Note: The RESET command in Figure 16 and the practice of disabling the MX919A's  $\overline{IRQ}$  output when not needed are not essential but can eliminate problems during debugging and if errors occur in operation. The CRC bit should be set appropriately when a byte is written to the Command Register.



Value of μC variable 'STATE' on entry to IRQ routine and corresponding MX919A's actions:

- 0 : Symbol Sync pattern being transmitted, load Frame Sync pattern & T24S task.
- 1 : Frame Sync pattern being transmitted, load Header block bytes and THB task.
- 2 : Header or Intermediate block being transmitted, load Intermediate or Last block bytes & TIB or TLB task.
- 3 : Last block being transmitted, ignore this interrupt.
- 4 : Waiting for end of transmission, finish on interrupt with IBEMPTY bit set.

Figure 17: Tx Interrupt Service Routine

## 5.2 Receive Frame Example

The operations needed to receive a single Frame consisting of Symbol and Frame Sync sequences and one each Header, Intermediate and Last blocks are shown below;

1. Ensure that the Control Register has been loaded with suitable CKDIV, FSTOL, LEVRES and PLLBW values, and that the IRQEN bit of the Mode Register is '1', the TX/RX PSAVE, and RXEYE bits are '0', and the INVSYM bit is set appropriately.
2. Wait until the received carrier has been present for at least 8 symbol times (see Section 5.3).
3. Read the Status Register to ensure that the BFREE bit is '1'.
4. Write a byte containing a SFSH task and with the AQSC and AQLEV bits set to '1' to the Command Register.
5. Wait for an interrupt from the modem, read the Status Register; the IRQ and BFREE bits should be '1' and the CRCERR and DIBOVF bits should be '0'.
6. Check that the CRCERR bit of the Status Register is '0' and read 10 Header Block bytes from the Data Block Buffer.
7. Write a RILB task to the Command Register.
8. Wait for an interrupt from the modem, read the Status Register; the IRQ and BFREE bits should be '1' and the DIBOVF bit '0'.
9. Read 12 Intermediate Block bytes from the Data Block Buffer.
10. Write a RILB task to the Command Register.
11. Wait for an interrupt from the modem, read the Status Register; the IRQ and BFREE bits should be '1' and the DIBOVF bit '0'.
12. Check that the CRCERR bit of the Status Register is '0' and read the 8 Last Block bytes from Data Buffer.

Figure 18 and Figure 19 illustrate the host  $\mu$ C routines needed to receive a single Frame consisting of Symbol and Frame Sync patterns, a Header Block, any number of Intermediate blocks and one Last block. It is assumed that the Rx Interrupt Service Routine Figure 19 is called when the MX919A's  $\overline{\text{IRQ}}$  output goes low.

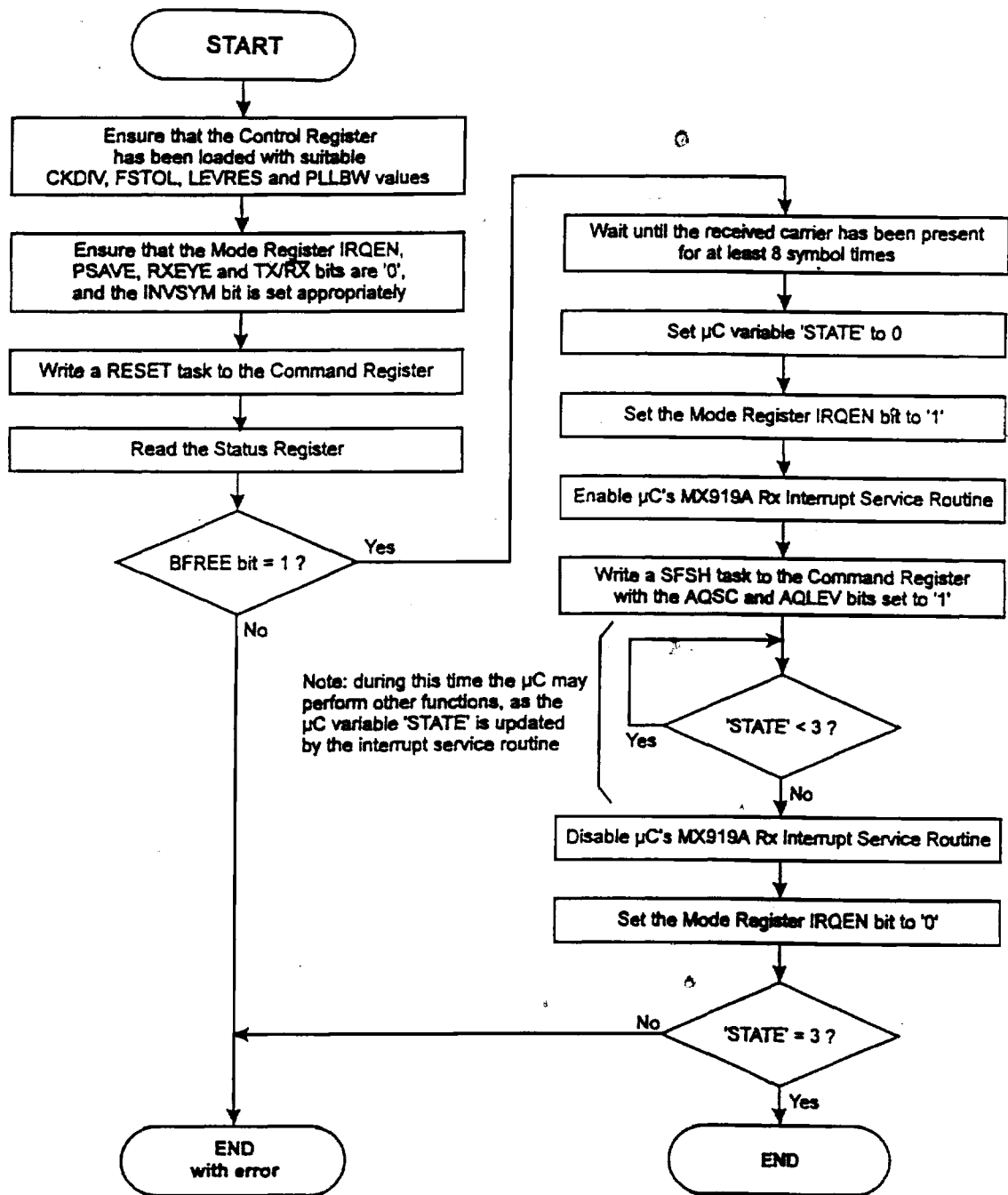


Figure 18: Receive Frame Example Flowchart, Main Program

Note: The RESET command in Figure 18 and the practice of disabling the MX919A's  $\overline{IRQ}$  output when not needed are not essential but can eliminate problems during debugging and if errors occur in operation. The CRC bit should be set appropriately when a byte is written to the Command Register.

