

## NSAM266SP CompactSPEECH™ Digital Speech Processor with Full-Duplex Speakerphone

### General Description

The NSAM266SP is a member of National Semiconductor's CompactSPEECH Digital Speech Processor family. This processor provides Digital Answering Machine (DAM) functionality to embedded systems.

The CompactSPEECH interfaces with National Semiconductor's NM29A040 and NM29A080 Serial Flash memory devices to provide a cost-effective solution for DAM and Cordless DAM (CDAM) applications.

The CompactSPEECH processor integrates the functions of a traditional Digital Signal Processing (DSP) chip and the CR16A, a 16-bit general-purpose RISC core implementation of the CompactRISC™ architecture. It contains system support functions such as Interrupt Control Unit, Codec interface, MICROWIRE™ interfaces to a microcontroller and Serial Flash, WATCHDOG™ timer, and a Clock Generator. The CompactSPEECH processor operates as a slave peripheral that is controlled by an external microcontroller via a serial MICROWIRE interface. In a typical DAM environment, the microcontroller controls the analog circuits, buttons and display, and activates the CompactSPEECH by sending it commands. The CompactSPEECH processor executes the commands and returns status information to the microcontroller.

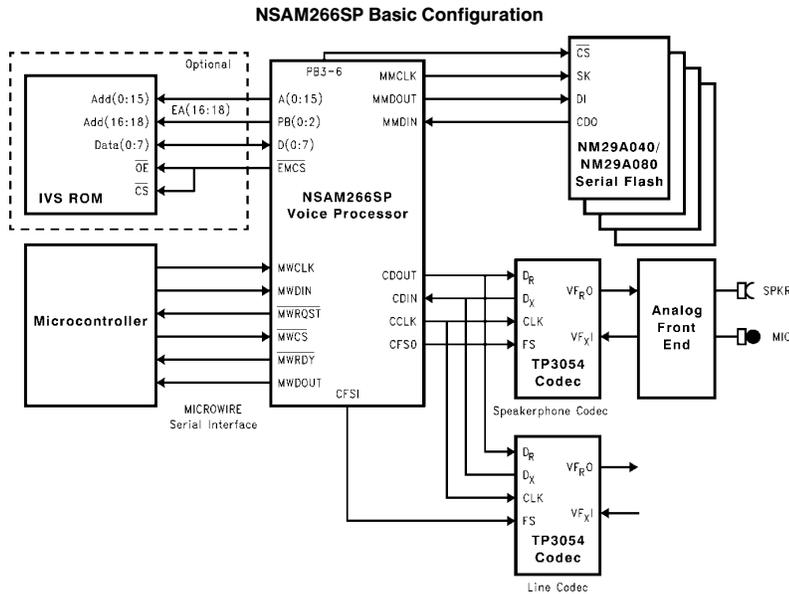
The CompactSPEECH firmware implements voice compression and decompression, tone detection and generation, message storage management, speech synthesis for time-and-day stamp, and supports user-defined voice prompts in various languages.

The CompactSPEECH implements a digital full-duplex speakerphone, which utilizes acoustic echo-cancellation techniques to enable simultaneous talking and listening during hands free conversation. Minimum microcontroller intervention (launch-and-forget) is required during speakerphone sessions. The speakerphone monitors its performance in real-time, and continually updates its internal state and filters to enable high-quality hands-free conversation.

The CompactSPEECH implements echo-cancellation techniques to support high-quality DTMF tone detection during message playback.

The CompactSPEECH can synthesize messages in various languages via the International Vocabulary Support (IVS) mechanism. The NSAM266SP can store vocabularies on either Serial Flash, or Expansion ROM memories. DAM manufacturers can thus create machines that "speak" in different languages, simply by using other vocabularies. For more details about IVS, refer to the *IVS User's Manual*.

### Block Diagram



TL/EE/12868-1

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## Features

- Designed around the CR16A, a 16-bit general-purpose RISC core implementation of the CompactRISC architecture
- 16-bit architecture and implementation
- 20.48 MHz operation
- On-chip DSP Module (DSPM) for high-speed DSP operations
- On-chip codec clock generation and interface
- Power-down mode
- Digital full-duplex speakerphone
- Acoustic-echo cancellation
- Line echo cancellation
- Digital volume control for the speaker
- Microphone MUTE mode with smooth switching between normal and mute modes
- Continuous on-the-fly monitoring of external (acoustic and line) and internal conditions provides high-quality hands-free conversation in a changing environment
- No microcontroller control needed for the speakerphone operation
- No need for a special signal to train the echo cancelers
- No need for special hardware circuits
- Selectable speech compression rate of 5.2 kbit/s or 7.3 kbit/s with silence compression
- Up to 16 minutes recording on a 4-Mbit Serial Flash (more than 1 hour total recording time on four devices)
- The number of messages that can be stored is limited only by memory size
- MICROWIRE slave interface to an external microcontroller
- MICROWIRE master interface to Serial Flash memory devices
- Storage and management of messages
- Programmable message tag for message categorization, e.g., Mailboxes, InComing Messages (ICM), Out-Going Messages (OGM)
- Skip forward or backward during message playback
- Variable speed playback
- Supports external vocabularies, using Serial Flash or expansion ROM
- Multi-lingual speech synthesis using International Vocabulary Support (IVS)
- Vocabularies available in: English, Japanese, Mandarin, German, French and Spanish
- DTMF generation and detection
- DTMF detection during OutGoing Message playback
- Single tone generation
- Telephone line functions, including busy and dial tone detection
- Real-time clock
- Direct access to message memory
- Supports long-frame and short-frame codecs
- Call screening (input signal echoed to codec output)
- Supports up to four 4-Mbit, or two 8-Mbit, Serial Flash devices
- Supports prerecorded vocabularies on Serial Flash
- Available in PLCC 68-pin, and PQFP 100-pin packages

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#### SCHEMATIC DIAGRAMS

## 1.0 Hardware

### 1.2 PIN ASSIGNMENT

The following sections detail the pins of the NSAM266SP processor. Slashes separate the names of signals that share the same pin.

### 1.2.1 Pin—Signal Assignment

Table 1-1 shows all the pins, and the signals that use them in different configurations. It also shows the type and direction of each signal.

**TABLE 1-1. CompactSPEECH Pin—Signal Assignment**

| Pin Name                   | Type                           | Signal Name               | I/O             |
|----------------------------|--------------------------------|---------------------------|-----------------|
| A(0:15)                    | TTL                            | A(0:15)                   | Output          |
| CCLK                       | TTL                            | CCLK                      | Output          |
| CDIN                       | TTL                            | CDIN                      | Input           |
| CDOUT                      | TTL                            | CDOUT                     | Output          |
| CFS0                       | TTL                            | CFS0                      | Output          |
| CFS1                       | TTL                            | CFS1                      | Output          |
| D(0:7)                     | TTL                            | D(0:7)                    | I/O             |
| $\overline{MWCS}$          | TTL (Note A)                   | $\overline{MWCS}$         | Input           |
| $\overline{TST}$           | TTL                            | $\overline{TST}$          | Input           |
| $\overline{MWRDY}$         | TTL                            | $\overline{MWRDY}$        | I/O             |
| $\overline{MWRQST}$        | TTL                            | $\overline{MWRQST}$       | I/O             |
| MWDOUT                     | TTL                            | MWDOUT                    | Output          |
| PB(0:2)<br>(Note B)        | TTL                            | EA(16:18)                 | Output          |
| PB(3:6)<br>(Note C)        | TTL                            | CS(0:3)                   | Output          |
| $\overline{EMCS}/$<br>ENV0 | TTL1 (Note D)<br>CMOS (Note E) | $\overline{EMCS}$<br>ENV0 | Output<br>Input |
| MWCLK                      | TTL                            | MWCLK                     | Input           |
| MWDIN                      | TTL                            | MWDIN                     | Input           |
| MMCLK                      | TTL1 (Note D)                  | MMCLK                     | Output          |
| MMDIN                      | TTL                            | MMDIN                     | Input           |
| MMDOUT                     | TTL1 (Note D)                  | MMDOUT                    | Output          |
| $\overline{RESET}$         | Schmitt (Note A)               | $\overline{RESET}$        | Input           |
| V <sub>CC</sub>            | Power                          | V <sub>CC</sub>           |                 |
| V <sub>SS</sub>            | Power                          | V <sub>SS</sub>           |                 |
| X1                         | XTAL                           | X1                        | OSC             |
| X2/CLKIN                   | XTAL<br>TTL                    | X2<br>CLKIN               | OSC<br>Input    |

**Note A:** Schmitt trigger input.

**Note B:** Virtual address lines for IVS ROM.

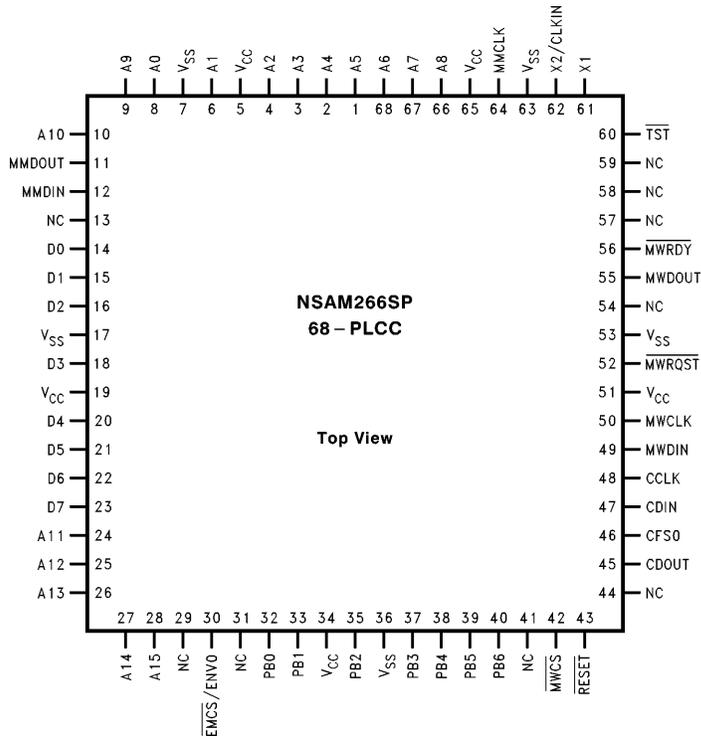
**Note C:** Chip select lines for Serial Flash devices.

**Note D:** TTL1 output signals provide CMOS levels in the steady state, for small loads.

**Note E:** Input during reset, CMOS level input.

# 1.0 Hardware (Continued)

## 1.1.2 Pin Assignment in the 68-PLCC Package



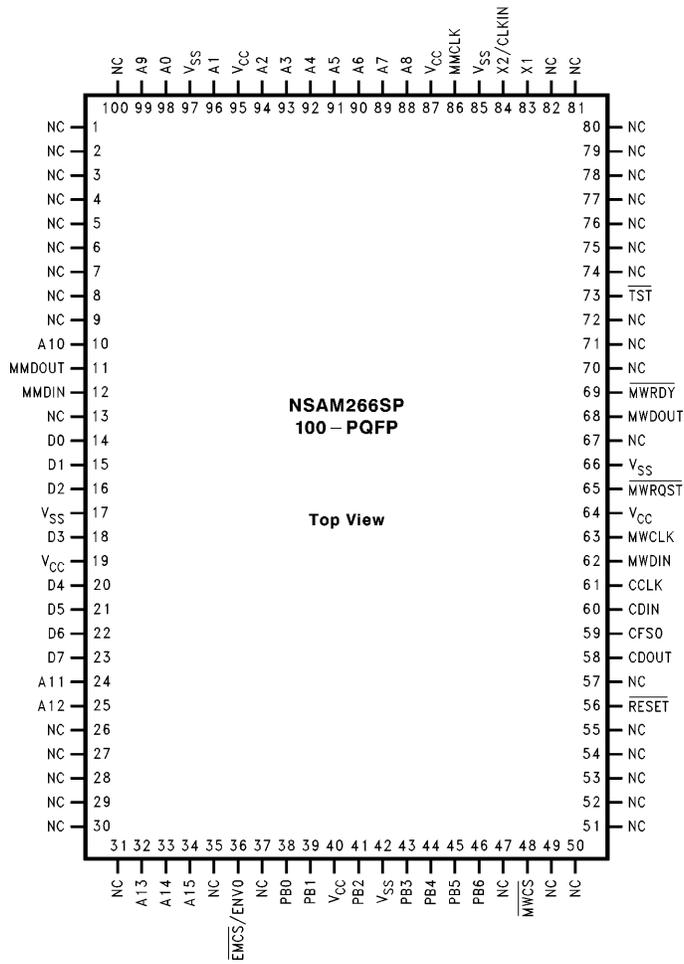
**Note:** Pins marked NC should not be connected.

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**FIGURE 1-1. 68-PLCC Package Connection Diagram**

# 1.0 Hardware (Continued)

## 1.1.3 Pin Assignment in the 100-PQFP Package



**Note:** Pins marked NC should not be connected.

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**FIGURE 1-2. 100-PQFP Package Connection Diagram**

## 1.0 Hardware (Continued)

### 1.2 FUNCTIONAL DESCRIPTION

This section provides details of the functional characteristics of the CompactSPEECH processor. It is divided into the following sections:

- Resetting
- Clocking
- Power-down Mode
- Power and Grounding
- Memory Interface
- Codec Interface

#### 1.2.1 Resetting

The RESET pin is used to reset the CompactSPEECH processor.

On application of power,  $\overline{\text{RESET}}$  must be held low for at least  $t_{\text{pwr}}$  after  $V_{\text{CC}}$  is stable. This ensures that all on-chip voltages are completely stable before operation. Whenever  $\overline{\text{RESET}}$  is applied, it must also remain active for not less than  $t_{\text{RST}}$ . During this period, and for 100  $\mu\text{s}$  after, the TST signal must be high. This can be done with a pull-up resistor on the TST pin.

The value of  $\overline{\text{MWRD}\overline{\text{Y}}}$  is undefined during the reset period, and for 100  $\mu\text{s}$  after. The microcontroller should either wait before polling the signal for the first time, or the signal should be pulled high during this period.

Upon reset, the ENVO signal is sampled to determine the operating environment. During reset, the EMCS/ENVO pin is used for the ENVO input signals. An internal pull-up resistor sets ENVO to 1.

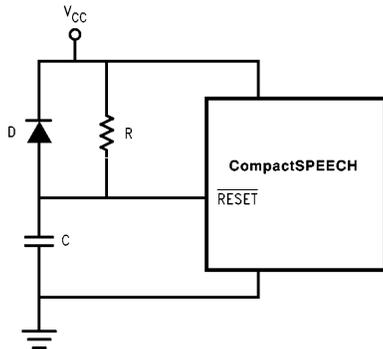
After reset, the same pin is used for EMCS.

#### System Load on ENVO

For any load on the ENVO pin, the voltage should not drop below  $V_{\text{ENVH}}$ .

If the load on the ENVO pin causes the current to exceed 10  $\mu\text{A}$ , use an external pull-up resistor to keep the pin at 1.

Figure 1-3 shows a recommended circuit for generating a reset signal when the power is turned on.



