MX·COM, INC.

Preliminary Information
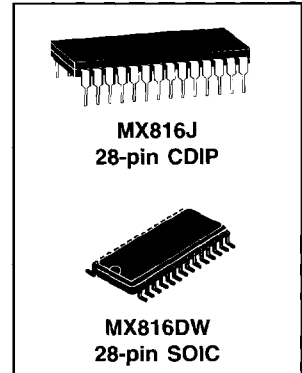
MX816

C-BUS COMPATIBLE

NMT AUDIO PROCESSOR

Features

- **Full-Duplex Audio Processing for NMT Cellular System**
- **On-Chip Speech and SAT Abilities**
  TX/RX/SAT Filtering & Gain -- VOGAD -- Pre-/De-Emphasis -- Deviation Limiter
- **Serial Microprocessor Interface**
- **Separate SAT Channel**
- **Sidetone Output Available**
- **HandsFree Compatibility**
- **Access to External Processes**
  Compression -- Expansion -- Signaling/Data Mixing -- VSR Codec (Store/Play)
- **Powersave (Low Current) Settings**

**MX816J
28-pin CDIP**

**MX816DW
28-pin SOIC**

Description

The MX816 is a microprocessor controlled full-duplex audio processor on a single chip with separate TX and RX paths to provide all the filter/gain/limiting functions necessary to pre-process audio, data and signaling in the Nordic Mobile Telephone (NMT) cellular communications system.

Selectable inputs to the transmit path include a choice of two microphones, DTMF/signaling or MSK/data with access in this path to external compression circuitry. The TX path provides input/gain filtering, VOGAD, a deviation limiter and TX Modulation Drive controls.

In the RX path the SAT signal is separated from the incoming audio via a gain/filter block and made available at a separate pin for mixing externally with the TX Modulation Drive.
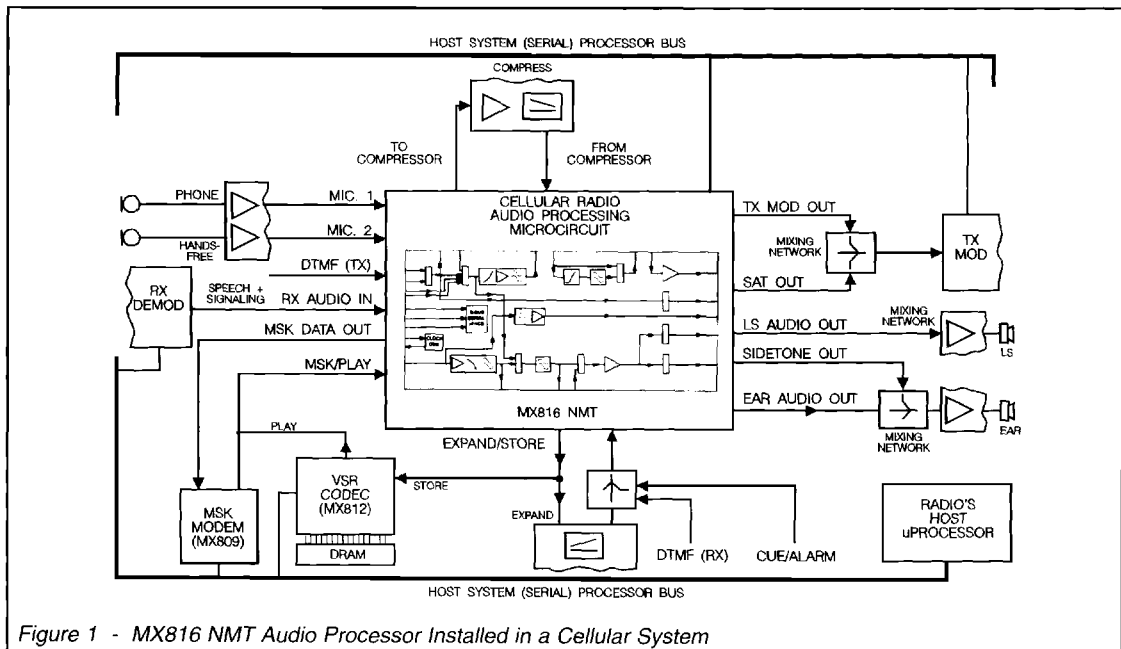
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Figure 1 - MX816 NMT Audio Processor Installed in a Cellular System

MX816

Description...

The RX path consists of an input gain/filter block for voice and data, inputs from an external audio expansion system and an output gain (volume) control driving either a loudspeaker (handsfree) system or earpiece.

Unique to the MX816/826/836 cellular audio processors is the ability to route audio (TX or RX) to an external Voice Storage and Retrieval device such as the MX802 or MX812, thus providing the radio system with a voice answering and announcement capability using external DRAM.

The MX816, a low-power 5V CMOS integrated circuit, reduces the amount of components required in a cellular audio system by providing more functions on a single chip. It is available in 28-pin Cerdip and small outline (SOIC) packages.