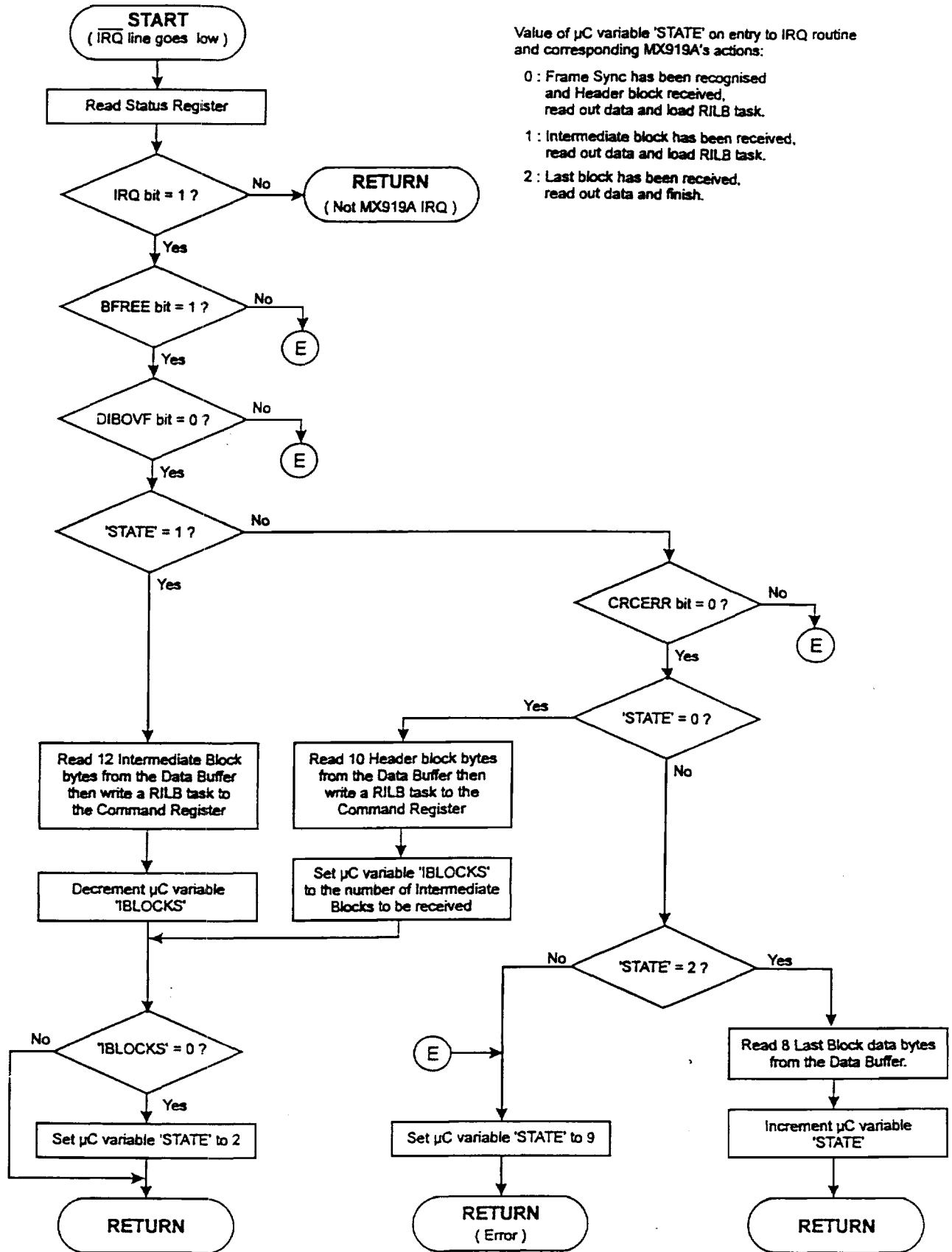


Figure 19: Rx Interrupt Service routine

Note: This routine assumes that the number of Intermediate blocks in the Frame is contained within the Header Block Data

### 5.3 Clock Extraction and Level Measurement Systems

The MX919A is intended for use in systems where the Symbol Sync pattern is transmitted immediately on start-up of the transmitter.

When the carrier is detected by the receiver or when the receiver is switched to another channel, the controlling  $\mu$ C should wait approximately 8 symbol times for the received signal to propagate through the modem's RRC filter then issue a SFS or SFSH task with the AQSC and AQLEV bits set to '1'. The 8-symbol delay can usefully be included in the carrier detect circuitry.

Setting the AQSC and AQLEV bits to '1' triggers the modem's automatic Symbol Clock Extraction and Level Measurement acquisition sequences, which are designed to measure the received symbol timing, amplitude and dc offset as quickly as possible during the Symbol Sync period before switching to more accurate - but slower - measurement modes for the remainder of the received message.

Note: If the acquisition sequences are triggered after the Symbol Sync period - as can happen when the receiver is switched to another channel - they will still function correctly, but will take much longer to acquire accurate level and timing information.