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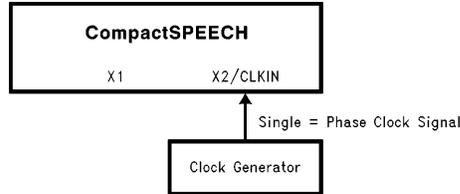
FIGURE 1-3. Recommended Power-On Reset Circuit

#### 1.2.2 Clocking

The CompactSPEECH provides an internal oscillator that interacts with an external clock source through the X1 and X2/CLKIN pins. Either an external single-phase clock signal, or a crystal oscillator, may be used as the clock source.

#### External Single-Phase Clock Signal

If an external single-phase clock source is used, it should be connected to the CLKIN signal as shown in Figure 1-4, and should conform to the voltage-level requirements for CLKIN stated in Section 1.3.2.

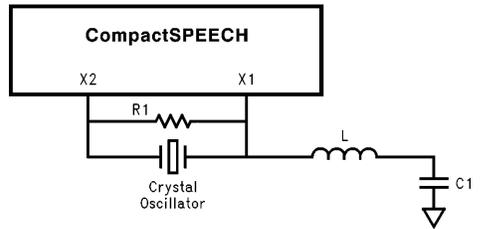


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FIGURE 1-4. External Clock Source

#### Crystal Oscillator

A crystal oscillator is connected to the on-chip oscillator circuit via the X1 and X2 signals, as shown in Figure 1-5.



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FIGURE 1-5. Connections for an External Crystal Oscillator

Keep stray capacitance and inductance, in the oscillator circuit, as low as possible. The crystal resonator, and the external components, should be as close to the X1 and X2/CLKIN pins as possible, to keep the trace lengths in the printed circuit to an absolute minimum.

You can use crystal resonators with maximum load capacitance of 20 pF, although the oscillation frequency may differ from the crystal's specified value.

Table 1-2 lists the components in the crystal oscillator circuit.

TABLE 1-2. Crystal Oscillator Component List

| Component         | Parameters                | Values            | Tolerance |
|-------------------|---------------------------|-------------------|-----------|
| Crystal Resonator | Resonance Frequency       | 40.96 MHz         | N/A       |
|                   | Third Overtone            | Parallel          |           |
|                   | Type                      | AT-Cut            |           |
|                   | Maximum Serial Resistance | 50 $\Omega$       |           |
|                   | Maximum Shunt Capacitance | 7 pF              |           |
|                   | Maximum Load Capacitance  | 12 pF             |           |
| Resistor R1       |                           | 10 M $\Omega$     | 5%        |
| Capacitor C1      |                           | 1000 pF           | 20%       |
| Inductor L        |                           | 3.9 $\mu\text{H}$ | 10%       |

## 1.0 Hardware (Continued)

### 1.2.3 Power-Down Mode

Power-down mode is useful during a power failure, when the power source for the CompactSPEECH is a backup battery, or in battery powered devices, while the CompactSPEECH is idle.

In power-down mode, the clock frequency of the CompactSPEECH is reduced, and some of the processor modules are deactivated. As a result, the CompactSPEECH consumes much less power than in normal-power mode (< 1.5 mA). Although the CompactSPEECH does not perform all its usual functions in power-down mode, it still keeps stored messages and maintains the time of day.

**Note:** In power-down mode all the chip select signals, CS0 to CS3, are set to 1. To guarantee that there is no current flow from these signals to the Serial Flash devices, the power supply to these devices must not be disconnected.

The CompactSPEECH stores messages, and all memory management information, in flash memory. Thus, there is no need to maintain the power to the processor to preserve stored messages. If the microcontroller's real-time clock (and *not* the CompactSPEECH's real-time clock) is used to maintain the time and day, neither the flash nor the CompactSPEECH require battery backup during power failure. In this case, when returning to normal mode, the microcontroller should perform the initialization sequence, as described in Section 2.11, and use the SETD command to set the time and day.

To keep power consumption low in power-down mode, the RESET, MWCS, MWCLK and MWDIN signals should be held above  $V_{CC} - 0.5V$  or below  $V_{SS} + 0.5V$ .

The PDM (Go To Power-down Mode) command switches the CompactSPEECH to power-down mode. (For an explanation of the CompactSPEECH commands, see Section 2.15.) It may only be issued when the CompactSPEECH is in the IDLE state. (For an explanation of the CompactSPEECH states, see Section 2.3.) If it is necessary to switch to power-down mode from any other state, the controller must first issue an S command to switch the CompactSPEECH to the IDLE state, and then issue the PDM command. Sending any command while in power-down mode resets the CompactSPEECH detectors, and returns the CompactSPEECH to normal operation mode.

### 1.2.4 Power and Grounding

The CompactSPEECH processor requires a single 5V power supply, applied to the  $V_{CC}$  pins.

The grounding connections are made on the GND pins.

For optimal noise immunity, the power and ground pins should be connected to  $V_{CC}$  and the ground planes, respectively, on the printed circuit board. If  $V_{CC}$  and the ground planes are not used, single conductors should be run directly from each  $V_{CC}$  pin to a power point, and from each GND pin to a ground point. Avoid daisy-chained connections.

Use decoupling capacitors to keep the noise level to a minimum. Attach standard 0.1  $\mu F$  ceramic capacitors to the  $V_{CC}$  and GND pins, as close as possible to the CompactSPEECH.

When you build a prototype, using wire-wrap or other methods, solder the capacitors directly to the power pins of the CompactSPEECH socket, or as close as possible, with very short leads.

### 1.2.5 Memory Interface

#### Serial Flash Interface

The CompactSPEECH supports up to four NM29A040 4-Mbit, or up to two NM29A080 8-Mbit, serial flash memory devices for storing messages.

#### NM29A040

The NM29A040 is organized as 128 blocks of 128 pages, each containing 32 bytes. A block is the smallest unit that can be erased, and is 4 kbytes in size.

Not all 128 blocks are available for recording. Up to 10 blocks may contain bad bits, and one block is write-once and holds the locations of these unusable blocks.

For further information about the NM29A040, see the *NM29A040 Datasheet*.

#### NM29A080

The NM29A080 is organized as 256 blocks of 128 pages, each containing 32 bytes. A block is the smallest unit that can be erased, and is 4 kbytes in size.

Not all 256 blocks are available for recording. Up to 20 blocks may contain bad bits, and two blocks are write-once and hold the locations of these unusable blocks.

For further information about the NM29A080, see the *NM29A080 Datasheet*.

#### Message Organization and Recording Time

A CompactSPEECH message uses at least one block.

The number of messages that can be stored on one NM29A040 device is 117 to 127, and on one NM29A080 device is 234 to 254 depending on the number of bad blocks.

The maximum recording time depends on four factors:

1. The basic compression rate (5.2 kbit/s or 7.3 kbit/s).
2. The amount of silence in the recorded speech.
3. The number of bad blocks.
4. The number of recorded messages. (The basic memory allocation unit for a message is a 4 kbyte block which means that half a block in average is wasted per recorded message.)

Assuming a single message is recorded in all the available memory space of a 4 Mbit device with no bad blocks, the maximum recording time using 5.2 kbit/s compression is as follows:

TABLE 1-3. Recording Time on 4 Mbit Device

| Amount of Silence | Total Recording Time  |
|-------------------|-----------------------|
| 0%                | 13 minutes 9 seconds  |
| 10%               | 14 minutes 25 seconds |
| 15%               | 15 minutes 7 seconds  |
| 20%               | 15 minutes 47 seconds |
| 25%               | 16 minutes 25 seconds |

#### Serial Flash Endurance

The serial flash may be erased up to 100,000 times. To reduce the effect of this limitation, the memory manager utilizes the serial flash's blocks evenly, i.e., each block is erased more or less the same number of times, to ensure that all blocks have the same lifetime.

## 1.0 Hardware (Continued)

Consider the following extensive usage of all the NM29A040's blocks:

1. Record 15 minutes of messages (until the memory is full).
2. Playback 15 minutes (all the recorded messages).
3. Delete all messages.

Assuming a NM29A040 device is used in this manner 24 times a day, its expected lifetime is:

$$\text{Flash Lifetime} = 100,000 / (24 * 365) = 11.4 \text{ years}$$

Thus the NM29A040 device will last for over ten years, even when used for six hours of recording per day.

Note, that if an NM29A080 device is used, then, under the same conditions, it will last for more than 20 years.

### ROM Interface

IVS vocabularies can be stored in either serial flash and/or ROM. The CompactSPEECH supports IVS ROM devices through Expansion Memory. Up to 64 kbytes (64k x 8) of Expansion Memory are supported directly. Nevertheless, the CompactSPEECH uses bits of the on-chip port (PB) to further extend the 64 kbytes address space up to 0.5 Mbytes address space.

ROM is connected to the CompactSPEECH using the data bus, D(0:7), the address bus, A(0:15), the extended address signals, EA(16:18), and Expansion Memory Chip Select, EMCS, controls. The number of extended address pins to use may vary, depending on the size and configuration of the ROM.

### Reading from Expansion Memory

An Expansion Memory read bus-cycle starts at T1, when the data bus is in TRI-STATE®, and the address is driven on the address bus. EMCS is asserted (cleared to 0) on a T2W1 cycle. This cycle is followed by three T2W cycles and one T2 cycle. The CompactSPEECH samples data at the end of the T2 cycle.

The transaction is terminated at T3, when EMCS becomes inactive (set to 1). The address remains valid until T3 is complete. A T3H cycle is added after the T3 cycle. The address remains valid until the end of T3H.

### 1.2.6 Codec Interface

The CompactSPEECH provides an on-chip interface to two serial codecs. This interface supports codec operation in long or short-frame formats. The format is selected with the CFG command.

The codec interface uses five signals CDIN, CDOUT, CCLK, CFS0 and CFS1.

The CDIN input pin and the CDOUT, CCLK and CFS0 output pins are connected to the first codec. The second codec is connected to CDIN, CDOUT, CCLK and the CFS1 output pin.

Data is transferred to the codec through the CDOUT pin. Data is read from the codec through the CDIN pin.

#### Short Frame Protocol

When short frame protocol is configured, eight data bits are exchanged with each codec in each frame, i.e., CFS0 cycle.

Data transfer starts when CFS0 is set to 1 for one CCLK cycle. The data is then transmitted, bit-by-bit, via the CDOUT output pin. Concurrently, the received data is shifted in via the CDIN input pin. Data is shifted one bit in each CCLK cycle.

After the last bit has been shifted, CFS1 is set to 1 for one CCLK cycle. Then, the data from the second codec is shifted out via CDOUT, concurrently with the inward shift of the data received via CDIN.

Figure 1-6 shows how the codec interface signals behave when short frame protocol is configured.

#### Long Frame Protocol

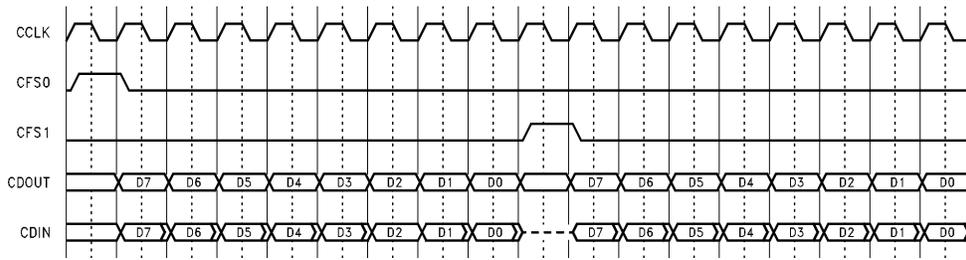
When long frame protocol is configured, eight data bits are exchanged with each codec, as for the short frame protocol. However, for the long frame protocol, data transfer starts by setting CFS0 to 1 for eight CCLK cycles.

Simultaneously, the data for the first codec is shifted out bit-by-bit, via the CDOUT output pin, as in short frame protocol. Concurrently, the received data is shifted in through the CDIN input. The data is shifted one bit in each CCLK cycle.

One CCLK cycle after CFS0 has become inactive (0), CFS1 is set to 1, for eight CCLK cycles. Simultaneously, the data for the second codec is shifted out, MSB first, via CDOUT, concurrently with the received data shifted in from CDIN.

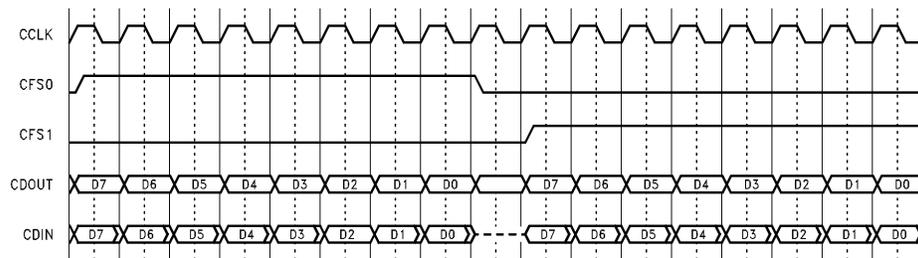
Figure 1-7 shows how the codec interface signals behave when long frame protocol is configured.

## 1.0 Hardware (Continued)



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FIGURE 1-6. Codec Protocol—Short Frame



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FIGURE 1-7. Codec Protocol—Long Frame

## 1.0 Hardware (Continued)

### 1.3 SPECIFICATIONS

#### 1.3.1 Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Storage Temperature  $-65^{\circ}\text{C}$  to  $+150^{\circ}\text{C}$

Temperature under Bias  $0^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$

All Input or Output Voltages,  
with Respect to GND

$-0.5\text{V}$  to  $+6.5\text{V}$

Note: Absolute maximum ratings indicate limits beyond which permanent damage may occur. Continuous operation at these limits is not intended; operation should be limited to those conditions specified below.