Pin Function Chart

Pin	Function
1	**Xtal:** The output of the 4.032 MHz on-chip clock oscillator. External components are required at this output when a Xtal is used. See Figure 2.
2	**Xtal/Clock:** The input to the on-chip clock oscillator. A Xtal or externally derived clock should be connected here. Note that operation of the MX816 without a suitable Xtal or clock input may cause device damage. See Figure 2 (notes).
3	**Serial Clock:** The "C-BUS" serial data clock input. This clock, produced by the microcontroller, is used for transfer timing of commands and data to the MX816. See Timing diagrams.
4	**Command Data:** The "C-BUS" serial data input from the microcontroller. Data is loaded to this device in 8-bit bytes, MSB (B7) first and LSB (B0) last, synchronized to the Serial Clock. See Timing diagrams.
5	**Chip Select (CS):** The "C-BUS" data loading control function. This input is provided by the microcontroller. Data transfer sequences are initiated, completed or aborted by the CS signal. See Timing Diagrams.
6	V_{BIAS}: The internal circuitry bias line, held at $V_{DD}/2$. This pin should be decoupled to V_{SS}. See Figure 2.
7	**RX Audio In:** The audio input to the MX816. Normally taken from the radio's discriminator output, this input has a 1MΩ internal resistor to V_{BIAS}, and must be connected with a capacitor.
8	**Expand/Store:** This is a common output that can be used as either an input to an external audio expander or the input to a voice storage medium such as the MX812. Components relevant to the external device requirements should be used at this output. See Figures 2 and 3.
9	**Expanded Audio In:** This is the audio input, via SW5, from an external expander or audio mixing function. This input has a 1MΩ internal resistor to V_{BIAS}, and must be connected via a capacitor. See Figures 2 and 3.
10	**TX Mod Out:** This is the composite TX audio output to the transmitter modulator from a variable attenuation stage (11_H). This output is set to V_{BIAS} via an internal 1MΩ resistor when set to Powersave or OFF.
11	**LS Audio Out:** This is an audio output of the RX path (or selected audios - see Figures 3 and 4) for a loudspeaker system. This is available for handsfree operation. This output can be connected to V_{BIAS} when not required, by SW6 (Configuration Command 10_H). A driver amplifier may be required.
12	**Ear Audio Out:** This is an audio output of the RX path (or selected audios - see Figures 3 and 4), available as an output for a handset earpiece. This output in parallel with the LS Audio Out function can be connected to V_{BIAS} when not required by SW7 (Configuration Command 10_H). A driver amplifier may be required.
13	**Sidetone:** This is a switched "sidetone" from the microphone inputs made available for mixing externally with the Ear audio. See Figure 3.
14	V_{SS}: Negative supply (GND).

Pin Function Chart

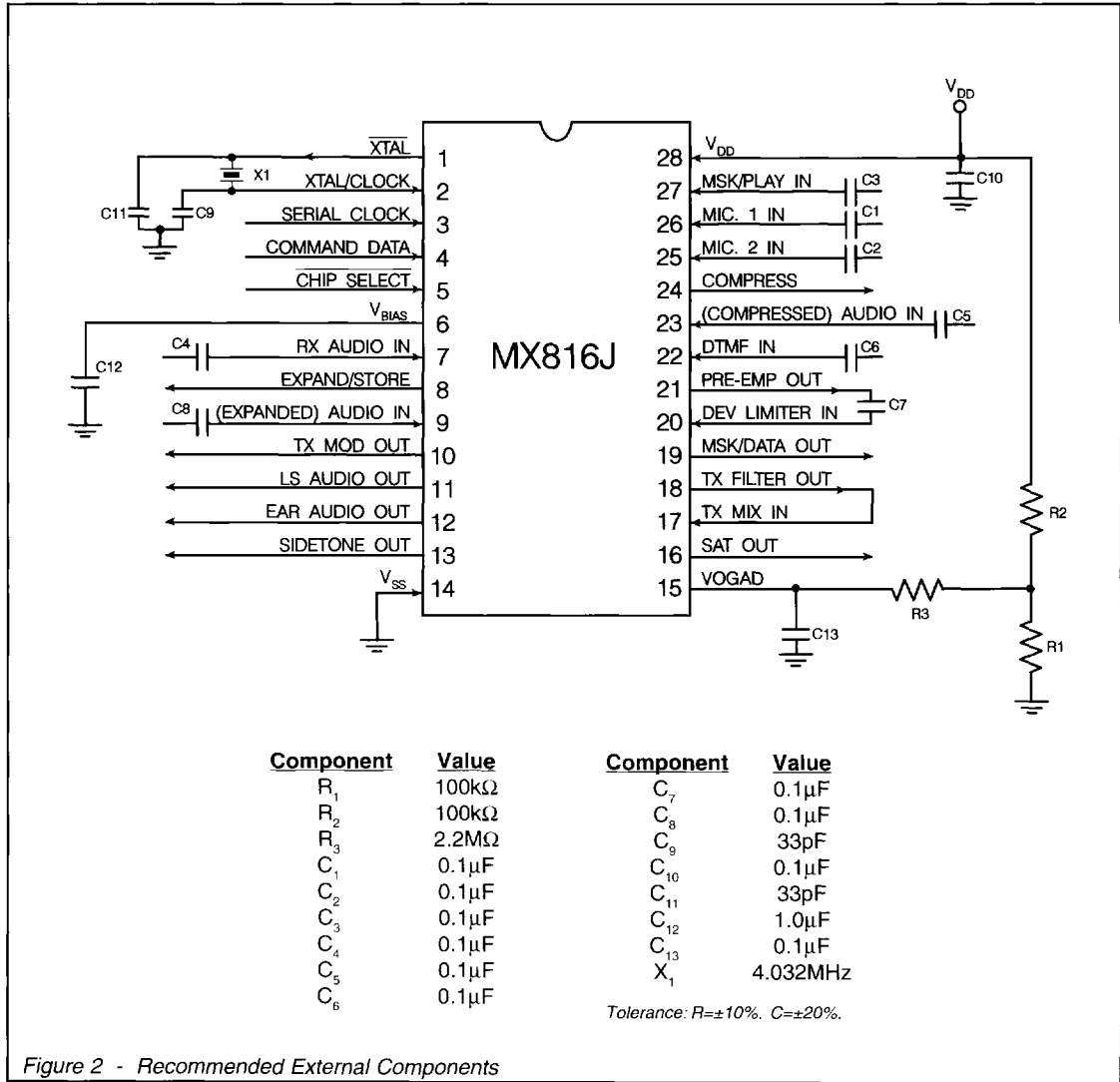| Pin	Function
15	**VOGAD:** External components (R and C) at this pin control the attack and decay time constants of the on-chip VOGAD function.
16	**SAT Out:** This is the output of the SAT bandpass filter. This level is recovered from the Input RX Audio. This tone level can be modified by the SAT and Powersave Command (13_H) and is available for mixing internally with the transmitter modulation. See Figures 3 and 4.
17	**TX Mix In:**
	An input and an output available, with external components, to introduce signaling tones into the TX Path prior to the final level adjustments.
18	**TX Filter Out:**
19	**MSK Out:** This is the de-emphasized RX audio output available for access to the received MSK data. It could be directed to an MSK Modem such as the MX439.
20	**Deviation Limiter In:** This is the input to the on-chip deviation limiter. This input should be a.c. coupled to the Pre-Emphasis Out pin. The a.c. coupling will achieve macimum possible symmetry of limiting as this input has a 1MΩ reisistor to V_{BIAS}. See Figure 2.
21	**Pre-Emphasis Out:** Audio output from the VOGAD circuitry in the TX Input Gain/Pre-Emphasis function. This output should be a.c. coupled to the Deviation Limiter In pin. See Figure 2.
22	**DTMF In:** This input, which introduces DTMF type audio to the TX path at a suitable level for transmission, is controlled by SW2 (Configuration Command 10_H). This input has an internal 1MΩ resistor to V_{BIAS} and should be connected via a capacitor.
23	**Compression In:** This is the audio input from an external compression system. This input has an internal 1MΩ resistor to V_{BIAS} and should be connected via a capacitor.
24	**Compression:** This is the output to an external audio compression system. Currently available compressor/expanders have op-amps incorporated. The compressor can be bypassed by SW2.
25	**Mic 2 In:** These TX voice (Mic.) inputs, selectable by SW1, are available for handsfree mic./handset mic. or and TX audio input. Pre-amplification may be required at these inputs.
26	**Mic 1 In:** These inputs each have an internal 1MΩ resistor to V_{BIAS} and should be connected via a capacitor.
27	**MSK/Play In:** This is the TX MSK data input via SW2. This can also be used to input (replay) from a voice storage device such as the MX812. This "replayed" audio can be sent to RX or TX paths, allowing a Messaging/Voice Notepad/Answering function. Both the MX439 MSK Modem and the MX812 VSR Codec outputs can be wired directly to this pin if the functions are activated one at a time. This input has an internal 1MΩ resistor to V_{BIAS} and should be connected via a capacitor.
28	**V_{DD}:** Positive supply. A single, stable +5 volt supply is required. Levels and voltages within this Audio Processor are dependent upon this supply.
	C-BUS is MX-COM's proprietary standard for the transmission of commands and data between a μController and DBS 800 IC's. It may be used with any μController, and can, if desired, take advantage of hardware serial I/O functions embodied into many types of μController. The C-BUS data rate is determined solely by the μController.
	Notes on Inputs: *To minimize aliasing effects, lowpass filtering may be required at the inputs to this device (especially thise supplied from switched-capacitor-type devices) to ensure the input spectrum is kept below 63 kHz.*