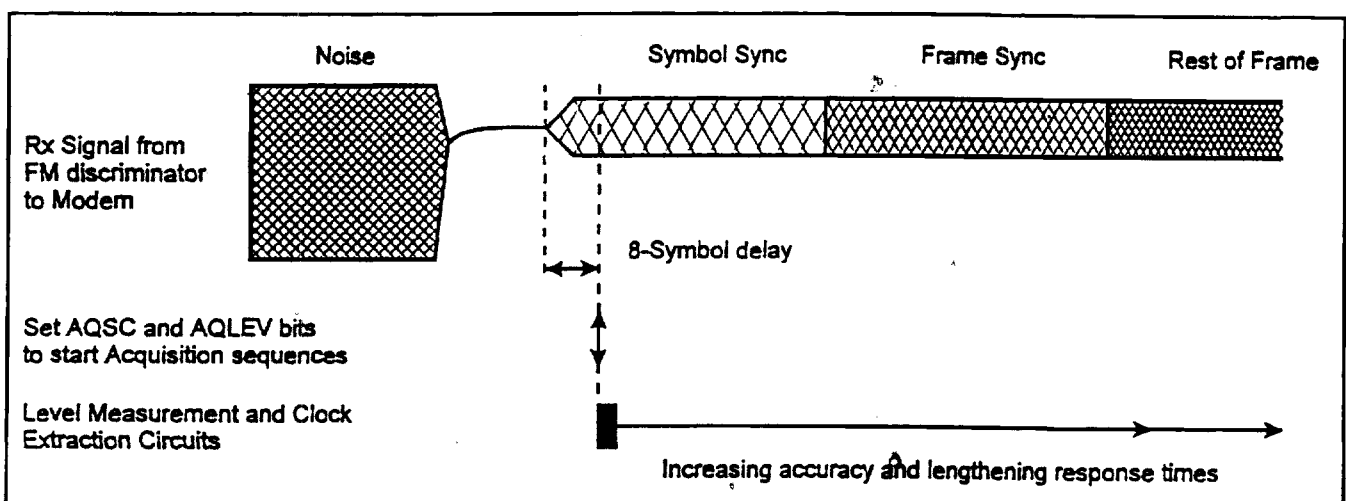


Figure 20: Acquisition Sequence Timing

The operation of the Level Acquisition Sequence depends on the settings of the Control Register LEVRES bits:

LEVRES setting:	B3	B2	Details of Level Acquisition Sequence
'Hold'	0	0	1 symbol time of 'Clamp' mode then 15 symbol times of 'Lossy Peak Detect' mode before reverting to 'Hold' mode.
'Slow Peak Detect'	0	1	1 symbol time of 'Clamp' mode then 15 symbol times of 'Lossy Peak Detect' mode before reverting to 'Slow Peak Detect' mode.
'Lossy Peak Detect'	1	0	1 symbol time of 'Clamp' mode before reverting to 'Lossy Peak Detect' mode
'Clamp'	1	1	Remain in 'Clamp' mode.

The 1-symbol 'Clamp' time at the start of these sequences is used to make an initial measurement of the dc offset present on the received signal, after which the 'Lossy Peak Detect' period is used to estimate the signal amplitude.

The operation of the Symbol Clock Acquisition Sequence depends on the settings of the Control Register PLLBW bits:

PLLBW setting:	B1	B0	Details of Symbol Clock Acquisition Sequence
'Hold'	0	0	16 symbol times of 'Extra-wide BW' mode followed by 30 symbol times of 'Wide BW' mode before reverting to 'Hold' mode.
'Narrow' BW	0	1	16 symbol times of 'Extra-wide BW' mode followed by 30 symbol times of 'Wide BW' mode before reverting to 'Narrow BW' mode.
'Medium BW'	1	0	16 symbol times of 'Extra-wide BW' mode followed by 30 symbol times of 'Wide BW' mode before reverting to 'Medium BW' mode.
'Wide BW'	1	1	16 symbol times of 'Extra-wide BW' mode before reverting to 'Wide BW' mode.

Note: The 'Extra-wide BW' PLL mode is designed to synchronize rapidly to the '+3 +3 -3 -3 ...' Symbol Sync pattern and is available only as part of an automatic acquisition sequence.

Although it is not recommended, it is possible to use the modem in a non-standard system where there is an indeterminate delay between the transmitter start-up and the Symbol Sync pattern, or where a receive carrier detect signal is not available to the controlling  $\mu$ C. In these cases the Symbol Sync pattern should be extended to about 100 symbols, and the Control Register LEVRES bits should be set to 'Lossy Peak Detect' and the PLLBW bits to 'Wide BW' before initiating a 'SFS + AQSC + AQLEV' task. Once the Frame Sync pattern has been detected, the Control Register settings may be changed to 'Slow Peak Detect' and 'Medium' or 'Narrow' PLL bandwidth for the remainder of the received message.

## 5.4 AC Coupling

For a practical circuit, ac coupling from the modem's transmit output to the frequency modulator and between the receiver's frequency discriminator and the receive input of the modem may be desired. There are, however, two problems:

1. AC Coupling of the signal degrades the Bit Error Rate performance of the modem. The following graph illustrates the typical bit error rates at 4800 symbols/sec (without FEC) for differing degrees of ac coupling:

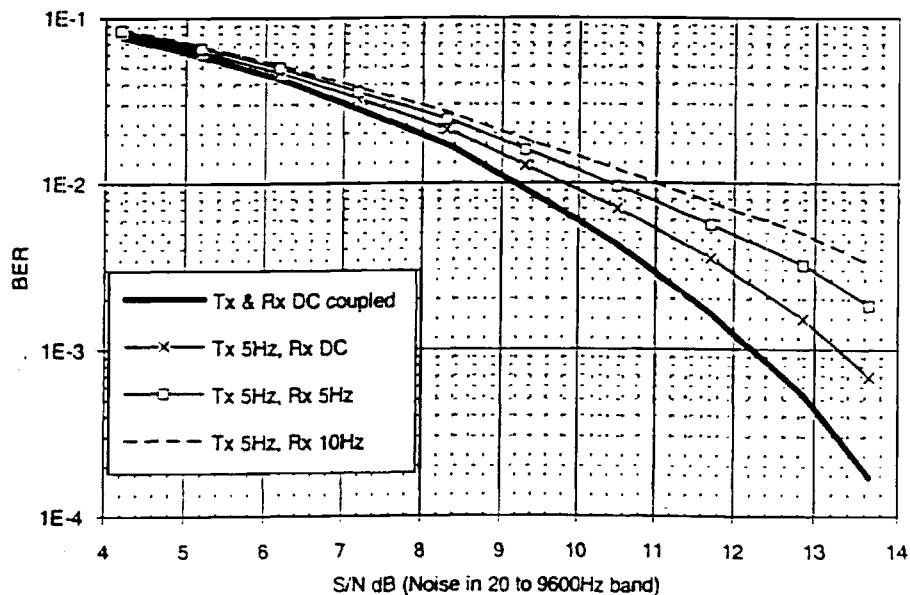


Figure 21: Effect of AC Coupling on BER

2. Any AC Coupling at the receive input will transform any step in the voltage at the discriminator output to a slowly decaying pulse which can confuse the modem's level measuring circuits. As illustrated in Figure 22 below, the time for this step to decay to 37% of its original value is 'RC' where:

$$RC = 1 / (2 \times \pi \times \text{the 3dB cut-off frequency of the RC network})$$

which is 32 msec, or 153 symbol times at 4800 symbols/sec, for a 5Hz network.

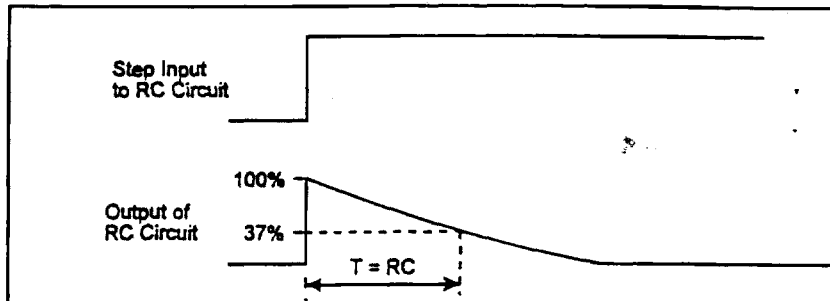


Figure 22: Decay Time - AC Coupling

In general, it is best to DC Couple the receiver discriminator to the modem, and to ensure that any AC Coupling to the transmitter's frequency modulator has a -3dB cut-off frequency of no higher than 5Hz (for 4800 symbols/sec).

## 5.5 Radio Performance

The maximum data rate that can be transmitted over a radio channel using these modems depends on:

- RF channel spacing.
- Allowable adjacent channel interference.
- Symbol rate.
- Peak carrier deviation (modulation index).
- Tx and Rx reference oscillator accuracies.
- Modulator and demodulator linearity.
- Receiver IF filter frequency and phase characteristics.
- Use of error correction techniques.
- Acceptable error rate.

As a guide, 4800 symbols/sec can be achieved (subject to local regulatory requirements) over a system with 12.5kHz channel spacing if the transmitter frequency deviation is set to  $\pm 2.5$ kHz peak for a repetitive '+3 +3 -3 -3 ...' pattern and the maximum difference between transmitter and receiver 'carrier' frequencies is less than 2400Hz.

The modulation scheme employed by these modems is designed to achieve high data throughput by exploiting as much as possible of the RF channel bandwidth. However, this does place constraints on the performance of the radio. Particular attention must be paid to:

- Linearity, frequency and phase response of the Tx Frequency Modulator. For a 4800 symbols/sec system, the frequency response should be within  $\pm 2$ dB over the range 3Hz to 5kHz, relative to 2400Hz.
- The bandwidth and phase response of the receiver's IF filters.
- Accuracy of the Tx and Rx reference oscillators, as any difference will shift the received signal towards the skirts of the IF filter response and cause a dc offset at the discriminator output.

Viewing the received signal eye - using the Mode Register RXEYE function - gives a good indication of the overall transmitter/receiver performance.

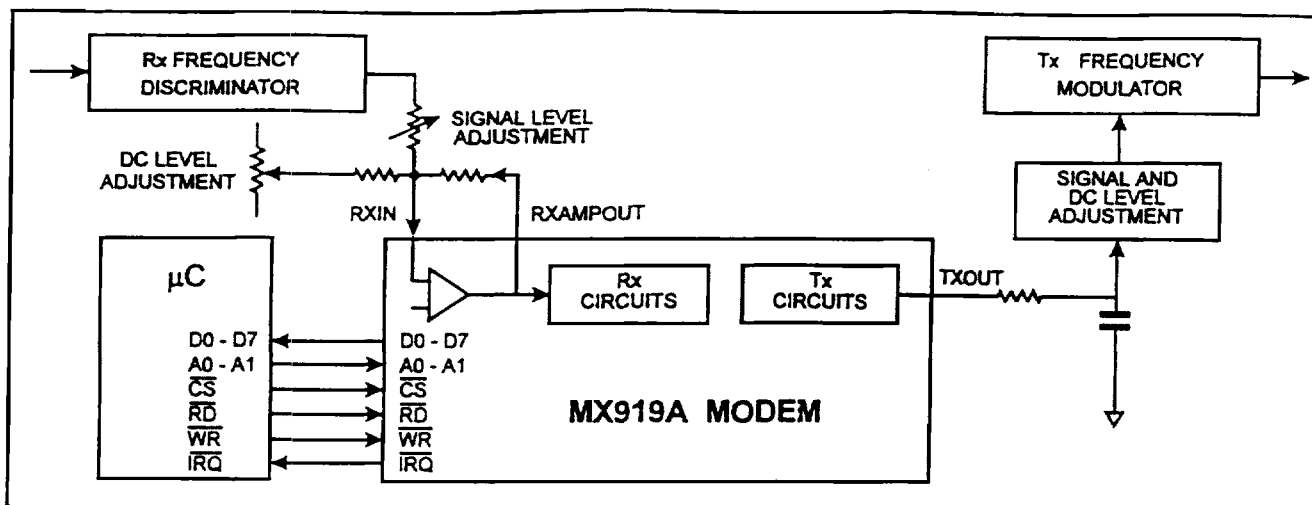


Figure 23: Typical Connections between Radio and MX919A

## 6. Performance Specification

### 6.1 Electrical Performance

#### Absolute Maximum Ratings

Exceeding these maximum ratings can result in damage to the device.