#### 1.3.2 Electrical Characteristics $T_A = 0^{\circ}\text{C}$ to $+70^{\circ}\text{C}$ , $V_{CC} = 5\text{V} \pm 10\%$ , $\text{GND} = 0\text{V}$

| Symbol      | Parameter  | Conditions  | Min            | Typ  | Max            | Units         |
|-------------|--|---|----------------|------|----------------|---------------|
| $V_{IH}$    | TTL Input, Logical 1 Input Voltage                                   |   | 2.0            |      | $V_{CC} + 0.5$ | V             |
| $V_{IL}$    | TTL Input, Logical 0 Input Voltage                                   |   | $-0.5$         |      | 0.8            | V             |
| $V_{XH}$    | CLKIN Input, High Voltage  | External Clock  | 2.0            |      |                | V             |
| $V_{XL}$    | CLKIN Input, Low Voltage   | External Clock  |                |      | 0.8            | V             |
| $V_{ENVh}$  | ENV0 High Level, Input Voltage                                       |   | 3.6            |      |                | V             |
| $V_{Hh}$    | CMOS Input with Hysteresis, Logical 1 Input Voltage                  |   | 3.6            |      |                | V             |
| $V_{Hl}$    | CMOS Input with Hysteresis, Logical 0 Input Voltage                  |   |                |      | 1.1            | V             |
| $V_{Hys}$   | Hysteresis Loop Width (Note A)                                       |   | 0.5            |      |                | V             |
| $V_{OH}$    | Logical 1 TTL, Output Voltage  | $I_{OH} = -0.4\text{ mA}$                                   | 2.4            |      |                | V             |
| $V_{OHWC}$  | MMCLK, MMDOUT and $\overline{\text{EMCS}}$ Logical 1, Output Voltage | $I_{OH} = -0.4\text{ mA}$                                   | 2.4            |      |                | V             |
|             |  | $I_{OH} = -50\text{ }\mu\text{A}$ (Note B)                  | $V_{CC} - 0.2$ |      |                | V             |
| $V_{OL}$    | Logical 0, TTL Output Voltage  | $I_{OL} = 4\text{ mA}$                                      |                |      | 0.45           | V             |
|             |  | $I_{OL} = 50\text{ }\mu\text{A}$ (Note B)                   |                |      | 0.2            | V             |
| $V_{OLWC}$  | MMCLK, MMDOUT and $\overline{\text{EMCS}}$ Logical 0, Output Voltage | $I_{OL} = 4.0\text{ mA}$                                    |                |      | 0.45           | V             |
|             |  | $I_{OL} = 50\text{ }\mu\text{A}$ (Note B)                   |                |      | 0.2            | V             |
| $I_L$       | Input Load Current (Note C)  | $0\text{V} \leq V_{IN} \leq V_{CC}$                         | $-5.0$         |      | 5.0            | $\mu\text{A}$ |
| $I_O$ (Off) | Output Leakage Current (I/O Pins in Input Mode) (Note C)             | $0\text{V} \leq V_{OUT} \leq V_{CC}$                        | $-5.0$         |      | 5.0            | $\mu\text{A}$ |
| $I_{CC1}$   | Active Supply Current  | Normal Operation Mode, Running Speech Applications (Note D) |                | 65.0 | 80.0           | mA            |
| $I_{CC2}$   | Standby Supply Current   | Normal Operation Mode, DSPM Idle (Note D)                   |                | 40.0 |                | mA            |
| $I_{CC3}$   | Power-Down Mode Supply Current                                       | Power-Down Mode (Notes D and E)                             |                |      | 1.5            | mA            |
| $C_X$       | X1 and X2 Capacitance (Note A)                                       |   |                | 17.0 |                | pF            |

**Note A:** Guaranteed by design.

**Note B:** Measured in power-down mode. The total current driven, or sourced, by all the CompactSPEECH's output signals is  $< 50\text{ }\mu\text{A}$ .

**Note C:** Maximum  $20\text{ }\mu\text{A}$  for all pins together.

**Note D:**  $I_{OUT} = 0$ ,  $T_A = 25^{\circ}\text{C}$ ,  $V_{CC} = 5\text{V}$ , operating from a 40.96 MHz crystal, and running from internal memory with Expansion Memory disabled.

**Note E:** All input signals are tied to 1 or 0 (above  $V_{CC} - 0.5$  or below  $V_{SS} + 0.5\text{V}$ ).

# 1.0 Hardware (Continued)

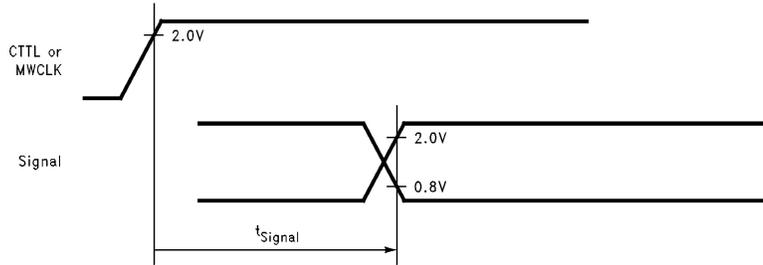
## 1.3.3 Switching Characteristics

### Definitions

All timing specifications in this section refer to 0.8V or 2.0V on the rising or falling edges of the signals, as illustrated in Figures 1-8 through 1-14, unless specifically stated otherwise.

Maximum times assume capacitive loading of 50 pF.  
CLKIN crystal frequency is 40.96 MHz.

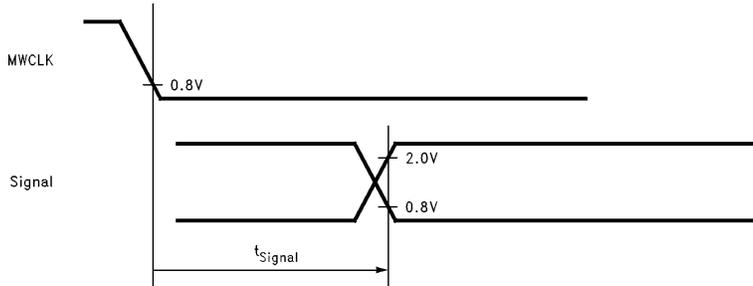
**Note:** CTTL is an internal signal and is used as a reference to explain the timing of other signals. See Figure 1-22.



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Signal valid, active or inactive time, after a rising edge of CTTL or MWCLK.

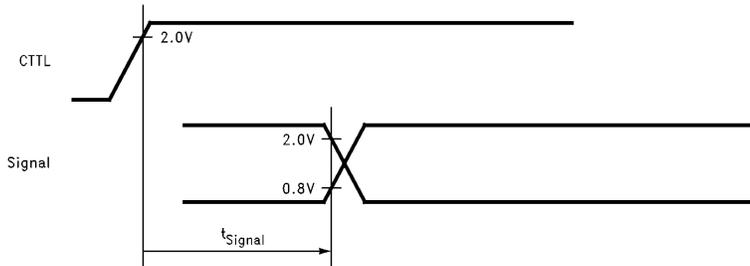
**FIGURE 1-8. Synchronous Output Signals (Valid, Active and Inactive)**



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Signal valid time, after a falling edge of MWCLK.

**FIGURE 1-9. Synchronous Output Signals (Valid)**

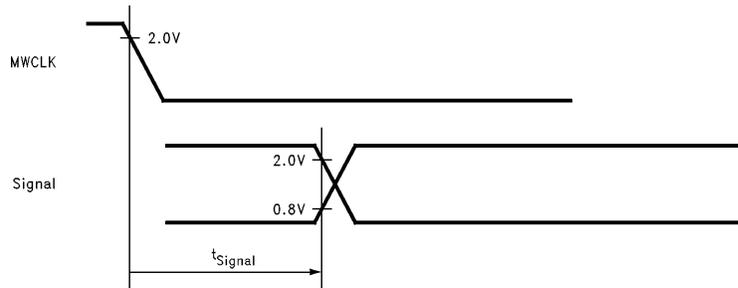


TL/EE/12868-11

Signal hold time, after a rising edge of CTTL.

**FIGURE 1-10. Synchronous Output Signals (Hold)**

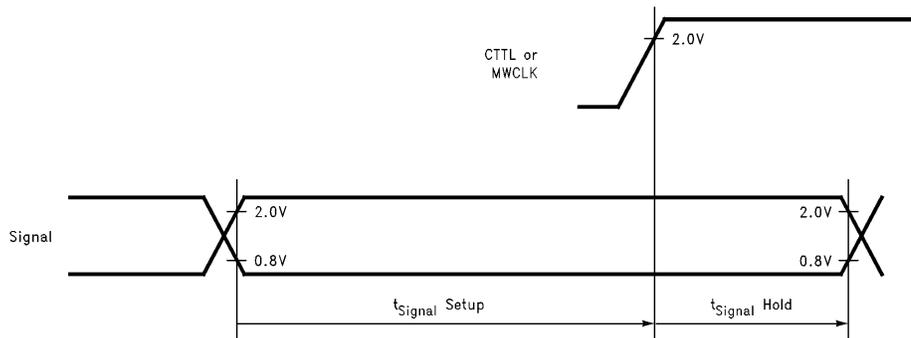
## 1.0 Hardware (Continued)



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Signal hold time, after a falling edge of MWCLK.

**FIGURE 1-11. Synchronous Output Signals (Hold)**

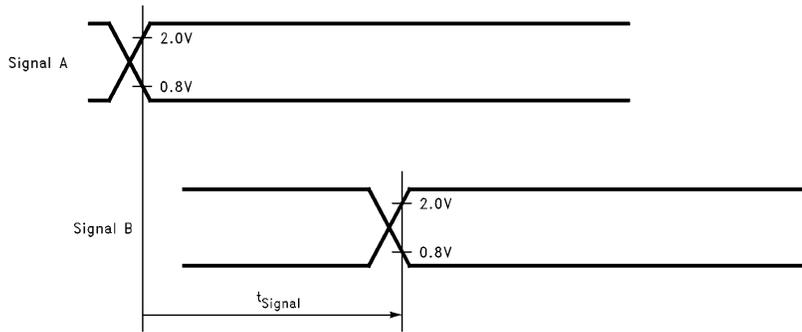


TL/EE/12868-13

Signal setup time, before a rising edge of CCTL or MWCLK, and signal hold time after a rising edge of CCTL or MWCLK.

**FIGURE 1-12. Synchronous Input Signals**

## 1.0 Hardware (Continued)

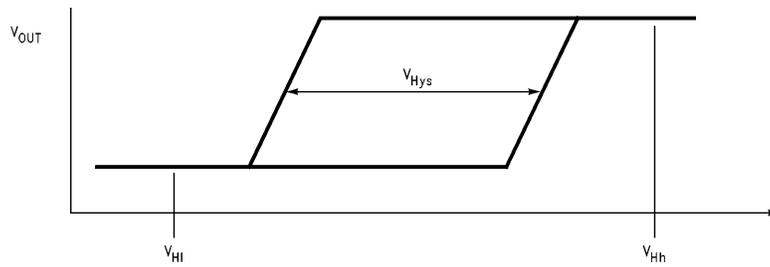


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Signal B starts after rising or falling edge of signal A.

**FIGURE 1-13. Asynchronous Signals**

The  $\overline{\text{RESET}}$  signal has a Schmitt trigger input buffer. *Figure 1-14* shows the characteristics of the input buffer.



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**FIGURE 1-14. Hysteresis Input Characteristics**

## 1.0 Hardware (Continued)

### 1.3.4 Synchronous Timing Tables

In this section, R.E. means Rising Edge and F.E. means Falling Edge.

#### OUTPUT SIGNALS

| Symbol        | Figure | Description                       | Reference Conditions         | Min (ns) | Max (ns) |
|---------------|--------|-----------------------------------|------------------------------|----------|----------|
| $t_{Ah}$      | 1-17   | Address Hold                      | After R.E. CTTL              | 0.0      |          |
| $t_{Av}$      | 1-17   | Address Valid                     | After R.E. CTTL, T1          |          | 12.0     |
| $t_{CCLKa}$   | 1-15   | CCLK Active                       | After R.E. CTTL              |          | 12.0     |
| $t_{CCLKh}$   | 1-15   | CCLK Hold                         | After R.E. CTTL              | 0.0      |          |
| $t_{CCLKia}$  | 1-15   | CCLK Inactive                     | After R.E. CTTL              |          | 12.0     |
| $t_{CDOh}$    | 1-15   | CDOOUT Hold                       | After R.E. CTTL              | 0.0      |          |
| $t_{CDOv}$    | 1-15   | CDOOUT Valid                      | After R.E. CTTL              |          | 12.0     |
| $t_{CTP}$     | 1-22   | CTTL Clock Period (Note A)        | R.E. CTTL to next R.E. CTTL  | 48.8     | 50,000   |
| $t_{EMCSa}$   | 1-17   | $\overline{EMCS}$ Active          | After R.E. CTTL, T2W1        |          | 12.0     |
| $t_{EMCSH}$   | 1-17   | $\overline{EMCS}$ Hold            | After R.E. CTTL              | 0.0      |          |
| $t_{EMCSia}$  | 1-17   | $\overline{EMCS}$ Inactive        | After R.E. CTTL, T3          |          | 12.0     |
| $t_{FSa}$     | 1-15   | CFS0 and CFS1 Active              | After R.E. CTTL              |          | 25.0     |
| $t_{FSh}$     | 1-15   | CFS0 and CFS1 Hold                | After R.E. CTTL              | 0.0      |          |
| $t_{FSia}$    | 1-15   | CFS0 and CFS1 Inactive            | After R.E. CTTL              |          | 25.0     |
| $t_{MMCLKa}$  | 1-20   | Master MICROWIRE Clock Active     | After R.E. CTTL              |          | 12.0     |
| $t_{MMCLKh}$  | 1-20   | Master MICROWIRE Clock Hold       | After R.E. CTTL              | 0.0      |          |
| $t_{MMCLKia}$ | 1-20   | Master MICROWIRE Clock Inactive   | After R.E. CTTL              |          | 12.0     |
| $t_{MMDOh}$   | 1-20   | Master MICROWIRE Data Out Hold    | After R.E. CTTL              | 0.0      |          |
| $t_{MMDOv}$   | 1-20   | Master MICROWIRE Data Out Valid   | After R.E. CTTL              |          | 12.0     |
| $t_{MWDOF}$   | 1-18   | MICROWIRE Data Float (Note B)     | After R.E. $\overline{MWCS}$ |          | 70.0     |
| $t_{MWDOh}$   | 1-18   | MICROWIRE Data Out Hold (Note B)  | After F.E. MWCK              | 0.0      |          |
| $t_{MWDOhf}$  | 1-18   | MICROWIRE Data No Float (Note B)  | After F.E. $\overline{MWCS}$ | 0.0      | 70.0     |
| $t_{MWDOv}$   | 1-18   | MICROWIRE Data Out Valid (Note B) | After F.E. MWCK              |          | 70.0     |
| $t_{MWITOp}$  | 1-19   | MWDIN to MWDOOUT                  | Propagation Time             |          | 70.0     |
| $t_{MWRDYa}$  | 1-18   | $\overline{MWRDY}$ Active         | After R.E. of CTTL           | 0.0      | 35.0     |
| $t_{MWRDYia}$ | 1-18   | $\overline{MWRDY}$ Inactive       | After F.E. MWCLK             | 0.0      | 70.0     |
| $t_{PABCh}$   | 1-21   | PB and $\overline{MWRQST}$        | After R.E. CTTL              | 0.0      |          |
| $t_{PABCv}$   | 1-21   | PB and $\overline{MWRQST}$        | After R.E. CTTL, T2W1        |          | 12.0     |