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MX816

Component	Value		Component	Value
R_1	100kΩ		C_7	0.1µF
R_2	100kΩ		C_8	0.1µF
R_3	2.2MΩ		C_9	33pF
C_1	0.1µF		C_{10}	0.1µF
C_2	0.1µF		C_{11}	33pF
C_3	0.1µF		C_{12}	1.0µF
C_4	0.1µF		C_{13}	0.1µF
C_5	0.1µF		X_1	4.032MHz
C_6	0.1µF			

Tolerance: R=±10%. C=±20%.

Figure 2 - Recommended External Components

Notes:

1. Xtal/clock Operation
Operation of any MX-COM IC without a Xtal or clock input may cause device damage. To minimize damage in the event of a Xtal/drive failure, you should install a current limiting device (resistor or fast-reaction fuse) on the power input (V_{DD}).

2. VOGAD Components
R_1, R_2, R_3, C_{13} and the VOGAD Pin internal impedance form the VOGAD timing circuitry.

Control-Voltage Attack Time is set by
  C_{13} x Internal Impedance
Control-Voltage Decay Time is set by
  C_{13} x R_3 (assuming R_3 >> R_1 and R_2).

3. MSK Modem
The MX439, a general purpose MSK Modem, could be used within this NMT system Audio Processor. The MX439 is a non-formatted modem, which with due regard to Xtal/clock frequencies and Microprocessor interface, is compatible with both Mobile/Portable and Base Station applications.