General	Min.	Max.	Units
Supply ( $V_{DD} - V_{SS}$ )	-0.3	7.0	V
Voltage on any pin to $V_{SS}$	-0.3	$V_{DD} + 0.3$	V
Current			
$V_{DD}$	-30	30	mA
$V_{SS}$	-30	30	mA
Any other pin	-20	20	mA
DW, LH, P Package	Min.	Max.	Units
Total Allowable Power Dissipation at $T_{AMB} = 25^{\circ}\text{C}$		800	mW
Derating above $25^{\circ}\text{C}$		13	mW/ $^{\circ}\text{C}$ above $^{\circ}\text{C}$
Storage Temperature	-55	125	$^{\circ}\text{C}$
Operating Temperature	-40	85	$^{\circ}\text{C}$
D5 Package	Min.	Max.	Units
Total Allowable Power Dissipation at $T_{AMB} = 25^{\circ}\text{C}$		550	mW
Derating above $25^{\circ}\text{C}$		9	mW/ $^{\circ}\text{C}$ above $^{\circ}\text{C}$
Storage Temperature	-55	125	$^{\circ}\text{C}$
Operating Temperature	-40	85	$^{\circ}\text{C}$

### Operating Limits

Correct operation of the device outside these limits is not implied.

	Notes	Min.	Max.	Units
Supply ( $V_{DD} - V_{SS}$ )		3.0	5.5	V
Symbol Rate		2400	9600	Symbols/sec
Xtal Frequency		1.0	10.0	MHz

### Operating Characteristics

For the following conditions unless otherwise specified:

Xtal Frequency = 4.9152MHz, Symbol Rate = 4800 symbols/sec,

Noise Bandwidth = 0 to 9600Hz,  $V_{DD}$  = 3.3V to 5.0V,  $T_{AMB}$  = -40°C to 85°C.

	Notes	Min.	Typ.	Max.	Units
<b>DC Parameters</b>					
$I_{DD}$ ( $V_{DD} = 5.0V$ )	1		4.0	10.0	mA
$I_{DD}$ ( $V_{DD} = 3.3V$ )	1		2.5	6.3	mA
$I_{DD}$ (Powersave Mode, $V_{DD} = 5.0V$ )	1		1.5		mA
$I_{DD}$ (Powersave Mode, $V_{DD} = 3.3V$ )	1		0.6		mA
<b>AC Parameters</b>					
Tx Output					
TXOUT Impedance	2		1.0	2.5	k $\Omega$
Signal Level	3	0.8	1.0	1.2	V <sub>p,p</sub>
Output DC Offset wrt $V_{DD}/2$	4	-0.25		0.25	V
Rx Input					
RXIN Impedance (at 100Hz)			10.0		M $\Omega$
RXIN Amp Voltage Gain (input = 1mV <sub>RMS</sub> at 100Hz)			300		V/V
Input Signal Level	5	0.7	1.0	1.3	V <sub>p,p</sub>
DC Offset wrt $V_{DD}/2$	5	-0.5		0.5	V
Xtal/Clock Input					
'High' Pulse Width	6	40			ns
'Low' Pulse Width	6	40			ns
Input Impedance (at 100Hz)		10.0			M $\Omega$
Gain (input = 1 mV <sub>RMS</sub> at 100Hz)		20			dB
$\mu$ C Interface					
Input Logic '1' Level	7, 8	70%			$V_{DD}$
Input Logic '0' Level	7, 8			30%	$V_{DD}$
Input Leakage Current ( $V_{IN} = 0$ to $V_{DD}$ )	7, 8	-5.0		5.0	$\mu$ A
Input Capacitance	7, 8		10.0		pF
Output Logic '1' Level ( $I_{OH} = 120\mu$ A)	8	92%			$V_{DD}$
Output Logic '0' Level ( $I_{OL} = 360\mu$ A)	8, 9			8%	$V_{DD}$
'Off' State Leakage Current ( $V_{OUT} = V_{DD}$ )	9			10	$\mu$ A

**Operating Characteristics Notes:**

- At 25°C. Not including any current drawn from the modem pins by external circuitry other than the Xtal oscillator.
- Small signal impedance, at  $V_{DD} = 5.0V$  and  $T_{AMB} = 25^{\circ}C$ .
- Measured after the external RC filter (R4/C5) for a "+3 +3 -3 -3..." symbol sequence, at  $V_{DD} = 5.0V$  and  $T_{AMB} = 25^{\circ}C$  (output level is proportional to  $V_{DD}$ ).
- Measured at the TXOUT pin with the modem in the Tx idle mode.
- For optimum performance, measured at RXAMPOUT pin, for a "...+3 +3 -3 -3..." symbol sequence, at  $V_{DD} = 5.0V$  and  $T_{AMB} = 25^{\circ}C$ . Optimum level is proportional to  $V_{DD}$ .
- Timing for an external input to the CLOCK/XTAL pin.
- $\overline{WR}$ ,  $\overline{RD}$ ,  $\overline{CS}$ , A0 and A1 pins.
- D0 - D7 pins.
- $\overline{IRQ}$  pin.

**Timing**

$\mu C$ Parallel Interface Timings (ref. Figure 24)		Notes	Min.	Typ.	Max.	Units
$t_{ACSL}$	Address valid to $\overline{CS}$ low time		0			ns
$t_{AH}$	Address hold time		0			ns
$t_{CSH}$	$\overline{CS}$ hold time		0			ns
$t_{CSHI}$	$\overline{CS}$ high time	1	6			clock cycles
$t_{CSRWL}$	$\overline{CS}$ to $\overline{WR}$ or $\overline{RD}$ low time		0			ns
$t_{DHR}$	Read data hold time		0			ns
$t_{DHW}$	Write data hold time		0			ns
$t_{DSW}$	Write data setup time		90			ns
$t_{RHCSL}$	$\overline{RD}$ high to $\overline{CS}$ low time (write)		0			ns
$t_{RACL}$	Read access time from $\overline{CS}$ low	2			175	ns
$t_{RARL}$	Read access time from $\overline{RD}$ low	2			145	ns
$t_{RL}$	$\overline{RD}$ low time		200			ns
$t_{RX}$	$\overline{RD}$ high to D0-D7 3-state time				50	ns
$t_{WHCSL}$	$\overline{WR}$ high to $\overline{CS}$ low time (read)		0			ns
$t_{WL}$	$\overline{CS}$ low time		200			ns

**Timing Notes:**

- Xtal/Clock cycles at the XTAL/CLOCK pin.
- With 30pF max to  $V_{SS}$  on D0 - D7 pins.