**Note A:** In normal operation mode  $t_{CTP}$  must be 48.8 ns; in power-down mode,  $t_{CTP}$  must be 50,000 ns.

**Note B:** Guaranteed by design, but not fully tested.

## 1.0 Hardware (Continued)

### INPUT SIGNALS

| Symbol       | Figure | Description                                      | Reference Conditions                     | Min (ns)        |
|--------------|--------|--|--|-----------------|
| $t_{CDih}$   | 1-15   | CDIN Hold  | After R.E. CTTL                          | 0.0             |
| $t_{CDIs}$   | 1-15   | CDIN Setup                                       | Before R.E. CTTL                         | 11.0            |
| $t_{DIh}$    | 1-17   | Data in Hold (D0:7)                              | After R.E. CTTL T1, T3 or TI             | 0.0             |
| $t_{DI s}$   | 1-17   | Data in Setup (D0:7)                             | Before R.E. CTTL T1, T3 or TI            | 15.0            |
| $t_{MMDINh}$ | 1-20   | Master MICROWIRE Data In Hold                    | After R.E. CTTL                          | 0.0             |
| $t_{MMDINs}$ | 1-20   | Master MICROWIRE Data In Setup                   | Before R.E. CTTL                         | 11.0            |
| $t_{MWCKh}$  | 1-18   | MICROWIRE Clock High (Slave)                     | At 2.0V (Both Edges)                     | 100.0           |
| $t_{MWCKl}$  | 1-18   | MICROWIRE Clock Low (Slave)                      | At 0.8V (Both Edges)                     | 100.0           |
| $t_{MWCKp}$  | 1-18   | MICROWIRE Clock Period (Slave) (Note A)          | R.E. MWCLK to next R.E. MWCLK            | 2.5 $\mu$ s     |
| $t_{MWCLKh}$ | 1-18   | MWCLK Hold                                       | After $\overline{MWCS}$ becomes Inactive | 50.0            |
| $t_{MWCLKs}$ | 1-18   | MWCLK Setup                                      | Before $\overline{MWCS}$ becomes Active  | 100.0           |
| $t_{MWCS h}$ | 1-18   | $\overline{MWCS}$ Hold                           | After F.E. MWCLK                         | 50.0            |
| $t_{MWCS s}$ | 1-18   | $\overline{MWCS}$ Setup                          | Before R.E. MWCLK                        | 100.0           |
| $t_{MWDIh}$  | 1-18   | MWDIN Hold                                       | After R.E. MWCLK                         | 50.0            |
| $t_{MWDIs}$  | 1-18   | MWDIN Setup                                      | Before R.E. MWCLK                        | 100.0           |
| $t_{PWR}$    | 1-24   | Power Stable to $\overline{RESET}$ R.E. (Note B) | After $V_{CC}$ reaches 4.5V              | 30.0 ms         |
| $t_{RSTw}$   | 1-23   | $\overline{RESET}$ Pulse Width                   | At 0.8V (Both Edges)                     | 10.0 ms         |
| $t_{Xh}$     | 1-22   | CLKIN High                                       | At 2.0V (Both Edges)                     | $t_{X1p}/2 - 5$ |
| $t_{Xl}$     | 1-22   | CLKIN Low  | At 0.8V (Both Edges)                     | $t_{X1p}/2 - 5$ |
| $t_{Xp}$     | 1-22   | CLKIN Clock Period                               | R.E. CLKIN to next R.E. CLKIN            | 24.4            |

**Note A:** Guaranteed by design, but not fully tested in power-down mode.

**Note B:** Guaranteed by design, but not fully tested.

# 1.0 Hardware (Continued)

## 1.3.5 Timing Diagrams

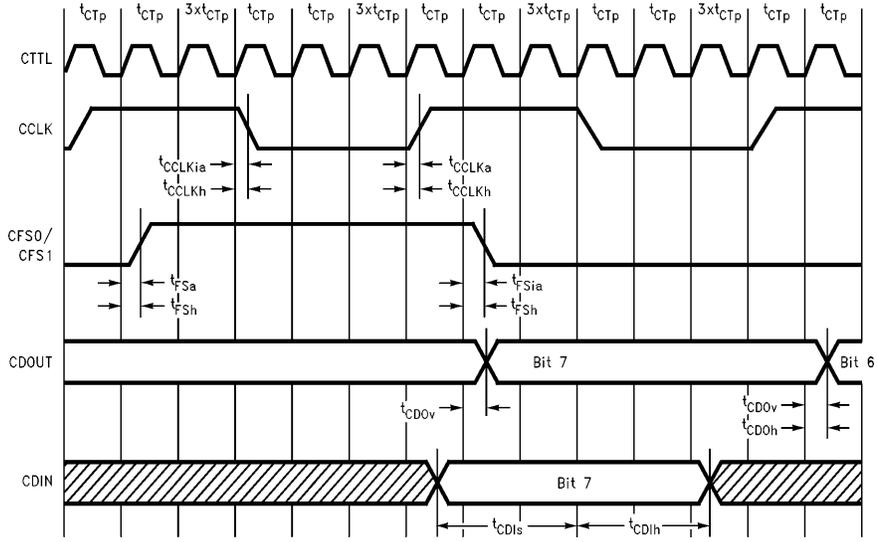


FIGURE 1-15. Codec Short Frame Timing

TL/EE/12868-16

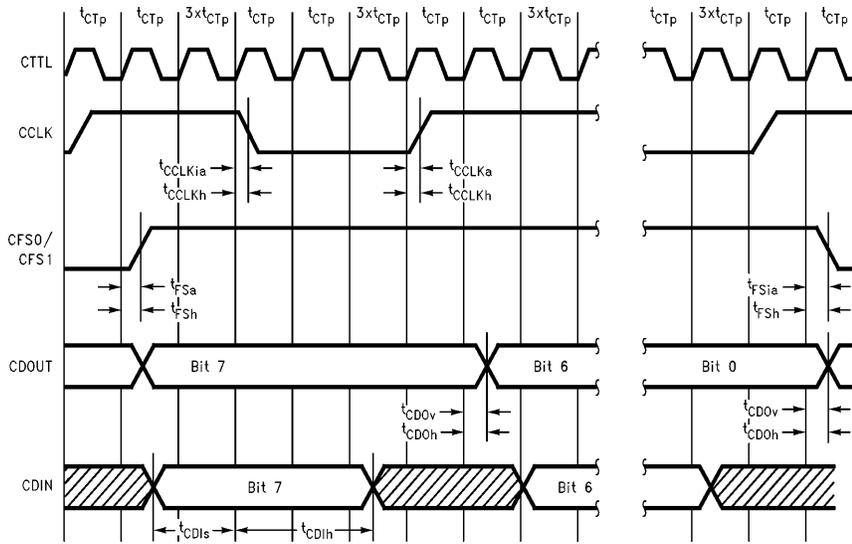
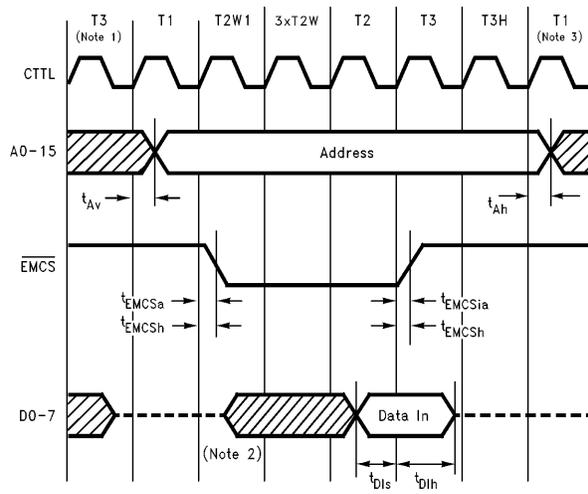


FIGURE 1-16. Codec Long Frame Timing

TL/EE/12868-17

## 1.0 Hardware (Continued)



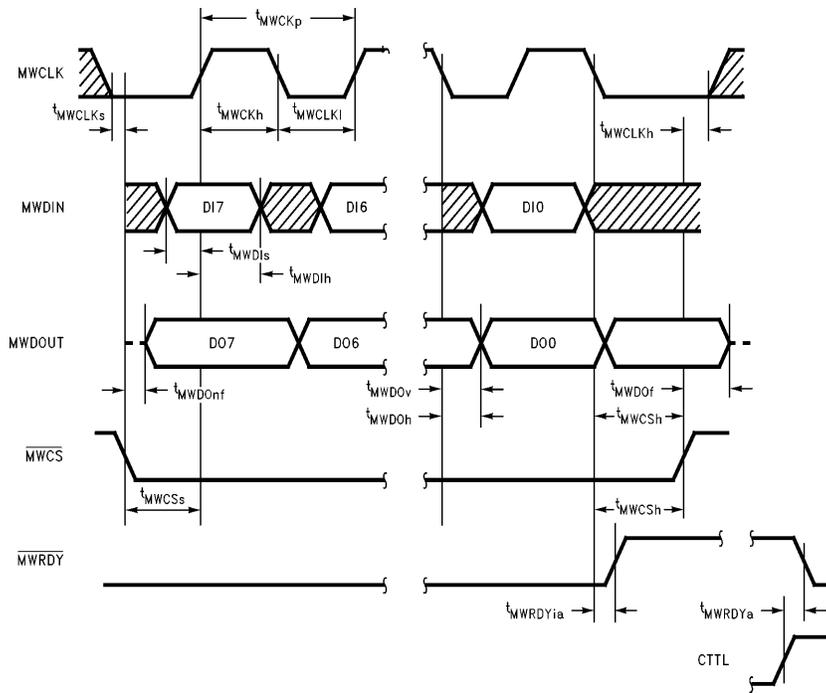
TL/EE/12868-18

**Note 1:** This cycle may be either T1 (Idle), T3 or T3H.

**Note 2:** Data can be driven by an external device at T2W1, T2W, T2 and T3.

**Note 3:** This cycle may be either T1 (Idle) or T1.

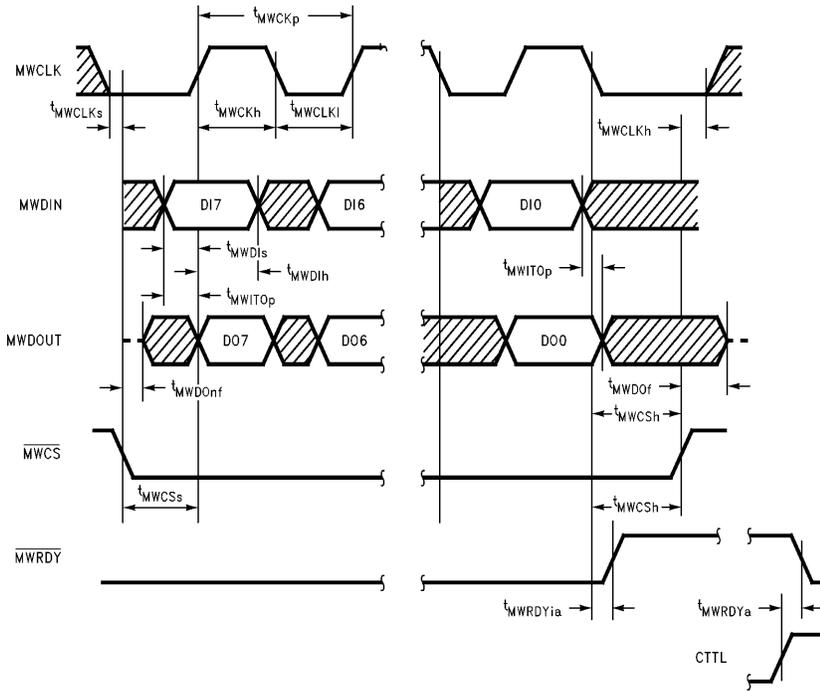
**FIGURE 1-17. ROM Read Cycle Timing**



TL/EE/12868-19

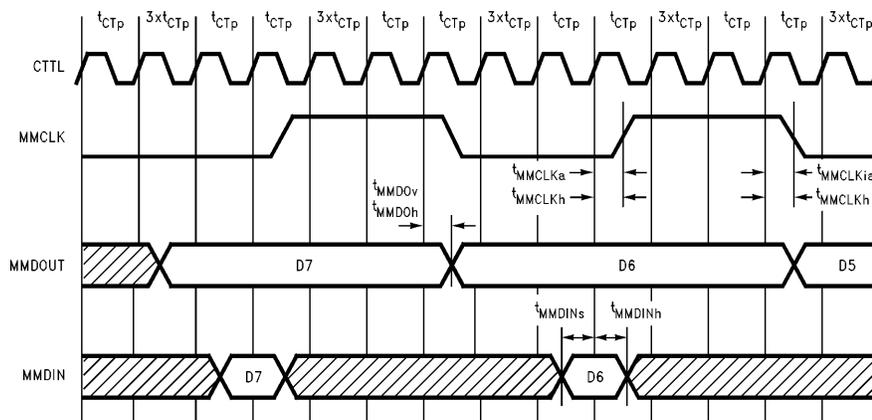
**FIGURE 1-18. MICROWIRE Transaction Timing—Data Transmitted to Output**

## 1.0 Hardware (Continued)



TL/EE/12868-20

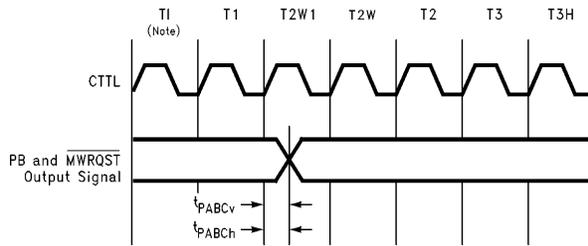
FIGURE 1-19. MICROWIRE Transaction Timing—Data Echoed to Output



TL/EE/12868-21

FIGURE 1-20. Master MICROWIRE Timing

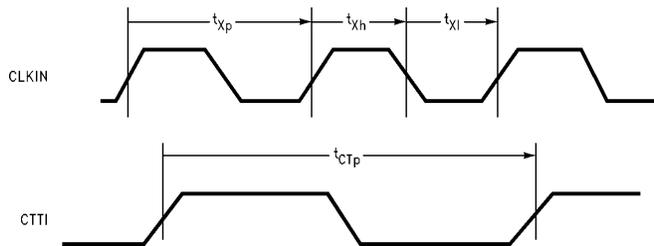
## 1.0 Hardware (Continued)



TL/EE/12868-22

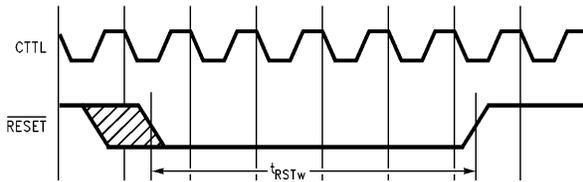
**Note:** This cycle may be either T1 (idle), T2, T3 or T3H.

**FIGURE 1-21. Output Signal Timing for Port PB and MWRQST**



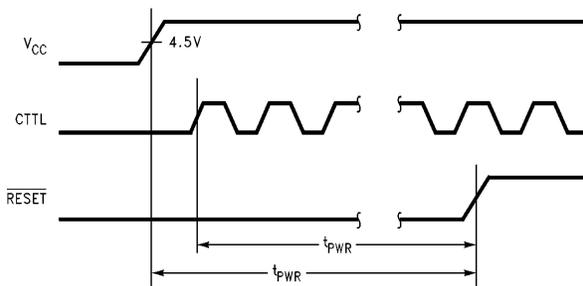
TL/EE/12868-23

**FIGURE 1-22. CCTL and CLKIN Timing**



TL/EE/12868-24

**FIGURE 1-23. Reset Timing When Reset is not at Power-Up**



TL/EE/12868-25

**FIGURE 1-24. Reset Timing When Reset is at Power-Up**

## 2.0 Software

### 2.1 OVERVIEW

The CompactSPEECH software resides in the on-chip ROM. It includes DSP-based algorithms, system support functions and a software interface to hardware peripherals.