4. SAT Output
Due to the high output impedance of this output, an external buffer amplifier may be required at this output when interfacing or mixing with other system sections.
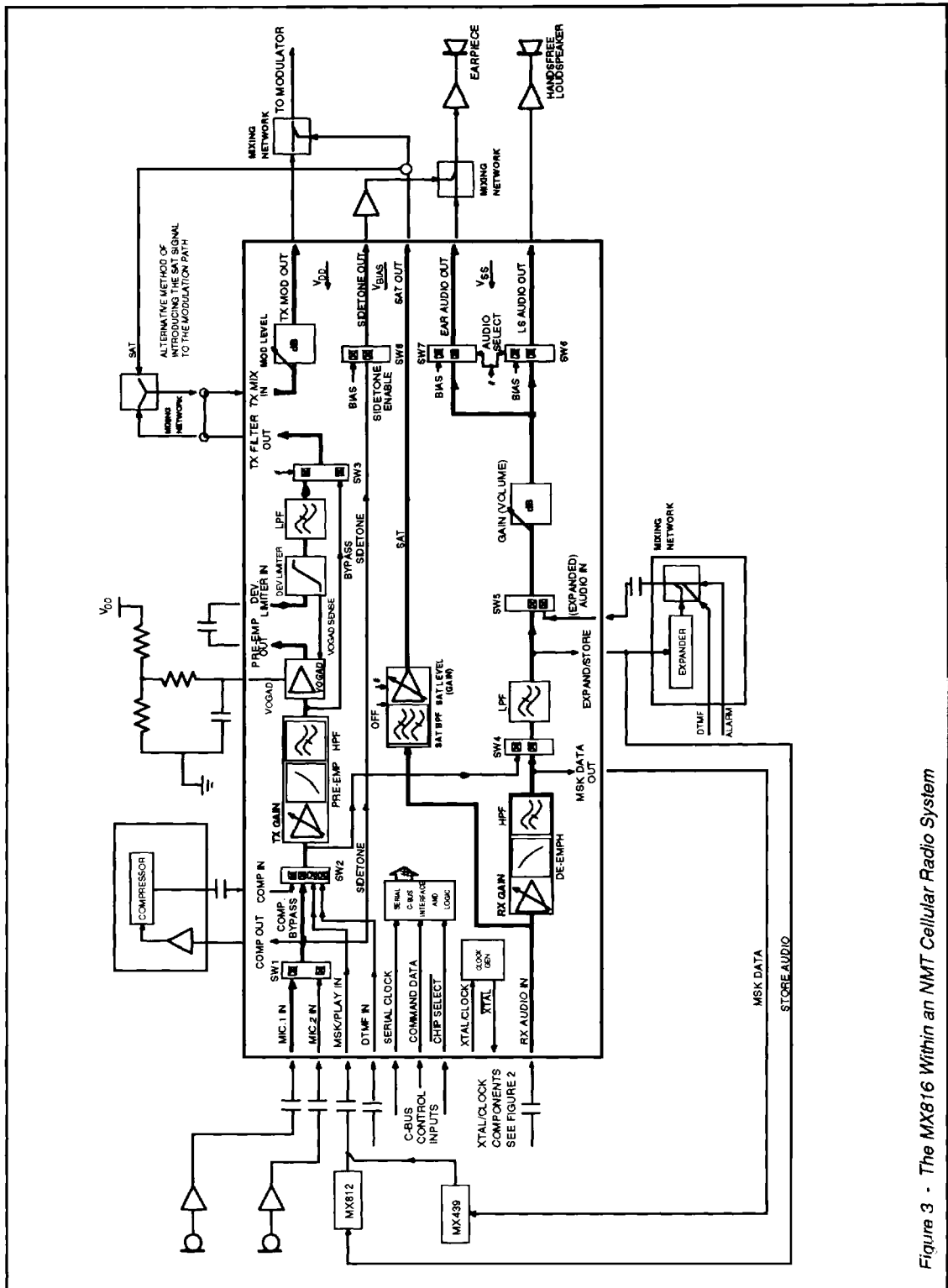
Figure 3 - The MX816 Within an NMT Cellular Radio System

The Controlling System

C-BUS is designed for low IC pin-count, flexibility in handling variable amounts of data, and simplicity of system design and μController software. It may be used with any μController, and can, if desired, take advantage of the hardware and serial I/O functions built into many types of μController. Because of this flexibility and because the BUS data rate is determined solely by the μController, the system designer has complete freedom to choose a μController appropriate to the overall system processing requirements.

Control of the functions and levels within the MX816 NMT Audio Processor is by a group of Address/Commands and appended data instructions from the system microcontroller. The use of these instructions is detailed in the following paragraphs and tables.

Command Assignment	Hex.	Address/Command Binary MSB LSB		Command Data	Table
General Reset	01	0 0 0 0 0 0 0 1			
Configuration Command	10	0 0 0 1 0 0 0 0	+	1 byte	2
TX Gain & Mod. Command	11	0 0 0 1 0 0 0 1	+	1 byte	3
RX Gain & Vol. Command	12	0 0 0 1 0 0 1 0	+	1 byte	4
Volume Set	13	0 0 0 1 0 0 1 1	+	1 byte	5

Table 1 - C-BUS Address/Commands

In C-BUS protocol the MX816 is allocated Address/Command values 10_H to 13_H. Configuration, TX/RX Gains, and SAT/Powersave assignments and data requirements are given in Table 1.

Each instruction consists of an Address/Command (A/C) byte followed by a data instruction formulated from the following tables.

Commands and Data are only to be loaded in the group configurations detailed, as the C-BUS interface recognized the first byte after Chip Select (logic 0) as an Address/Command. Function or Level control data, which is detailed in Tables 2, 3, 4, and 5, is acted upon at the end of the loaded instruction. See Timing Diagrams, Figures 5 and 6.

Upon power-up the value of the "bits" in this device will be random (either "0" or "1"). A General Reset Command (01_H) is required to set all MX816 registers to 00_H.

Configuration Command (Preceded by A/C 10_H)

Setting		Control Bits
(MSB) Bit 7		**Transmitted First SW8 Sidetone**
0		Sidetone Bias
1		Sidetone Enabled
6		**SW6/7 RX Audio**
0		Ear Enabled, LS Bias
1		LS Enabled, Ear Bias
5		**SW5 Expander**
0		Expander Bypass
1		Expander Route
4		**SW4 TX/RX Audio**
0		TX Store/Audio
1		RX Store/Audio
3		**SW3 Dev. Limiter**
0		Dev. Limiter Bypass
1		Dev. Limiter Route
2		**SW1 Mic. Inputs**
0		Mic. 1 Input
1		Mic. 2 Input
1	**0**	**SW2 TX Function**
0	0	DTMF In
0	1	Compressor In
1	0	Compressor Bypass
1	1	MSK/Play In