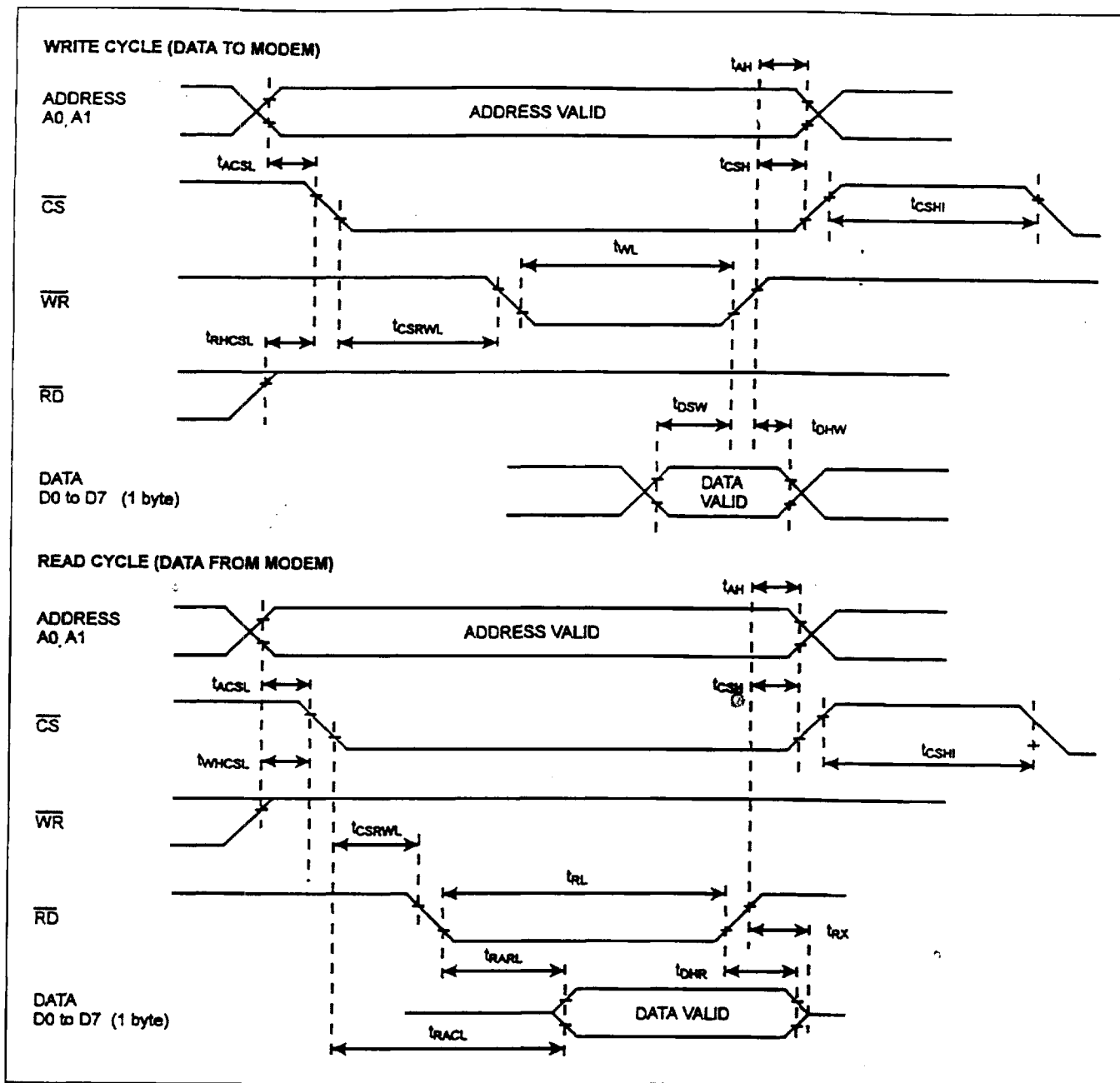


Figure 24:  $\mu$ C Parallel Interface Timings

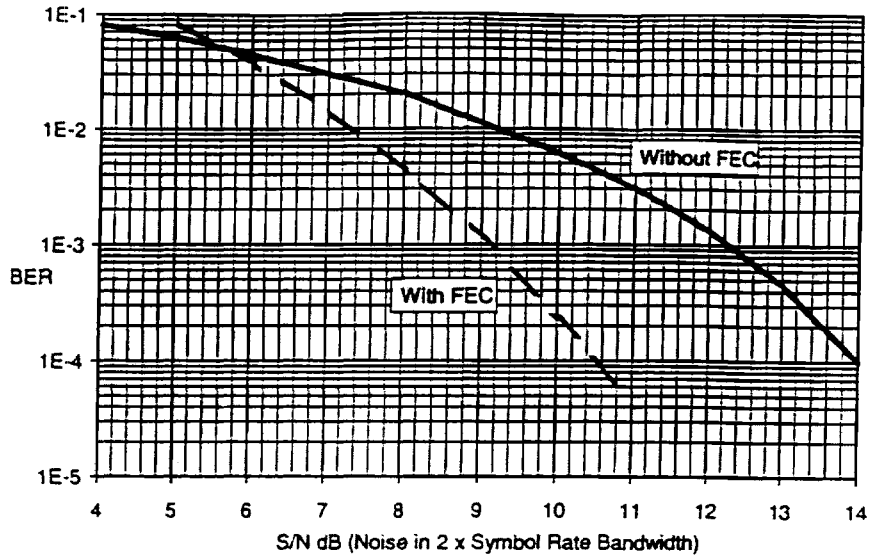


Figure 25: Typical Bit Error Rate With and Without FEC

6.2 Packaging

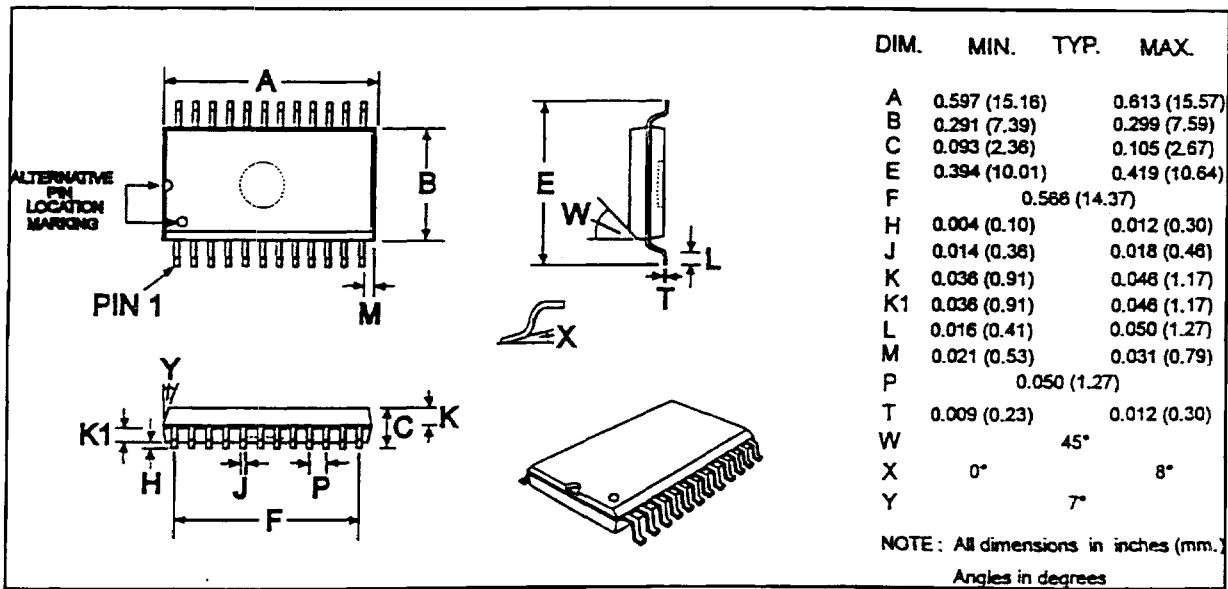


Figure 26: 24-pin SOIC Mechanical Outline: order as part no. MX919ADW

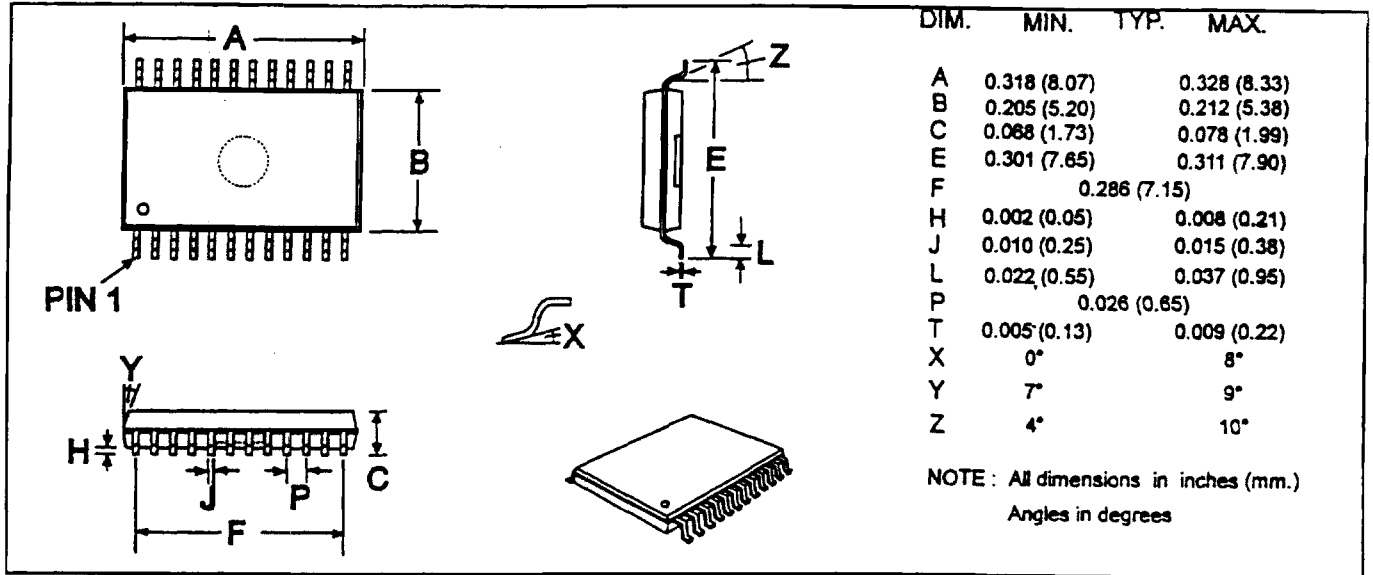


Figure 27: 24-pin SSOP Mechanical Outline: Order as part no. MX919ADS

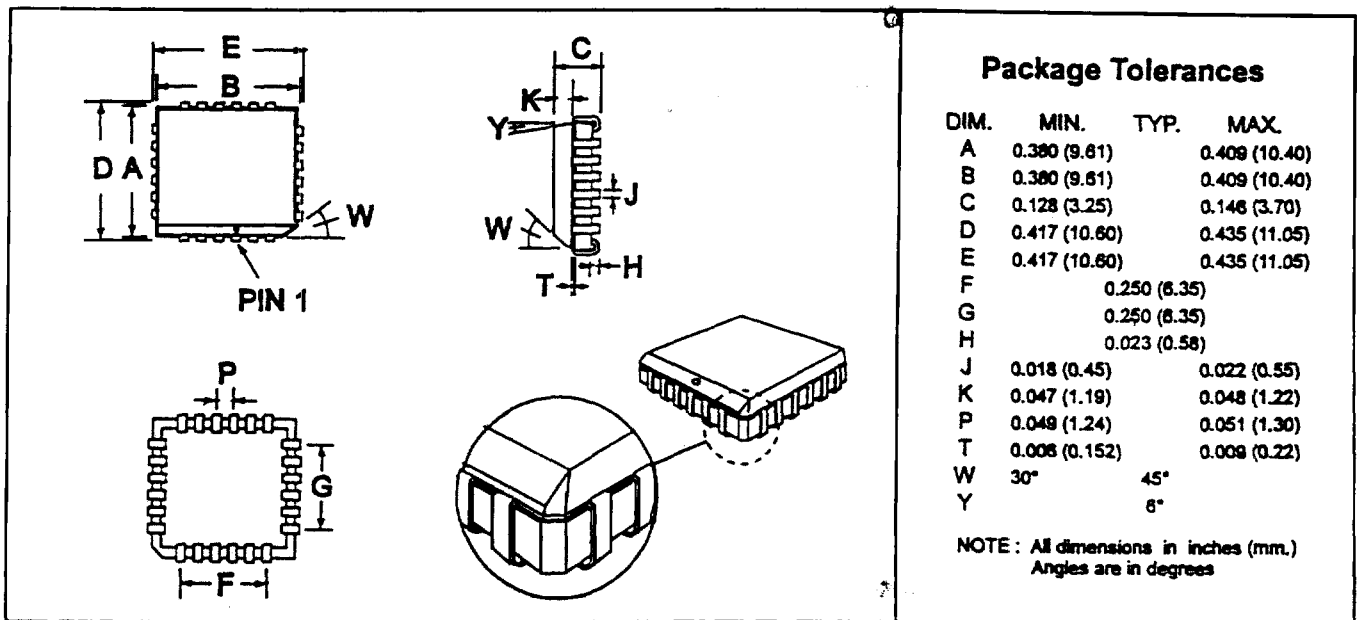


Figure 28: 24-pin PLCC Mechanical Outline : Order as part no. MX919ALH

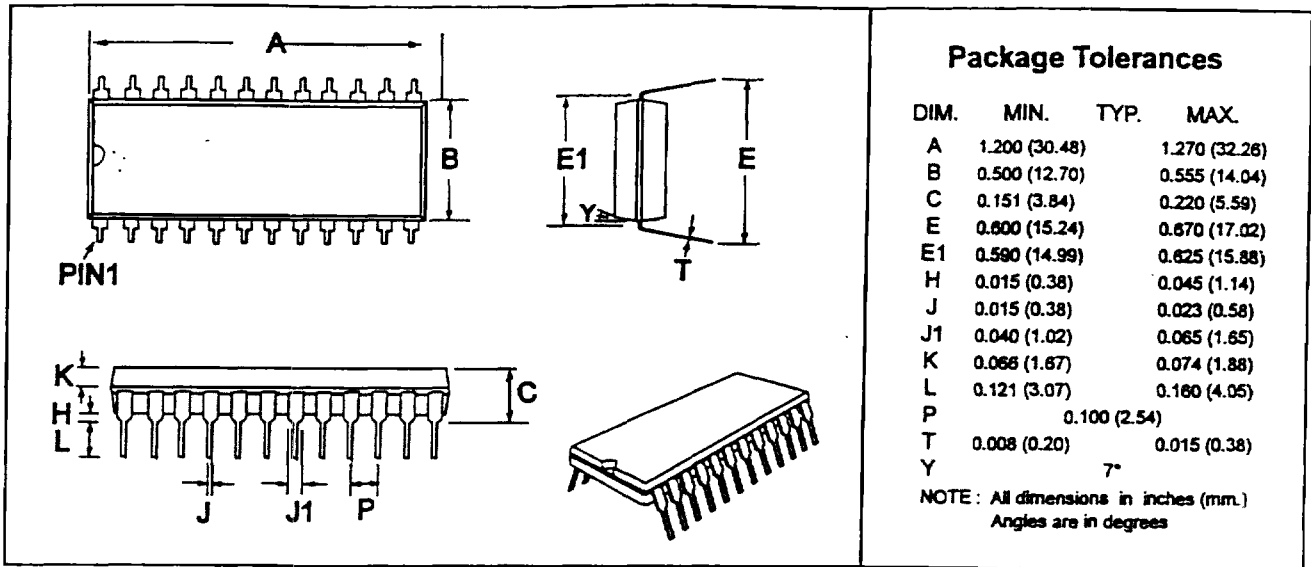


Figure 29: 24-pin PDIP Mechanical Outline: Order as part no. MX919AP

## 7. Errata

Coincident transitions of the  $\overline{WR}$  signal and an internal clock can cause a newly written task to be ignored. In typical applications 1 out of 100,000 tasks may be ignored. Many users may never notice such an infrequent event, but to ensure that each task is loaded correctly, the software must check to see if the BFREE bit is low '0' immediately after every task set. Below is a recommended method for writing tasks.

- Procedure for writing RESET tasks:
  - Write the RESET task twice
- Procedure for writing NULL tasks with either of the Acquire bits set:
  - Write the NULL task twice
- Procedure for writing other tasks:
  - The  $\mu$ C should wait until the BFREE (Buffer Free) bit of the Status Register is '1' before writing the desired task to the Command Register.
  - Immediately after the task is written, the controlling device should check the value of the BFREE bit in the Status Register:
    - If BFREE = '0' then the task has been accepted.
    - If BFREE = '0' then the task needs to be rewritten to the Command Register

### Note:

1. In Tx, the Data Buffer contents do not have to be rewritten if the task is not accepted.
2. In Rx, if either of the Acquire bits need to be set, then they will also have to be set in the repeated task.
3. Future revisions of this part will ensure that all newly written tasks will be accepted without requiring any task writes to be repeated.