#### 2.1.1 DSP-based Algorithms

- Speech compression and decompression
- Full-duplex speakerphone
- DTMF detector with echo canceler
- Energy-based busy and dial-tone detector
- Digital volume control

#### 2.1.2 System Support

- Command interface to an external microcontroller
- Memory and message manager
- IVS support
- Tone generator
- Real-time clock handler
- Power-down mode support

#### 2.1.3 Peripherals Support

- Serial flash interface (Master MICROWIRE handler)
- Microcontroller interface (Slave MICROWIRE handler)
- Codec interface

The following sections describe the CompactSPEECH software in detail.

## 2.0 Software (Continued)

### 2.2 CompactSPEECH COMMANDS—QUICK REFERENCE TABLE

#### Normal Mode Commands

| Command |     | Description             | Opcode Hex | Source State                                  | Result State  | Command Parameters     |           | Return Value          |       |
|---------|-----|-------------------------|------------|---|---------------|------------------------|-----------|-----------------------|-------|
| Name    | S/A |                         |            |   |               | Description            | Bytes     | Description           | Bytes |
| AMAP**  | S   | Check and Map ARAM      | 06         |   |               | Action_number          | 1         | Test Result           | 1     |
| CCIO    | S   | Configure Codec I/O     | 34         | RESET, IDLE                                   | No Change     | Config_value           | 1         | None                  |       |
| CFG     | S   | Configure CompactSPEECH | 01         | RESET   | RESET         | Config_value           | 2         | None                  |       |
| CMSG    | S   | Create Message          | 33         | IDLE  | No Change     | Tag, Num_of_Blocks     | 2 + 2     | None                  |       |
| CMT     | S   | Cut Message Tail        | 26         | IDLE  | IDLE          | Length of Time         | 2         | None                  |       |
| CVOC    | S   | Check Vocabulary        | 2B         | IDLE  | IDLE          | None                   |           | Test Result           | 1     |
| DM      | S   | Delete Message          | 0A         | IDLE  | IDLE          | None                   |           | None                  |       |
| DMS     | S   | Delete Messages         | 0B         | IDLE  | IDLE          | Tag_ref, Tag_mask      | 2 + 2     | None                  |       |
| FR**    | A   | Free Memory             | 08         |   |               | None                   |           | None                  |       |
| GCFG    | S   | Get Configuration Value | 02         | RESET, IDLE                                   | No Change     | None                   |           | Version, Config_value | 2     |
| GEW     | S   | Get Error Word          | 1B         | All States                                    | No Change     | None                   |           | Error Word            | 2     |
| GI      | S   | Get Information Item    | 25         | PLAY, RECORD, SYNTHESIS, TONE_GENERATE, IDLE  | No Change     | Index                  | 1         | Value                 | 2     |
| GL      | S   | Get Length              | 19         | IDLE  | IDLE          | None                   |           | Message Length        | 2     |
| GMS     | S   | Get Memory Status       | 12         | IDLE  | IDLE          | Type                   | 1         | Recording Time Left   | 2     |
| GMT     | S   | Get Message Tag         | 04         | IDLE  | IDLE          | None                   |           | Message Tag           | 2     |
| GNM     | S   | Get Number of Messages  | 11         | IDLE  | IDLE          | Tag_ref, Tag_mask      | 2 + 2     | Number of Messages    | 2     |
| GSW     | S   | Get Status Word         | 14         | All States                                    | No Change     | None                   |           | Status Word           | 2     |
| GT      | A   | Generate Tone           | 0D         | IDLE  | TONE_GENERATE | Tone or DTMF           | 1         | None                  |       |
| GTD     | S   | Get Time and Day        | 0E         | IDLE  | IDLE          | Time/Day Option        | 1         | Time/Day              | 2     |
| GTM     | S   | Get Tagged Message      | 09         | IDLE  | IDLE          | Tag_ref, Tag_Mask, Dir | 2 + 2 + 1 | Message Found         | 1     |
| INIT    | S   | Initialize System       | 13         | RESET, IDLE                                   | IDLE          | None                   |           | None                  |       |
| INJ     | S   | Inject IVS Data         | 29         | IDLE  | IDLE          | N, byte1 . . . byteN   | 4 + n     | None                  |       |
| MR      | S   | Memory Reset            | 2A         | IDLE  | IDLE          | None                   |           | None                  |       |
| P       | A   | Playback                | 03         | IDLE  | PLAY          | None                   |           | None                  |       |
| PA      | S   | Pause                   | 1C         | PLAY, RECORD, SYNTHESIS, TONE_GENERATE, IDLE* | No Change     | None                   |           | None                  |       |
| PDM     | S   | Go to Power-Down Mode   | 1A         | IDLE  | IDLE          | None                   |           | None                  |       |

## 2.0 Software (Continued)

### 2.2 CompactSPEECH COMMANDS—QUICK REFERENCE TABLE (Continued)

#### Normal Mode Commands (Continued)

| Command |     | Description             | Opcode Hex | Source State                                  | Result State | Command Parameters   |        | Return Value |       |
|---------|-----|-------------------------|------------|---|--------------|----------------------|--------|--------------|-------|
| Name    | S/A |                         |            |   |              | Description          | Bytes  | Description  | Bytes |
| R       | A   | Record Message          | 0C         | IDLE  | RECORD       | Message Tag          | 2      | None         |       |
| RDET    | S   | Reset Detectors         | 2C         | IDLE  | No Change    | Detectors Reset Mask | 1      | None         |       |
| RES     | S   | Resume                  | 1D         | PLAY, RECORD, SYNTHESIS, TONE_GENERATE, IDLE* | No Change    | None                 |        | None         |       |
| RRAM**  | S   | Read RAM                | 18         | IDLE, MEMORY_READ                             | MEMORY_READ  | None                 |        | Data         | 32    |
| S       | S   | Stop                    | 00         | All States but RESET                          | IDLE         | None                 |        | None         |       |
| SAS     | A   | Say Argumented Sentence | 1E         | IDLE  | SYNTHESIS    | Sentence_n arg1      | 1 + 1  | None         |       |
| SB      | S   | Skip Backward           | 23         | PLAY, IDLE*                                   | No Change    | Length of Time       | 2      | None         |       |
| SDET    | S   | Set Detectors Mask      | 10         | IDLE  | No Change    | Detectors Mask       | 1      | None         |       |
| SE      | S   | Skip to End of Message  | 24         | PLAY, IDLE*                                   | No Change    | None                 |        | None         |       |
| SETD    | S   | Set Time and Day        | 0F         | IDLE  | No Change    | Time/Day             | 2      | None         |       |
| SF      | S   | Skip Forward            | 22         | PLAY, IDLE*                                   | No Change    | Length of Time       | 2      | None         |       |
| SMSG    | S   | Set Message             | 30         | IDLE, Msg_Open                                | Msg_Open     | Num_of_Pages         | 2      | None         |       |
| SMT     | S   | Set Message Tag         | 05         | IDLE  | IDLE         | Message Tag          | 2      | None         |       |
| SO      | A   | Say One Word            | 07         | IDLE  | SYNTHESIS    | Word Number          | 1      | None         |       |
| SPS     | S   | Set Playback Speed      | 16         | PLAY, SYNTHESIS, IDLE                         | No Change    | Speed Value          | 1      | None         |       |
| SS      | A   | Say Sentence            | 1F         | IDLE  | SYNTHESIS    | Sentence_n           | 1      | None         |       |
| SSM     | S   | Set Speakerphone Mode   | 2F         | IDLE  | No Change    | Mode                 | 1      | None         |       |
| SV      | S   | Set Vocabulary Type     | 20         | IDLE  | IDLE         | Mode, Id             | 1 + 1  | None         |       |
| SW      | A   | Say Words               | 21         | IDLE  | SYNTHESIS    | N, word1 . . . wordn | 1 + n  | None         |       |
| TUNE    | S   | Tune                    | 15         | IDLE  | IDLE         | Index, Value         | 1 + 2  | None         |       |
| VC      | S   | Volume Control          | 28         | PLAY, SYNTHESIS, IDLE, TONE_GENERATE          | No Change    | Increment/Decrement  | 1      | None         |       |
| WMSG    | S   | Write Message           | 31         | IDLE, MSG_OPEN                                | MSG_OPEN     | Data                 | 32     | None         |       |
| WRAM    | S   | Write RAM               | 17         | IDLE, MEMORY_WRITE                            | MEMORY_WRITE | Message Tag, Data    | 2 + 32 | None         |       |

\*Command is valid in IDLE state, but has no effect.

\*\*This command exists for compatibility reasons only, and will be obsoleted in future revisions of CompactSPEECH.

S = Synchronous command.

A = Asynchronous command.

## 2.0 Software (Continued)

### 2.2 CompactSPEECH COMMANDS—QUICK REFERENCE TABLE (Continued)

#### Speakerphone Mode Commands

| Command |     | Description           | Opcode Hex | Source State                                 | Result State  | Command Parameters   |       | Return Value |             |
|---------|-----|-----------------------|------------|--|---------------|----------------------|-------|--------------|-------------|
| Name    | S/A |                       |            |  |               | Description          | Bytes | Description  | Description |
| GI      | S   | Get Information Item  | 25         | PLAY, RECORD, SYNTHESIS, TONE_GENERATE, IDLE | No Change     | Index                | 1     | Value        | 2           |
| GT      | A   | Generate Tone         | 0D         | IDLE   | TONE_GENERATE | Tone or DTMF         | 1     | None         |             |
| RDET    | S   | Reset Detectors       | 2C         | IDLE   | No Change     | Detectors Reset Mask | 1     | None         |             |
| S       | S   | Stop                  | 00         | All States but RESET                         | IDLE          | None                 |       | None         |             |
| SDET    | S   | Set Detectors Mask    | 10         | IDLE   | No Change     | Detectors Mask       | 1     | None         |             |
| SSM     | S   | Set SpeakerPhone Mode | 2F         | IDLE   | No Change     | Mode                 | 1     | None         |             |
| TUNE    | S   | Tune                  | 15         | IDLE   | IDLE          | Index, Value         | 1 + 2 | None         |             |
| VC      | S   | Volume Control        | 28         | PLAY, SYNTHESIS, IDLE, TONE_GENERATE         | No Change     | Increment/Decrement  | 1     | None         |             |

## 2.0 Software (Continued)

### 2.3 THE STATE MACHINE

The CompactSPEECH operates in one of two modes: normal mode and Speakerphone mode. The SSM command is used to change the mode of operation.

In each mode the CompactSPEECH functions as a state machine. It changes state either in response to a command sent by the microcontroller, after execution of the command is completed, or as a result of an internal event (e.g., memory full or power failure).

The main difference between the operation modes is that in Speakerphone mode only a limited set of commands is supported. (See the Quick Reference Tables in Section 2.2.)

The CompactSPEECH may be in one of the following states:

#### RESET

The CompactSPEECH is initialized to this state after a full hardware reset by the  $\overline{\text{RESET}}$  signal (see Section 1-3). CompactSPEECH detectors (VOX, call progress tones and DTMF tones) are not active. In all other states, the detectors are active. (See the SDET and RDET commands for further details.)

#### IDLE

This is the state from which most commands are executed. As soon as a command and all its parameters are received, the CompactSPEECH starts executing the command.

#### PLAY

In this state a message is decompressed, and played back.

#### RECORD

In this state a message is compressed, and recorded into the message memory.

#### SYNTHESIS

An individual word or a sentence is synthesized from an external vocabulary.

#### tone\_\_GENERATE

The CompactSPEECH generates single or DTMF tones.

#### MSG\_\_OPEN

The CompactSPEECH either reads, or writes, 32 bytes from, or to, the message memory, or sets the message Read/Write pointer on a 32-byte boundary.

After receiving an asynchronous command, (see Section 2.4) such as P (Playback), R (Record), SW (Say Words) or GT (Generate Tone), the CompactSPEECH switches to the appropriate state and executes the command until it is completed, or an S (Stop) or PA (Pause) command is received from the microcontroller.

When an asynchronous command execution is completed, the EV\_\_NORMAL\_\_END event is set, and the CompactSPEECH switches to the IDLE state.

Section 2.2 provides a table which shows all the CompactSPEECH commands, the source states in which these commands are valid, and the result states which the CompactSPEECH enters as a result of the command.

### 2.4 COMMAND EXECUTION

A CompactSPEECH command is represented by an 8-bit opcode. Some commands have parameters, and some have return values. Commands are either synchronous or asynchronous.

### SYNCHRONOUS COMMANDS

A synchronous command must complete execution before the microcontroller can send a new command (e.g., GMS, GEW).

A command sequence starts when the microcontroller sends an 8-bit opcode to the CompactSPEECH, followed by the command's parameters (if any).

The CompactSPEECH executes the command and, if required, transmits a return value to the microcontroller. Upon completion, the CompactSPEECH notifies the microcontroller that it is ready to accept a new command.

### ASYNCHRONOUS COMMANDS

An asynchronous command starts execution in the background and notifies the microcontroller, which can send more commands while the current command is still running (e.g., R, P).

### STATUS WORD

The 16-bit status word indicates events that occur during normal operation. The CompactSPEECH activates the MWRQST signal, to indicate a change in the status word. This signal remains active until the CompactSPEECH receives a GSW command.

### ERROR WORD

The 16-bit error word indicates errors that occurred during execution of the last command. If an error is detected, the command is not processed; the EV\_\_ERROR bit in the status word is set to 1, and the MWRQST signal is activated.

### ERROR HANDLING

When the microcontroller detects that the MWRQST signal is active, it should issue the GSW (Get Status Word) command, which deactivates the MWRQST signal. Then, it should test the EV\_\_ERROR bit in the status word, and, if it is set, send the GEW (Get Error Word) command to read the error word for details of the error.

For a detailed description of each of the CompactSPEECH commands, see Section 2.15.

### 2.5 TUNABLE PARAMETERS

The CompactSPEECH processor can be adjusted to your system's requirements. For this purpose the CompactSPEECH supports a set of tunable parameters, which are set to their default values after reset and can be later modified with the TUNE command. By tuning these parameters, you can control various aspects of the CompactSPEECH's operation, such as silence compression, tone detection, no-energy detection, etc.

Table 2-2 describes all the tunable parameters in detail. Section 2.15 describes the TUNE command.

### 2.6 MESSAGES

The CompactSPEECH message manager supports a wide range of applications, which require different levels of DAM functionality.

The message-organization scheme, and the message tag, support advanced memory-organization features such as multiple OutGoing Messages (OGMs), mailboxes, and the ability to distinguish between InComing Messages (ICMs) and OGMs.

## 2.0 Software (Continued)

A message is the basic unit on which most of the CompactSPEECH commands operate. A CompactSPEECH message, stored on a flash device, can be regarded as a computer file stored on a mass-storage device.

A message is created with either the R or the ( ) command. When a message is created, it is assigned a time-and-day stamp and a message tag which can be read by the microcontroller.

The R command takes voice samples from the codec, compresses them, and stores them in the message memory.

When a message is created with the CMSG command the data to be recorded is provided by the microcontroller via the WMSG (Write Message) command and not via the codec. The data is transferred directly to the message memory. It is not compressed by the CompactSPEECH voice compression algorithm.

WMSG, RMSG (Read Message) and SMSG (Seek Message) are a complete set of message-data access commands that can be used to store and read data to/from any location in the message memory (see Section 2.15 for more details about these commands). Using these commands, messages can be used by the microcontroller to implement such features as a Telephone Directory.