Table 2 - Configuration Commands

TX Gain & Mod. Command (Preceded by A/C 11_H)

Setting				Gain (dB)
(MSB) 7	**6**	**5**	**4**	**Transmitted First TX Mod. Level**
0	0	0	0	OFF (Low Z to V_{BIAS})
0	0	0	1	-5.6dB
0	0	1	0	-5.2dB
0	0	1	1	-4.8dB
0	1	0	0	-4.4dB
0	1	0	1	-4.0dB
0	1	1	0	-3.6dB
0	1	1	1	-3.2dB
1	0	0	0	-2.8dB
1	0	0	1	-2.4dB
1	0	1	0	-2.0dB
1	0	1	1	-1.6dB
1	1	0	0	-1.2dB
1	1	0	1	-0.8dB
1	1	1	0	-0.4dB
1	1	1	1	0dB
3	**2**	**1**	**0**	**TX Input Gain**
0	0	0	0	-2.65dB
0	0	0	1	-2.05dB
0	0	1	0	-1.50dB
0	0	1	1	-0.95dB
0	1	0	0	-0.45dB
0	1	0	1	0dB
0	1	1	0	0.45dB
0	1	1	1	0.85dB
1	0	0	0	1.25dB
1	0	0	1	1.65dB
1	0	1	0	2.05dB
1	0	1	1	2.40dB
1	1	0	0	2.70dB
1	1	0	1	3.05dB
1	1	1	0	3.35dB
1	1	1	1	3.65dB

Table 3 - TX Gain & Mod. Commands

The Controlling System

Configuration Command	(Preceded by A/C 10₁₄)

Setting				Control Bits
(MSB)				**Transmitted First**
7	**6**	**5**	**4**	**RX LS Volume**
0	0	0	0	OFF (Low Z to V_{BIAS})
0	0	0	1	-28.0dB
0	0	1	0	-26.0dB
0	0	1	1	-24.0dB
0	1	0	0	-22.0dB
0	1	0	1	-20.0dB
0	1	1	0	-18.0dB
0	1	1	1	-16.0dB
1	0	0	0	-14.0dB
1	0	0	1	-12.0dB
1	0	1	0	-10.0dB
1	0	1	1	-8.0dB
1	1	0	0	-6.0dB
1	1	0	1	-4.0dB
1	1	1	0	-2.0dB
1	1	1	1	0dB
3	**2**	**1**	**0**	**RX Input Gain**
0	0	0	0	3.75dB
0	0	0	1	4.30dB
0	0	1	0	4.80dB
0	0	1	1	5.30dB
0	1	0	0	5.80dB
0	1	0	1	6.20dB
0	1	1	0	6.55dB
0	1	1	1	7.05dB
1	0	0	0	7.40dB
1	0	0	1	7.80dB
1	0	1	0	8.15dB
1	0	1	1	8.50dB
1	1	0	0	8.80dB
1	1	0	1	9.10dB
1	1	1	0	9.40dB
1	1	1	1	9.70dB

Table 4 - RX Gain and Volume Commands

TX Gain & Mod. Command	(Preceded by A/C 11₁₄)

Setting				Gain (dB)
(MSB)				**Transmitted First**
Bit 7				
0				Must be a logic "0"
6				
0				Must be a logic "0"
5	**4**	**3**	**2**	**SAT Tone Level**
0	0	0	0	OFF (Low Z to V_{BIAS})
0	0	0	1	-1.95dB
0	0	1	0	-1.40dB
0	0	1	1	-0.90dB
0	1	0	0	-0.45dB
0	1	0	1	0dB
0	1	1	0	0.40dB
0	1	1	1	0.85dB
1	0	0	0	1.20dB
1	0	0	1	1.60dB
1	0	1	0	1.95dB
1	0	1	1	2.30dB
1	1	0	0	2.60dB
1	1	0	1	2.90dB
1	1	1	0	3.25dB
1	1	1	1	3.50dB
1				**Powersave RX Gain Element**
0				Powersave Element
1				Enable Element
0				**Powersave MX816** (except RX Gain Element)
0				Powersave MX816
1				Enable MX816

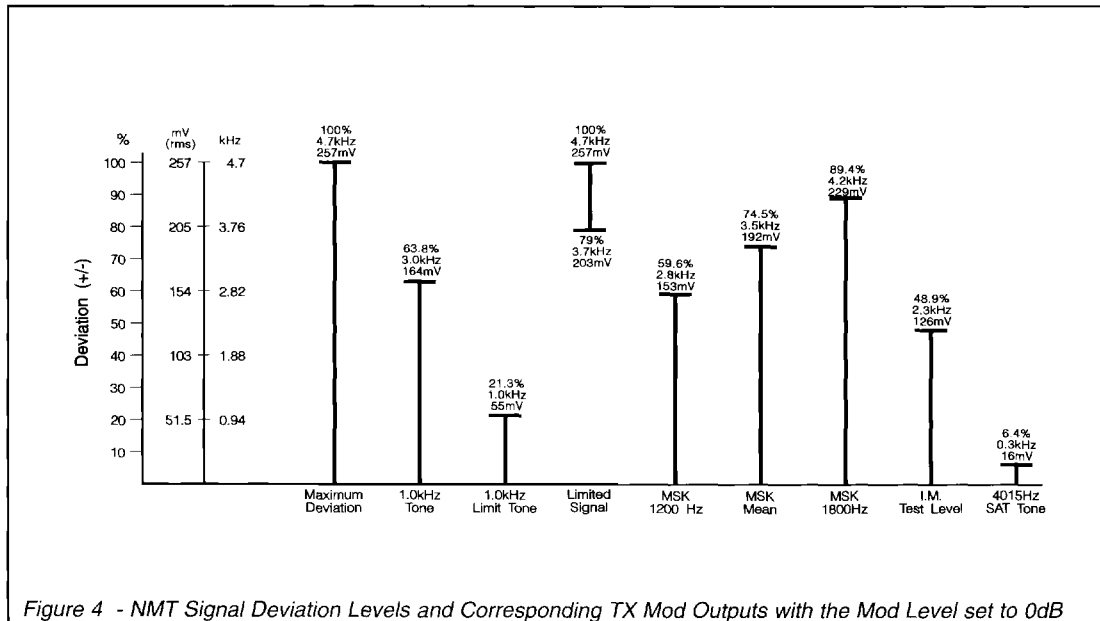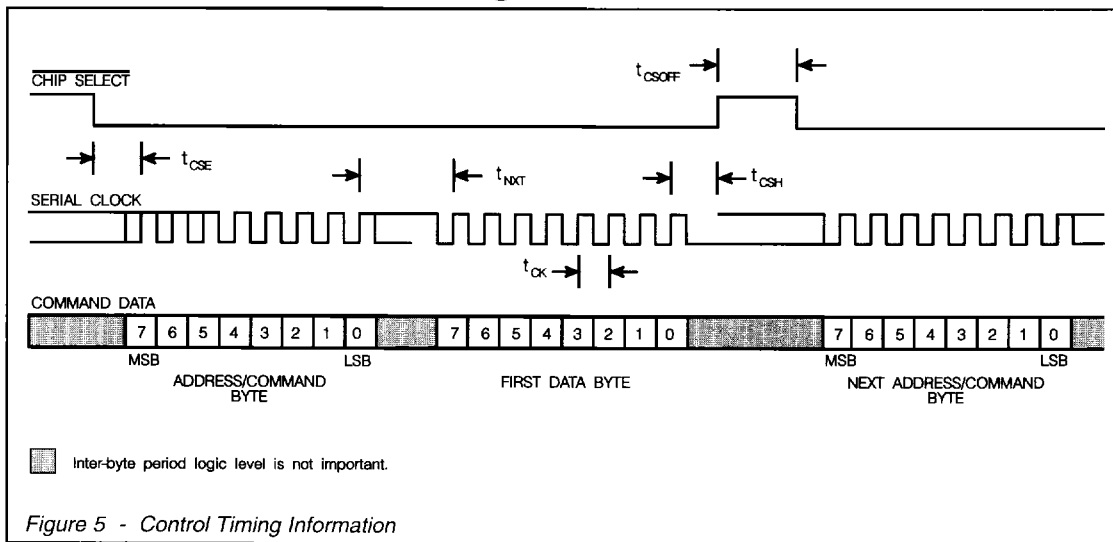*Table 5 - SAT and Powersave Commands*

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Reference Signal Levels

Figure 4 - NMT Signal Deviation Levels and Corresponding TX Mod Outputs with the Mod Level set to 0dB
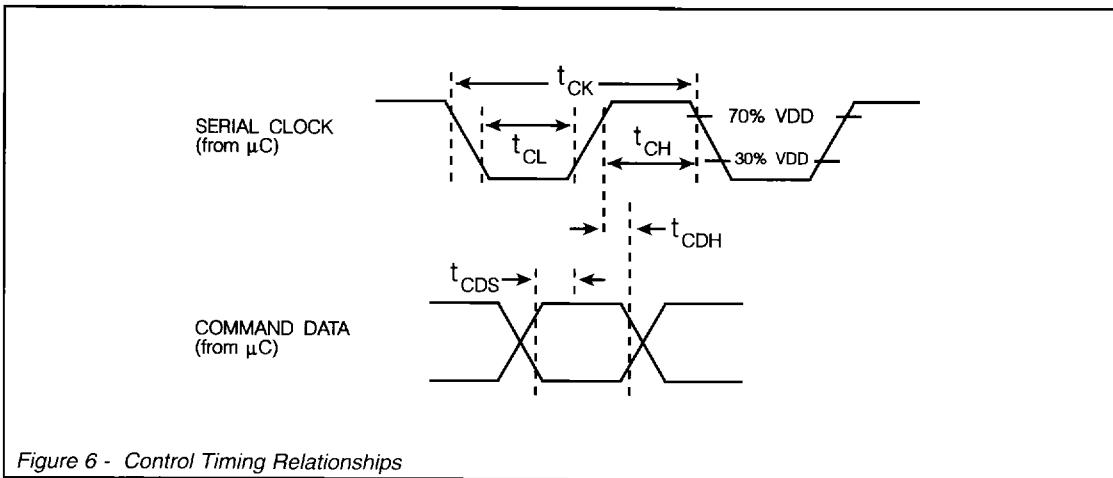
Timing Information

Inter-byte period logic level is not important.

Figure 5 - Control Timing Information

Parameter		See Note	Min.	Typ.	Max.	Unit
"$\overline{CS}$ Enable" to "clock high"	t_{CSE}	1	2.0	-	-	µs
Last "clock high" to "CS high"	t_{CSH}	1	4.0	-	-	µs
"$\overline{CS}$ high" time between transactions	t_{CSOFF}	1,2	2.0	-	-	µs
Clock Cycle Time	t_{CK}	1	2.0	-	-	µs
Inter byte time	t_{NXT}	1	4.0	-	-	µs
Serial Clock-High Period	t_{CH}		500	-	-	ns
Serial Clock-Low Period	t_{CL}		500	-	-	ns
Command Data Set-up Time	t_{CDS}		250	-	-	ns
Command Data Hold Time	t_{CDH}		0	-	-	ns

Notes
1. These minimum timing values are altered during operation of the MX812 VSR Codec.
2. Chip Select must be taken to a logic "1" between each individual transaction.