A message can be played back (P command) and deleted (DM command). Redundant data (e.g., trailing tones or silence) can be removed from the message tail with the CMT (Cut Message Tail) command.

The PA (Pause) and RES (Resume) commands, respectively, temporarily suspend the P and R commands, and then allow them to resume execution from where they were suspended.

### CURRENT MESSAGE

Most message handling commands, e.g., P, DM, RMSG, operate on the current message. The GTM (Get Tagged Message) command selects the current message.

Deleting the current message does not cause a different message to become current. The current message is undefined. If, however, you issue the GTM command to skip to the next message, the first message that is newer than the just deleted message is selected as the current message.

### 2.6.1 Message Tag

Each message has a 2-byte message tag which you can use to categorize messages, and implement such features as OutGoing Messages, mailboxes, and different handling of old and new messages.

The most significant bit of the message tag (bit 15) is used to indicate the speech compression rate. The microcontroller should program it before recording ("1" for 4.8 kbit/s, "0" for 6.6 kbit/s). The CompactSPEECH reads the bit before message playback to select the appropriate decompression algorithm.

The GMT (Get Message Tag) and SMT commands may be used to handle message tags.

**Note:** Message tag bits can only be cleared. Message tag bits are set only when a message is first created.

This limitation is inherent in flash memories, which only allow bits to be changed from 1 to 0 (changing bits from 0 to 1 requires a special erasure procedure, see Section 1.2.5). However, the main reason for updating an existing tag is to mark a message as old, and this can be done by using one of the bits as a new/old indicator, setting it to 1 when a message is first created, and clearing it when necessary.

### 2.7 SPEECH COMPRESSION

The CompactSPEECH implements two speech compression algorithms. One algorithm, with 5.2 kbit/s compression rate, enables up to 14–16 minutes of recording on a 4-Mbit device, while the other uses a 7.3 kbit/s compression rate to support 10–12 minutes of recording. Both compression rates assume 10% silence.

Before recording each message, the microcontroller can select one of the two algorithms by programming bit 15 of the message tag.

During message playback the CompactSPEECH reads this bit and selects the appropriate speech decompression algorithm.

IVS vocabularies can be prepared in either of the two compression formats using the IVS tool. All the messages in a single vocabulary must be recorded using the same algorithm. (See the *IVS User's Manual* for further details). During speech synthesis, the CompactSPEECH automatically selects the appropriate speech decompression algorithm.

### 2.8 TONE AND NO-ENERGY DETECTION

The CompactSPEECH detects DTMF, busy, and dial tones, and no-energy (VOX). This enables remote control operations and call progress. Detection is active throughout the operation of the CompactSPEECH. Detection can be configured using the SDET (Set Detectors Mask) command, which controls the reporting of the occurrence of tones, and the RDET (Reset Detectors) command which resets the detectors.

### DTMF

DTMF detection may be reported at the starting point, ending point, or both. The report is made through the status word (for further details, see GSW command in Section 2.15).

The DTMF detector performance, as measured on the line input using an NSV-AM265-DAA board, is summarized on following page (see Table 2-1).

### ECHO CANCELLATION

Echo cancellation is a technique used to improve the performance of DTMF tone detection during speech synthesis, tone generation, and OGM playback. For echo cancellation to work properly, AGC must not be active in parallel. Thus, to take advantage of echo cancellation, the microcontroller must control the AGC, i.e., disable the AGC during **PLAY**, **SYNTHESIS** and **TONE\_GENERATE** states and enable it again afterwards. If AGC cannot be disabled, do not use echo cancellation. The microcontroller should use the CFG command to activate/deactivate echo cancellation. (For further details, see Section 2.15.)

Echo cancellation applies only to DTMF tones. Busy and dial-tone detection is not affected by this technique. This implies that the performance of the busy and dial-tone detector during message playback depends on the message being played.

## 2.0 Software (Continued)

**TABLE 2-1. DTMF Detector Performance**

|                                | PLAY   | RECORD/IDLE  |
|--------------------------------|--|--------------|
| Detection Sensitivity (Note A) | Performance Depends on The Message Being Played (Note B) | -40 dBm      |
| Accepted DTMF Length           | > 50 ms  | > 40 ms      |
| Frequency Tolerance            | ± 1.5%   | ± 1.5%       |
| S/N Ratio                      | 12 dB  | 12 dB        |
| Minimum Spacing (Note C)       | > 50 ms  | > 45 ms      |
| Normal Twist                   | 8 dB   | 8 dB         |
| Reverse Twist (Note D)         | 4 dB or 8 dB   | 4 dB or 8 dB |

**Note A:** Performance depends on the DAA design.

**Note B:** Performance with echo canceler is 10 dB better than without echo canceler. For a silent message, Detection Sensitivity is -34 dBm with echo canceler.

**Note C:** If the interval between two consecutive DTMF tones is  $\leq 20$  ms, the two are detected as one long DTMF tone.

If the interval between two consecutive DTMF tones is between 20 ms and 45 ms, separate detection is unpredictable.

**Note D:** Determined by the DTMF\_REV\_TWIST tunable parameter value.

### OTHER DETECTORS

Detection of busy and dial tones, and no-energy is controlled by tunable parameters. You should tune these parameters to fit your hardware. For more information see the TUNE command in Section 2.15.

Dial and busy tone detectors work with a band-pass filter that limits the frequency range in which tones can be detected to 0 Hz–1100 Hz. Its frequency response is illustrated in Figure 2-1 and the busy tone cadences in Figure 2-2.

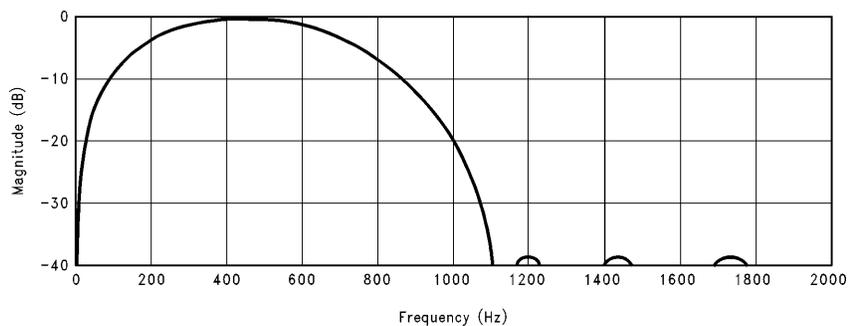
### TONE GENERATION

The CompactSPEECH can generate DTMF tones and single-frequency tones from 300 Hz to 3000 Hz in increments of 100 Hz. CompactSPEECH tone generation conforms to the EIA-470-RS standard. Note, however, that you may have

to change the value of some tunable parameters in order to meet the standard specifications since the energy level of generated tones depends on the analog circuits being used.

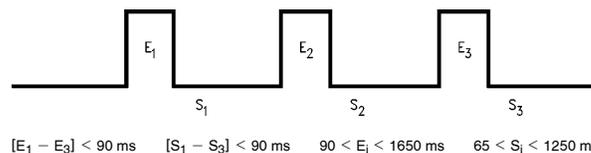
Tone generation is possible in both normal and speakerphone modes to support dialing while in speakerphone mode.

- Tune the DTMF\_TWIST\_LEVEL parameter to control the twist level of the generated DTMF tones.
- Use the VC command, and tune the TONE\_GENERATION\_LEVEL parameter, to control the energy level at which these tones are generated.
- Use the GT command to specify the DTMF tones, and the frequency at which single tones are generated.



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**FIGURE 2-1. Busy and Dial-Tone Band-Pass Filter Frequency Response**



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**FIGURE 2-2. Busy-Tone Detector—Cadence Specification**

## 2.0 Software (Continued)

### 2.9 FULL-DUPLEX SPEAKERPHONE

The speakerphone feature enables the user to communicate through a telephone line, using the speaker and the microphone of the unit instead of the handset. The speakerphone processes signals that are transferred from the line to the speaker, and from the microphone to the line, and performs the necessary switching, attenuation and echo cancellation on the signals that are present on the line/speaker.

The CompactSPEECH speakerphone is very simple to use. It requires no special hardware, and no training for the echo cancelers. The gain control is fully digital, which eliminates the need for analog gain control hardware.

Two types of echoes exist in a speakerphone. One is an electrical echo, which is a result of an imperfect impedance match between the 4 to 2-wire interface (hybrid), and the line impedance. This echo is relatively short term, and its transfer function varies quite slowly. The second echo is an acoustic echo returning from the speaker to the microphone. This echo is relatively long term, and its transfer function may vary quite quickly if anyone, or anything, moves in the room. Both echoes must be canceled to achieve a high-quality hands-free system.

#### 2.9.1 Speakerphone Modes of Operation

##### FULL-DUPLEX

The speakerphone works in full-duplex mode i.e., both parties can speak and hear each other at the same time. In this mode both the acoustic and electric echo controllers are active. The CompactSPEECH tone detectors are not active in this mode.

##### MUTE

The speakerphone generates silence to the line. The near-end speaker can hear the far-end listener but not vice versa. Tone detectors are not active.

##### HOLD

Interrupts from both codecs are stopped. Neither side can hear each other.

##### RESTART

The speakerphone re-initializes itself to the last speakerphone mode (Full-duplex, transparent or Mute). This mode should be used to resume the speakerphone operation after Hold mode or when there is a significant change in the environmental conditions (e.g., parallel pickup) that may affect the speakerphone quality.

##### TRANSPARENT

The speakerphone works in full-duplex mode, but with no echo cancellation.

Samples from the microphone are transferred to the line, and samples from the line are transferred to the speaker, with no processing. This mode should be used only for tuning and testing the system.

##### LISTEN

Line is audible on the speaker, and the CompactSPEECH tone detectors are active.

In this mode, dialing can be performed with the GT command, and call progress can be implemented, since the busy and dial tone detectors are active.

## 2.0 Software (Continued)

The following pseudo-code demonstrates how to make a call from speakerphone mode:

```
while ( ) {
  EV = wait_event ( )
  case EV of:
    skpr_button_pressed:
      if (speakerphone_on) {
        SSM 0 // Put CompactSPEECH in idle mode
        first_digit = TRUE
        deactivate_digit_timeout_event ( )
      }
      else
        SSM 1 // Put CompactSPEECH in full-duplex speakerphone mode
    digit_pressed:
      if (first_digit) {
        SSM 4 // Enter LISTEN mode
        first_digit = FALSE
      }
      GT <dtmf_of_digit> // Dial the digit
      S // Stop. Note that after the S command
        // the CompactSPEECH is still in speakerphone mode
        enable_digit_timeout_event() // To "guess"
        when dialing is completed.
    digit_timeout_event:
      SSM 1 // Dialing is completed, Go back to full-duplex mode
      deactivate_digit_timeout_event()
  }
}
```

### 2.9.2 Speakerphone Terminology

#### SEND PATH

The signal path from the microphone (near-end speaker) to the line (far-end listener). The microphone is the input port, and line-out is the output port of this signal path.

#### RECEIVE PATH

The signal path from the line (far-end speaker) to the loud-speaker (near-end listener). The line-in is the input port, and the speaker is the output port for this signal path.

#### AEC

Acoustic Echo Controller. The part in the speakerphone algorithm that controls the echo in the send path.

#### EEC

Electric Echo Controller. The part in the speakerphone algorithm that controls the echo in the receive path.

## 2.0 Software (Continued)

### 2.10 SPEECH SYNTHESIS

Speech synthesis is the technology that is used to create messages out of predefined words and phrases stored in a vocabulary.

There are two kinds of predefined messages: fixed messages (e.g., voice menus in a voice-mail system) and programmable messages (e.g., time and day stamp, or the *You have n messages* announcement in a DAM).

A vocabulary includes a set of predefined words and phrases, needed to synthesize messages in any language. Applications which support more than one language require a separate vocabulary for each language.

#### 2.10.1 International Vocabulary Support (IVS)

IVS is a mechanism by which the CompactSPEECH processor can use several vocabularies stored on an external storage device. IVS enables CompactSPEECH to synthesize messages with the same meaning, but in different languages, from separate vocabularies.

Among IVS features:

- Multiple vocabularies are stored on a single storage device.
- Plug-and-play. The same microcontroller code is used for all languages.
- Synthesized and recorded messages use the same voice compression algorithm to achieve equal quality.
- Argumented sentences. (For example *You have <n> messages*.)
- Auto-synthesized time-and-day stamp (driven by the CompactSPEECH's clock).
- Support for various language and sentence structures:
  - One versus many (for example: *You have one message* vs. *You have two messages*).
  - None versus many (for example: *You have no message* vs. *You have two messages*).
  - Number synthesis (English—*Eighty* vs. French—*Quatre-vingt*).
  - Word order (English—*Twenty one* vs. German—*Einundzwanzig*).
  - Days of the week (Monday through Sunday vs. Sunday through Saturday).

#### 2.10.2 Vocabulary Design

There are several issues, sometimes conflicting, which must be addressed when designing a vocabulary.

**Vocabulary content** If memory space is not an issue, the vocabulary could contain all the required sentences, each recorded separately.

If memory space is a concern, the vocabulary must be compact; it should contain the minimum set of words and phrases required to synthesize all the sentences. The least memory is used when phrases and words that are common to more than one sentence are recorded only once, and the IVS tool is used to synthesize sentences out of them.

A good combination of sentence quality and memory space is achieved if you take the "compact" approach, and extend it to solve pronunciation problems. For example, the word *twenty* is pronounced differently when

used in the sentences *You have twenty messages* and *You have twenty two messages*. To solve this problem, words that are pronounced differently should be recorded more than once, each in the correct pronunciation.

#### Vocabulary recording

When recording vocabulary words, there is a compromise between space and quality. On one hand, the words should be recorded and saved in a compressed form, and you would like to use the best voice compression for that purpose. On the other hand, the higher the compression rate, the worse the voice quality.

Another issue to consider is the difference in voice quality between synthesized and recorded messages (e.g., between time-and-day stamp and incoming messages (ICMs) in a DAM environment). It is more pleasant to the human ear to hear them both in the same quality.

#### Vocabulary access

Sometimes compactness and high quality are not enough. There should be a simple and flexible interface to access the vocabulary elements. Not only the vocabulary, but also the code to access it should be compact.

When designing for a multi-lingual environment, there are more issues to consider. Each vocabulary should be able to handle language-specific structures and designed in a cooperative way with the other vocabularies so that the code to access each vocabulary is the same. When you use the command to synthesize the sentence *Monday, 12:30 PM*, you should not care in what language it is going to be played back.

#### 2.10.3 IVS Vocabulary Components

This section describes the basic concept of an IVS vocabulary, its components, and the relationships between them.

##### The basic concepts

An IVS vocabulary consists of words, sentences, and special codes that control the behavior of the algorithm which CompactSPEECH uses to synthesize sentences.

##### The word table

The words are the basic units in the vocabulary. You create synthesized sentences by combining words in the vocabulary. Each word in the vocabulary is given an index which identifies it in the word table.

Note that, depending on the language structures and sentences that you wish to synthesize, you may need to record some words more than once in the vocabulary. For example, if you synthesize the sentences: *you have twenty messages* and *you have twenty five messages*, the word *twenty* is pronounced differently. They should, therefore, be defined as two different words.