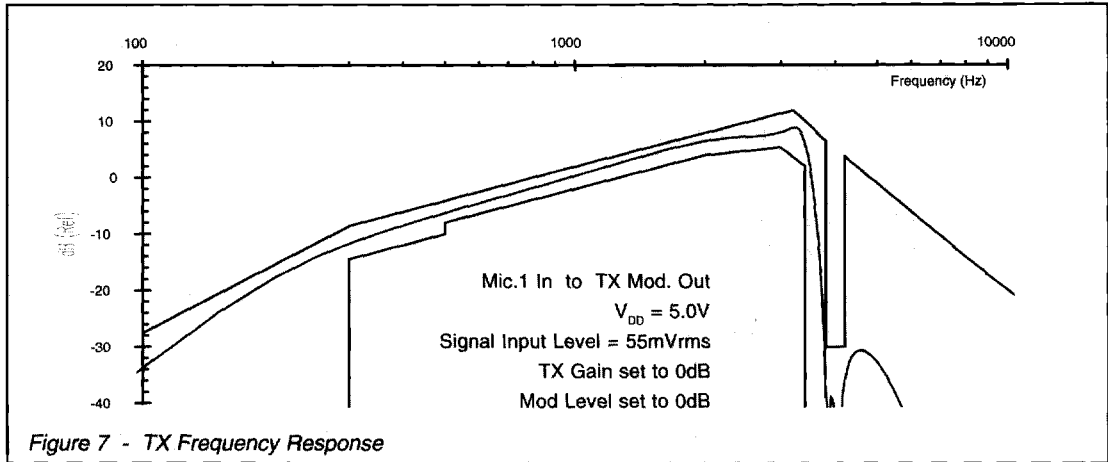*Figure 6 - Control Timing Relationships*

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System Performance

Figure 7 - TX Frequency Response

Mic.1 In to TX Mod. Out
$V_{DD} = 5.0V$
Signal Input Level = 55mVrms
TX Gain set to 0dB
Mod Level set to 0dB
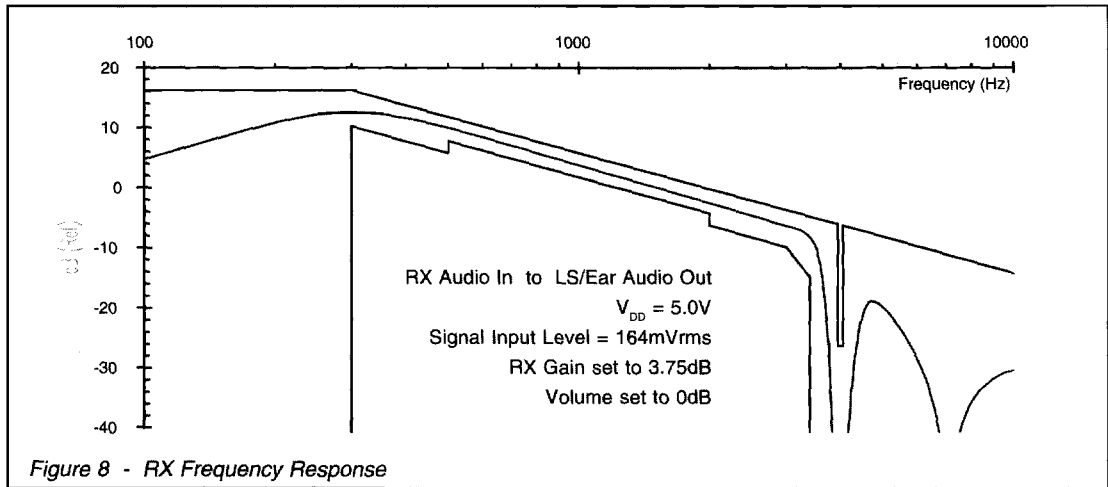
Figure 8 - RX Frequency Response

RX Audio In to LS/Ear Audio Out
$V_{DD} = 5.0V$
Signal Input Level = 164mVrms
RX Gain set to 3.75dB
Volume set to 0dB
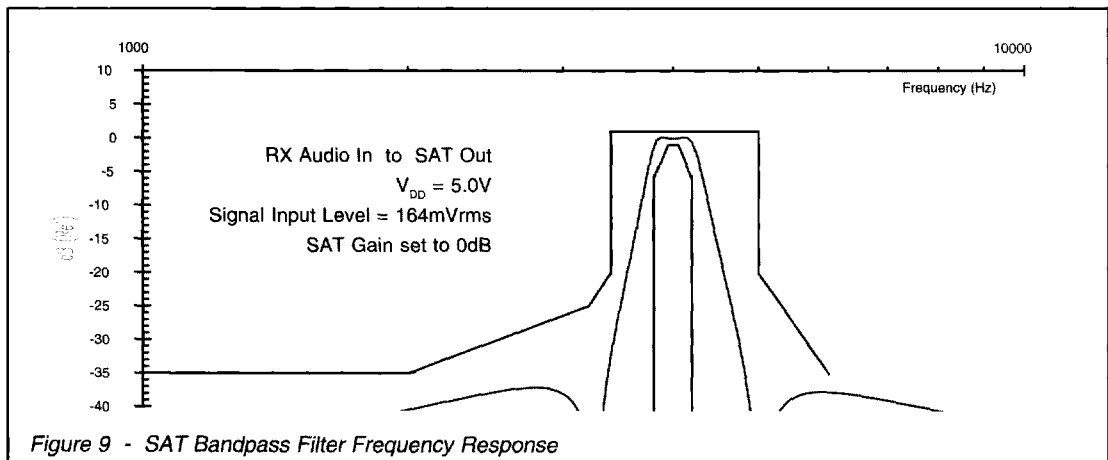
Figure 9 - SAT Bandpass Filter Frequency Response

RX Audio In to SAT Out
$V_{DD} = 5.0V$
Signal Input Level = 164mVrms
SAT Gain set to 0dB

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Specifications

Absolute Maximum Ratings

Exceeding the maximum rating can result in device damage. Operation of the device outside the operating limits is not suggested.