##### The number tables

The number tables allow you to treat numbers differently depending on the context.

Example 1: The number 1 can be announced as *one* as in *message number one* or as *first* as in *first message*.

## 2.0 Software (Continued)

**Example 2:** The number 0 can be announced as *no* as in *you have no messages* or as *oh* as in *monday, eight oh five am*.

A separate number table is required for each particular type of use. The number table contains the indices of the words in the vocabulary that are used to synthesize the number. Up to nine number tables can be included in a vocabulary.

### The sentence table

The sentence table describes the predefined sentences in the vocabulary. The purpose of this table is to make the microcontroller that drives the CompactSPEECH independent of the language being synthesized.

For example, if the serial flash and/or ROM contain vocabularies in various languages, and the first sentence in each vocabulary means *you have n messages*, the microcontroller switches languages by issuing the following command to CompactSPEECH:

```
SV <storage_media>,
<vocabulary_id>
```

Select a new vocabulary

The microcontroller software is thus independent of the grammar of the language in use.

The sentences consist of words, which are represented by their indices in the vocabulary.

### Sentence 0

All sentences but one are user defined. The CompactSPEECH treats the first sentence in the sentence table, i.e., sentence 0, in a special way to support time and

day announcement. It assumes that the sentence is designed for system and message time and day announcement and has one argument which is interpreted as follows:

0 - System time will be announced

1 - The time and day of the current message will be announced.

### Example 1:

When the microcontroller sends the command:

```
SAS 0, 0
```

The system time and day is announced.

### Example 2:

When the microcontroller sends the command:

```
SAS 0, 1
```

The current message time and day stamp is announced.

Figure 2-3 shows the interrelationship between the three types of tables:

### Control and option codes

The list of word indices alone cannot provide the entire range of sentences that the CompactSPEECH can synthesize. IVS control and option codes are used as special instructions that control the behavior of the speech synthesis algorithm in the CompactSPEECH.

For example, if the sentence should announce the time of day, the CompactSPEECH should be able to substitute the current day and time in the sentence. These control words do not represent recorded words, rather they instruct the CompactSPEECH to take special actions.

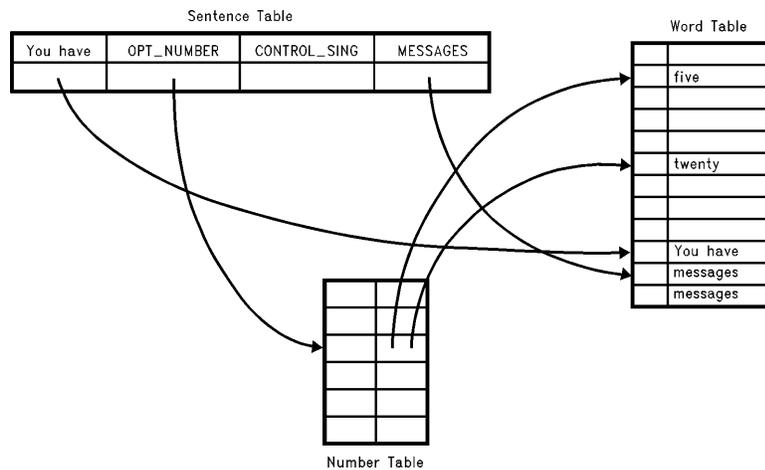


FIGURE 2-3. Relationship of IVS Tables

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## 2.0 Software (Continued)

### 2.10.4 The IVS Tool

The IVS tool includes two utilities:

- The DOS-based IVS Compiler
- IVSTOOL for Windows. A Windows 3.1 based utility.

The tools allow you to create vocabularies for the CompactSPEECH processor. They take you all the way from designing the vocabulary structure, through defining the vocabulary sentences, and recording the vocabulary words.

#### The IVS Compiler

The IVS compiler runs on MS-DOS (version 5.0 or later). It allows you to insert your own vocabulary, i.e., basic words and data used to create numbers and sentences, as directories and files in MS-DOS.

The IVS compiler then outputs a binary file containing that vocabulary. This information can be burned into an EPROM or serial flash for use by the CompactSPEECH software.

#### Voice Compression

Each IVS vocabulary can be compiled using either 5.2 kbit/s or 7.3 kbit/s voice compression algorithm. The user defines the compression rate before compilation. The CompactSPEECH automatically selects the required voice decompression algorithm when the SV command is used to select the active vocabulary.

#### The Graphical User Interface (GUI)

The IVS package includes a Windows utility that assists the vocabulary designer to synthesize sentences. With this utility, you can both compose sentences and listen to them.

### 2.10.5 How to Use the IVS Tool With the CompactSPEECH

The IVS tool creates IVS vocabularies, and stores them as a binary file. This file is burnt into a ROM device or programmed into a serial flash device using the INJ command. The CompactSPEECH SV command is used to select the required vocabulary. The SW, SO, SS and SAS commands

are used to synthesize the required word or sentence. The typical vocabulary-creation process is as follows:

1. Design the vocabulary.
2. Create the vocabulary files (as described in detail below). Use IVSTOOL for Windows 3.1 to simplify this process.
3. Record the words using any standard PC sound card and sound editing software, that can create .wav files.
4. Run the IVS compiler to compress the .wav files, and compile them and the vocabulary tables into an IVS vocabulary file.
5. Repeat steps 1 to 4 to create a separate IVS vocabulary for each language that you want to use.
6. Burn the IVS vocabulary files into a ROM (or serial flash) device. Use the INJ (Inject IVS) command to program the data into a serial flash device.
7. Once the vocabulary is in place, the speech synthesis commands of the CompactSPEECH can be used to synthesize sentences.

Figure 2-4 shows the vocabulary-creation process for a single table on a ROM or serial flash device.

### 2.11 INITIALIZATION

Use the following procedures to initialize the CompactSPEECH processor:

#### NORMAL INITIALIZATION

1. Reset the CompactSPEECH by activating the  $\overline{\text{RESET}}$  signal. (See Section 1.2.1.)
2. Issue a CFG (Configure CompactSPEECH) command to change the configuration according to your environment.
3. Issue an INIT (Initialize System) command to initialize the CompactSPEECH firmware.
4. Issue a series of TUNE commands to adjust the CompactSPEECH to the requirements of your system.

### 2.12 MICROWIRE SERIAL INTERFACE

MICROWIRE/PLUS™ is a synchronous serial communication protocol, originally implemented in National Semiconductor's COPS™ and HPC™ families of microcontrollers to minimize the number of connections, and thus the cost, of communicating with peripherals.

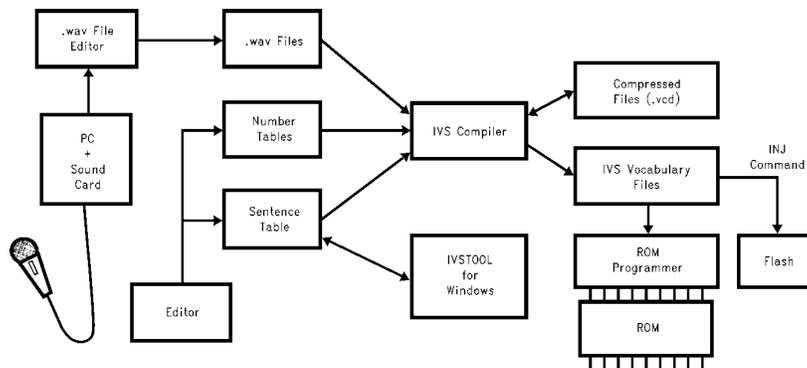


FIGURE 2-4. Creation of an IVS Vocabulary

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## 2.0 Software (Continued)

The CompactSPEECH MICROWIRE interface implements the MICROWIRE/PLUS interface in slave mode, with an additional ready signal. It enables a microcontroller to interface efficiently with the CompactSPEECH application.

The microcontroller is the protocol master, and provides the clock for the protocol. The CompactSPEECH supports clock rates of up to 400 kHz. This transfer rate refers to the bit transfer; the actual throughput is slower due to byte processing by the CompactSPEECH and the microcontroller.

Communication is handled in bursts of eight bits (one byte). In each burst the CompactSPEECH is able to receive and transmit eight bits of data. After eight bits have been transferred, an internal interrupt is issued for the CompactSPEECH to process the byte, or to prepare another byte for sending. In parallel, the CompactSPEECH sets  $\overline{\text{MWRDY}}$  to 1, to signal the microcontroller that it is busy with the byte processing. Another byte can be transferred only when the  $\overline{\text{MWRDY}}$  signal is cleared to 0 by the CompactSPEECH. When the CompactSPEECH transmits data, it expects to receive the value 0xAA before each transmitted byte. The CompactSPEECH reports any status change by clearing the  $\overline{\text{MWRQST}}$  signal to 0.

If a parameter of a CompactSPEECH command is bigger than one byte, the microcontroller should transmit the Most Significant Byte (MSB) first. If a return value is bigger than one byte, the CompactSPEECH transmits the MSB first.

### 2.13 SIGNAL DESCRIPTION

The following signals are used for the interface protocol. Input and output are relative to the CompactSPEECH.

#### INPUT SIGNALS

##### $\overline{\text{MWDIN}}$

MICROWIRE Data In. Used for input only, for transferring data from the microcontroller to the CompactSPEECH.

##### $\overline{\text{MWCLK}}$

This signal serves as the synchronization clock during communication. One bit of data is transferred on every clock cycle. The input data is available on  $\overline{\text{MWDIN}}$ , and is latched on the clock rising edge. The transmitted data is output on  $\overline{\text{MWDOU}}$  on the clock falling edge. The signal should remain low when switching  $\overline{\text{MWCS}}$ .

##### $\overline{\text{MWCS}}$

MICROWIRE Chip Select. The  $\overline{\text{MWCS}}$  signal is cleared to 0 to indicate that the CompactSPEECH is being accessed. Setting  $\overline{\text{MWCS}}$  to 1 causes the CompactSPEECH to start driving  $\overline{\text{MWDOU}}$  with bit 7 of the transmitted value. Setting the  $\overline{\text{MWCS}}$  signal resets the transfer-bit counter of the protocol, so the signal can be used to synchronize between the CompactSPEECH and the microcontroller.

To prevent false detection of access to the CompactSPEECH due to spikes on the  $\overline{\text{MWCLK}}$  signal, use this chip select signal, and toggle the  $\overline{\text{MWCLK}}$  input signal only when the CompactSPEECH is accessed.

#### OUTPUT SIGNALS

##### $\overline{\text{MWDOU}}$

MICROWIRE Data Out. Used for output only, for transferring data from the CompactSPEECH to the microcontroller. When the CompactSPEECH receives data it is echoed back to the microcontroller on this signal, unless the received data is 0xAA. In this case, the CompactSPEECH echoes a command's return value.

##### $\overline{\text{MWRDY}}$

MICROWIRE Ready. When active (0), this signal indicates that the CompactSPEECH is ready to transfer (receive or transmit) another byte of data.

This signal is set to 1 by the CompactSPEECH after each byte transfer has been completed. It remains 1, while the CompactSPEECH is busy reading the byte, writing the next byte, or executing the received command (after the last parameter has been received).  $\overline{\text{MWRDY}}$  is cleared to 0 after reset.

For proper operation after a hardware reset, this signal should be pulled up.

##### $\overline{\text{MWRQST}}$

MICROWIRE Request. When active (0), this signal indicates that new status information is available.  $\overline{\text{MWRQST}}$  is deactivated (set to 1), after the CompactSPEECH receives a GSW (Get Status Word) command from the microcontroller. After reset, this signal is active (0) to indicate that a reset occurred.  $\overline{\text{MWRQST}}$ , unlike all the signals of the communication protocol, is an asynchronous line that is controlled by the CompactSPEECH firmware.

### 2.13.1 Signal Use in the Interface Protocol

After reset, both  $\overline{\text{MWRQST}}$  and  $\overline{\text{MWRDY}}$  are cleared to 0.

The  $\overline{\text{MWRQST}}$  signal is activated to indicate that a reset occurred. The  $\text{EV\_RESET}$  bit in the status register is used to indicate a reset condition.

The GSW command should be issued after reset to verify that the  $\text{EV\_RESET}$  event occurred, and to deactivate the  $\overline{\text{MWRQST}}$  signal.

While the  $\overline{\text{MWCS}}$  signal is active (0), the CompactSPEECH reads data from  $\overline{\text{MWDIN}}$  on every rising edge of  $\overline{\text{MWCLK}}$ . CompactSPEECH also writes every bit back to  $\overline{\text{MWDOU}}$ . This bit is either the same bit which was read from  $\overline{\text{MWDIN}}$  (in this case it is written back as a synchronization echo after some propagation delay), or it is a bit of a value the CompactSPEECH transmits to the microcontroller (in this case it is written on every falling edge of the clock).

When a command has more than one parameter/return-value, the parameters/return-values are transmitted in the order of appearance. If a parameter/return-value is more than one byte long, the bytes are transmitted from the most significant to the least significant.

The  $\overline{\text{MWRDY}}$  signal is used as follows:

1. Active (0)  $\overline{\text{MWRDY}}$  signals the microcontroller that the last eight bits of data transferred to/from the voice module were accepted and processed (see below).
2. The  $\overline{\text{MWRDY}}$  signal is deactivated (set to 1 by the CompactSPEECH) after 8 bits of data were transferred to/from the CompactSPEECH. The bit is set following the falling edge of the eighth  $\overline{\text{MWCLK}}$  clock-cycle.
3. The  $\overline{\text{MWRDY}}$  signal is activated (cleared to 0) by the CompactSPEECH when it is ready to receive the first parameter byte (if there are any parameters) and so on till the last byte of parameters is transferred. An active  $\overline{\text{MWRDY}}$  signal after the last byte of parameters indicates that the command was parsed and (if possible) executed. If that command has a return value, the microcontroller must read the value before issuing a new command.

## 2.0 Software (Continued)

4. When a return value is transmitted, the MWRDY signal is deactivated after every byte, and activated again when the CompactSPEECH is ready to send another byte, or to receive a new command.

The MWRDY signal is activated (cleared to 0) after reset, and after a protocol time-out. (See Section 2.13.2.)

The MWRQST signal is used as follows:

1. The MWRQST signal is activated (cleared to 0), when the status word is changed.
2. The MWRQST signal remains active (0), until the CompactSPEECH receives a GSW command.

Figure 2-4 illustrates the sequence of activities during a MICROWIRE data transfer.

### 2.13.2 Interface Protocol Error Handling

#### Interface Protocol Time-Outs

Depending on the CompactSPEECH's state, if more than 20 ms–30 ms elapse between two consecutive byte transmissions, or two byte receptions, within the same command or return value, after the MWRDY signal is asserted, a time-out event occurs, and the CompactSPEECH responds as follows:

1. Sets the error bit in the status word to 1.
2. Sets the EV\_TIMEOUT bit in the error word to 1.
3. Activates the MWRQST signal (clears it to 0).
4. Activates the MWRDY signal (clears it to 0).
5. Waits for a new command. (After a time-out occurs, the microcontroller must wait at least four milliseconds before issuing the next command.)

#### Echo Mechanism

The CompactSPEECH echoes back to the microcontroller all the bits received by the CompactSPEECH. Upon detection of an error in the echo, the microcontroller should stop the protocol clock, which eventually causes a time-out error (i.e., ERR\_TIMEOUT bit is set in the error word).