Supply Voltage	-0.3 to 7.0 V
Input Voltage at any pin	
(ref V_{SS} = 0V)	-0.3 to (V_{DD}+0.3V)
Sink/source current (supply pins)	±30mA
(other pins)	±20mA
Total device dissipation	
@ T_{AMB} 25°C	800mW Max.
Derating	10mW/°C
Operating Temperature	-40°C to +85°C
Storage Temperature	-55°C to +125°C

Operating Limits

All devices were measured under the following conditions unless otherwise noted.

V_{DD} = 5.0V

T_{AMB} = 25°C

Xtal/Clock f_0 = 4.032MHz

Audio Level 0dB ref = 164mVrms @ 1kHz

Characteristics	See Note	Min.	Typ.	Max.	Unit
Static Values					
Supply Voltage		4.5	5.0	5.5	V
Supply Current (All elements enabled)		-	6.0	-	mA
(RX Data Mode)		-	1.0	-	mA
(Maximum Powersave)		-	0.6	-	mA
Alias Frequency		-	63.0	-	kHz
On-Chip Xtal Oscillator					
R_{IN}		10.0	-	-	MΩ
R_{OUT}		-	10.0	-	kΩ
Inverter DC Voltage Gain		-	10.0	-	V/V
Gain/Bandwidth Product		-	10.0	-	MHz
Analog Input Impedances					
Mic. 1 & 2		-	500	-	kΩ
MSK/Play		-	500	-	kΩ
Comp. In		-	500	-	kΩ
DTMF In		-	500	-	kΩ
Deviation Limiter In		-	100	-	kΩ
Expanded Audio In		-	47.0	-	kΩ
TX Mix In		-	100	-	kΩ
RX Audio In		-	100	-	kΩ
Analog Output Impedances					
Pre-Emphasis Out		-	600	-	Ω
TX Mod Out		-	600	-	Ω
Expand/Store		-	600	-	Ω
LS and Ear Audio		-	1.0	-	kΩ
MSK Data Out		-	600	-	Ω
SAT Out		-	10.0	-	kΩ
TX Filter Out		-	600	-	Ω
VOGAD		-	500	-	Ω
Switches - ON		-	1.0	-	kΩ
- OFF		10.0	-	-	MΩ
Control Interface Parameters					
Input Logic "1"	2	3.5	-	-	V
Input Logic "0"	2	-	-	1.5	V
Input Current	2	-1.0	-	1.0	µA
Input Capacitance	2	-	-	7.5	pF

Characteristics	See Note	Min.	Typ.	Max.	Unit
Channel Performance, TX Signal Path					
Analog Signal Input Levels					
Mic. 1 & 2	3	-	0	-	dB
MSK/Play	3	-	0	-	dB
DTMF	3	-	0	-	dB
Comp. In	3	-	0	-	dB
TX Mix In	3	-	0	-	dB
Analog Signal Output Levels					
Pre-Emphasis Out	3	-	0	-	dB
TX Filter Out	3	-	0	-	dB
TX Mod. Out	3	-	0	-	dB
Sidetone Out	3	-	0	-	dB
Path Gains/Levels					
TX Gain - 11$_H$					
Adjustment Range		-2.65	-	3.65	dB
Step Error		-0.2	-	0.2	dB
VOGAD					
Gain (Non-Compressing)		-	0	-	dB
(Full Compression)		-	-15.0	-	dB
Attack Time	4	-	3.0	-	ms
Deviation Limiter					
Threshold		-	713	-	mV p-p
Symmetry		-	7	-	%
Mod. Level Attenuation - 11$_H$					
Adjustment Range		-5.6	-	0	dB
Step Size		0.2	0.4	0.6	dB
Error of any Setting		-1.0	-	1.0	dB
Overall					
TX Distortion		-	-40.0	-32.0	dB
TX Hum and Noise		-	-40.0	-20.0	dB
Channel Performance, RX Signal Path					
RX Audio Input Level	3	-	-7.0	-	dB
LS/Ear Audio Output Level	3	-	0	-	dB
Path Gains/Levels					
RX Gain - 12$_H$					
Adjustment Range		3.75	-	9.70	dB
Error of any Setting		-0.2	-	0.2	dB
MSK Output					
Frequency Range		900	-	2100	dB
Gain at 1kHz		-1.0	0	1.0	dB
Response		-	6.0	-	dB/oct.
Volume - 12$_H$					
Adjustment Range		-28.0	-	0	dB
Step Size		1.5	2.0	2.5	dB
Error of any Setting		-1.0	-	1.0	dB
Overall					
RX Distortion		-	-40.0	-32.0	dBp
RX Hum and Noise		-	-40.0	-34.0	dB

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Channel Performance, SAT Signal Path

Bandpass Filter

Frequency Range		3945	-	4055	Hz
Gain		-1.0	-	1.0	dB
SAT Level - 13$_H$					
Adjustment Range		-1.95	-	3.50	dB
Step Error		-0.2	-	0.2	dB

Notes

1. With reference to the Powersave Command and Figure 3, all functions with the exception of the RX Gain Element may be powersaved. This will still allow signaling data through the MX816 to activate the system via the μProcessor.

2. Serial Clock, Command Data and Chip Select Inputs.

3. Levels equivalent to ±3.0 kHz deviation with the settings below:

    TX Gain = 0dB   Mod Level = 0dB
    RX Gain = 7.05dB   Volume = 0dB
    SAT Level = 0dB

    Other levels can be achieved by adjusting the above variable gain blocks in accordance with Tables 1 - 5.

4. Using the components shown in Figure 2.

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