**Note:** When a command has a return value, the CompactSPEECH transmits bytes of the return value instead of the echo value.

The CompactSPEECH transmits a byte as an echo when it receives the value 0xAA from the microprocessor. Upon detection of an error the CompactSPEECH activates the MWRQST signal, and sets the ERR\_COMM bit in the error word.

### 2.14 THE MASTER MICROWIRE INTERFACE

The CompactSPEECH's Master MICROWIRE controller implements the MICROWIRE/PUS interface in master mode. It enables the CompactSPEECH to control flash devices. Several devices may share the Master MICROWIRE channel. This can be implemented by connecting device selection signals to general purpose output ports.

#### 2.14.1 Master MICROWIRE Data Transfer

##### The Signals

The Master MICROWIRE controller's signals are the Master MICROWIRE serial CLock (MMCLK), the Master MICROWIRE serial Data OUT (MMDOUT) signal and the Master MICROWIRE serial Data In (MMDIN) signal.

The Master MICROWIRE controller can handle up to four flash devices. The CompactSPEECH uses the signals, CS0–CS3, as required for the number of devices in use, as device chip-select signals.

##### The Clock for Master MICROWIRE Data Transfer

Before data can be transferred, the transfer rate must be determined and set. The rate of data transfer on the Master MICROWIRE is determined by the Master MICROWIRE serial CLock (MMCLK) signal. This rate is the same as the Codec CLock (CCLK) signal. As long as the Master MICROWIRE is transferring data, the codec interface must be enabled and its sampling rate should not be changed.

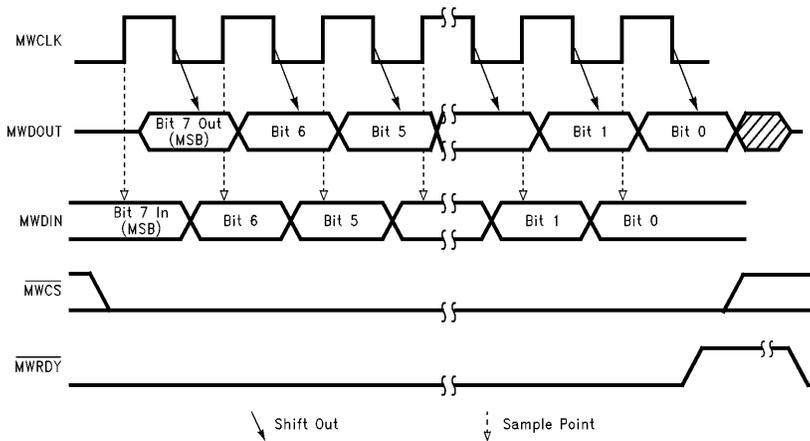


FIGURE 2-4. Sequence of Activities during a MICROWIRE Byte Transfer

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## 2.0 Software (Continued)

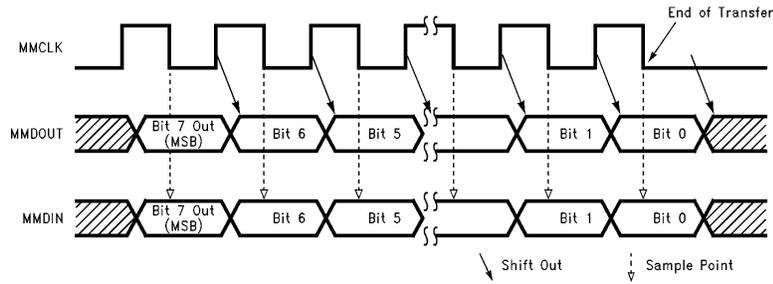


FIGURE 2-5. Master MICROWIRE Data Transfer

TL/EE/12868-31

### 2.15 COMMAND DESCRIPTION

The commands are listed in alphabetical order.

The execution time for all commands, when specified, includes the time required for the microcontroller to retrieve the return value, where appropriate.

The execution time does not include the protocol timing overhead, i.e., the execution times are measured from the moment that the command is detected as valid until the command is fully executed.

**Note:** Each command description includes an example application of the command. The examples show the opcode issued by the microcontroller, and the response returned by the CompactSPEECH. For commands which require a return value from the CompactSPEECH, the start of the return value is indicated by a thick vertical line.

#### CCIO Configure Codec I/O *config\_value*

Configures the voice samples paths in various states. It should be used to change the default CompactSPEECH configuration.

The *config\_value* parameter is encoded as follows:

- Bit 0** Loopback control.
  - 0: Loopback disable (default)
  - 1: Loopback enabled. During RECORD state, the input samples are echoed back unchanged (i.e., no volume control) to the codec.
- Bit 1** Codec input control
  - 0: Input is received via the line codec i.e., the codec which is controlled via CFS0. (default)
  - 1: Input is received via the speakerphone codec i.e., the codec which is controlled via CFS1.
- Bit 2-3** Codec output control.
  - 00: In PLAY, IDLE, SYNTHESIS and TONE\_\_GENERATE, output is to both codecs. In RECORD mode, output is to the non-input codec. Volume control is not supported in RECORD mode. If the loopback control bit is set, output is to both codecs (default).
  - 01: Output in all states is to the line codec
  - 10: Output in all states is to the speakerphone codec.
  - 11: Output in all states is to both codecs.
- Bits 4-7** Reserved.

#### Example

| CCIO 01        |  |    |    |
|----------------|--|----|----|
| Byte sequence: | Microcontroller  | 34 | 01 |
|                | CompactSPEECH  | 34 | 01 |
| Description:   | loopback enable. Input is from the line codec. Output goes to both codecs. |    |    |

#### CFG Configure CompactSPEECH *config\_value*

Configures the CompactSPEECH in various hardware environments. It should be used to change the default CompactSPEECH configuration.

The *config\_value* parameter is encoded as follows:

- Bit 0** Codec configuration.
  - 0: short-frame format (default)
  - 1: long-frame format. (Guaranteed by design, but not tested.)
- Bit 1** Reserved.
- Bit 2** Echo cancellation control.
  - 0: Echo cancellation off (default)
  - 1: Echo cancellation is on during playback.

Echo cancellation improves the performance of DTMF detection during playback. Echo cancellation can be turned on only with a system that can disable AGC during playback. A system with AGC that cannot be controlled (i.e., enabled/disabled) by the microcontroller must not turn on this bit.
- Bit 3** Reserved—must be cleared to 0.
- Bits 4-5** Reserved—must be set to 10.
- Bits 6-7** Reserved—must be cleared to 00.
- Bits 8-10** Number of installed flash devices.
  - Valid range 1 .. 4 flash devices.
  - Default is 1.
- Bits 11-15** Reserved—Must be cleared to 0.

**Note:** The CompactSPEECH automatically detects the type of flash device in use, i.e., NM29A040 or NM29A080.

## 2.0 Software (Continued)

### Example

| CFG 0324       |  |    |    |    |
|----------------|--|----|----|----|
| Byte sequence: | Microcontroller  | 01 | 03 | 24 |
|                | CompactSPEECH  | 01 | 03 | 24 |
| Description:   | Configure the CompactSPEECH to work with:<br>Codec that supports short-frame format.<br>Three, NM29A040, flash devices.<br>Echo cancellation on. |    |    |    |

### CMMSG Create Message tag num\_of\_blocks

Creates a new message with a message tag *tag*, allocates *num\_of\_blocks* 4 kbytes blocks for it, and sets the message pointer to the beginning of the message data. The command switches the CompactSPEECH to the **MSG\_OPEN** state.

The memory space available for the message data is computed as follows:

$$(127 \times \text{num\_of\_blocks} - 1) \times 32 \text{ bytes.}$$

Once a message is open i.e., the CompactSPEECH is in the **MSG\_OPEN** state, the message pointer can be set to any position on a page (32 bytes) boundary within the message with the SMSG command. The message contents can be modified with the WMSG command, and read with the RMSG command.

As long as the message is not closed by the S command, its length can be extended with the WMSG command. Once the message is closed, its length can not be extended.

The microcontroller must issue an S command to close the message and switch the CompactSPEECH to the **idle** state.

If the memory is full, EV\_MEMFULL is set in the status word and no message is created.

If the memory is not full, but there is not enough memory and the CompactSPEECH can not allocate the required memory space for the message, EV\_MEMLOW is set in the status word and no message is created.

### Example

| CMMSG 0101 01  |   |    |    |    |    |    |
|----------------|---|----|----|----|----|----|
| Byte sequence: | Microcontroller   | 33 | 01 | 01 | 00 | 01 |
|                | CompactSPEECH   | 33 | 01 | 01 | 00 | 01 |
| Description:   | Create a new message, and allocate 4 kbytes for its data. |    |    |    |    |    |

### CMT Cut Message Tail time\_length

Cut *time\_length* units, each of 10 ms duration, off the end of the current message. The maximum value of *time\_length* is 6550. Cut-time accuracy is  $\pm 0.14$  sec.

**Note:** If *time\_length* is longer than the total duration of the message, the EV\_NORMAL\_END event is set in the status word, and the message becomes empty (i.e., message length is 0), but is not deleted. Use the DM (Delete Message), or DMS (Delete Messages), command to delete the message.

### Example

| CMT 02BC       |  |    |    |    |
|----------------|--|----|----|----|
| Byte sequence: | Microcontroller                                    | 26 | 02 | BC |
|                | CompactSPEECH                                      | 26 | 02 | BC |
| Description:   | Cut the last seven seconds of the current message. |    |    |    |

### CVOC

### Check Vocabulary

Checks (checksum) if the IVS data was correctly programmed to the ROM or flash device.

If the vocabulary data is correct the return value is 1. Otherwise the return value is 0.

If the current vocabulary is undefined, ERR\_INVALID is reported.

### Example

| CVOC           |  |    |    |
|----------------|--|----|----|
| Byte sequence: | Microcontroller  | 2B | AA |
|                | CompactSPEECH  | 2B | 01 |
| Description:   | Check the current vocabulary.<br>The CompactSPEECH responds that the vocabulary is OK. |    |    |

### DM

### Delete Message

Deletes the current message. Deleting a message clears its message tag.

Deleting the current message does not cause a different message to become current. The current message is undefined. If, for example, you issue the GTM command to skip to the next message, the first message that is newer than the just deleted message is selected as the current message.

The memory space released by the deleted message is immediately available for recording new messages.

### Example

| DM             |                         |    |
|----------------|-------------------------|----|
| Byte sequence: | Microcontroller         | 0A |
|                | CompactSPEECH           | 0A |
| Description:   | Delete current message. |    |

### DMS

### Delete Messages tag\_ref tag\_mask

Deletes all messages whose message tags match the *tag\_ref* parameter. Only bits set in *tag\_mask* are compared i.e., a match is considered successful if:

$$\text{message tag and tag\_mask} = \text{tag\_ref and tag\_mask}$$

where **and** is a bitwise AND operation.

After the command completes execution, the current message is undefined. Use the GTM command to select a message to be the current message.

The memory space released by the deleted message is immediately available for recording new messages.

## 2.0 Software (Continued)

### Example

| DMS FFC2 003F  |  |    |    |    |    |    |
|----------------|--|----|----|----|----|----|
| Byte sequence: | Microcontroller  | 0B | FF | C2 | 00 | 3F |
|                | CompactSPEECH  | 0B | FF | C2 | 00 | 3F |
| Description:   | Delete all old incoming messages from mailbox Number 2 in a system where the message tag is encoded as follows:<br>Bits 0–2: mailbox ID<br>8 mailboxes indexed: 0 to 7<br>Bit 3: new/old message indicator<br>0: Message is old<br>1: Message is new<br>Bits 4–5: message type<br>00: ICM/memo<br>01: OGM<br>10: Call transfer message<br>Bits 6–15: not used<br><b>Note:</b> The description of the tag is an example only. All bits of the tag are user-definable. |    |    |    |    |    |

### GCFG Get Configuration Value

Returns a sequence of two bytes with the following information:

**Bits 0–7** Magic number, which specifies the CompactSPEECH firmware version.

**Bits 8–9** Memory type.

- 00: Reserved
- 01: Reserved
- 10: Serial Flash
- 11: Reserved

The command should be used together with the CFG and INIT commands during CompactSPEECH initialization. See the CFG command for more details, and an example of a typical initialization sequence.

### Example

| GCFG           |   |    |       |
|----------------|---|----|-------|
| Byte sequence: | Microcontroller   | 02 | AA AA |
|                | CompactSPEECH   | 02 | 02 01 |
| Description:   | Get the CompactSPEECH magic number. The CompactSPEECH responds that it is Version 1, with Serial Flash. |    |       |

### GEW Get Error Word

Returns the 2-byte error word.

#### THE ERROR WORD

The 16-bit error word indicates errors that occurred during execution of the last command. If an error is detected, the command is not processed; the EV\_ERROR bit in the status word is set to 1, and the MWRQST signal is activated (set to low).

The GEW command reads the error word. The error word is cleared during reset and after execution of the GEW command.

If errors ERR\_COMMAND or ERR\_PARAM occur during the execution of a command that has a return value, the return value is undefined. The microcontroller must still read the return value, to ensure proper synchronization.

| 15–9 | 8   | 7           | 6           | 5        | 4   | 3         | 2           | 1          | 0   |
|------|-----|-------------|-------------|----------|-----|-----------|-------------|------------|-----|
| Res  | Res | ERR_INVALID | ERR_TIMEOUT | ERR_COMM | Res | ERR_PARAM | ERR_COMMAND | ERR_OPCODE | Res |

The bits of the error word are used as follows:

#### ERR\_OPCODE

Illegal opcode. The command opcode is not recognized by the CompactSPEECH.

#### ERR\_COMMAND

Illegal command sequence. The command is not legal in the current state.

#### ERR\_PARAM

Illegal parameter. The value of the parameter is out of range, or is not appropriate for the command.

#### ERR\_COMM

Microcontroller MICROWIRE communication error.

#### ERR\_TIMEOUT

Time-out error. Depending on the CompactSPEECH's state, more than 20 ms to 30 ms elapsed between the arrival of two consecutive bytes (for commands that have parameters).

#### ERR\_INVALID

Command cannot be performed in current context.

### Example

| GEW            |   |    |       |
|----------------|---|----|-------|
| Byte sequence: | Microcontroller   | 1B | AA AA |
|                | CompactSPEECH   | 1B | 00 02 |
| Description:   | Get the CompactSPEECH error word (typically sent after GSW when EV_ERROR is reported in the status word). The CompactSPEECH responds:<br><b>ERR_OPCODE:</b> |    |       |

### GI Get Information *item*

Returns the 16-bit value specified by *item* from one of the internal registers of the CompactSPEECH.

*item* may be one of the following:

- 0: The duration of the last detected DTMF tone, in 10 ms units. The return value is meaningful only if DTMF detection is enabled, and the status word shows that a DTMF tone was detected.

## 2.0 Software (Continued)

1. The duration of the last detected busy tone in 10 ms units.
2. The energy level of the samples in the last 10 ms.
3. The energy level of the samples, in the last 10 ms, that are in the frequency range described in *Figure 2-1*. The return value is meaningful only if one of the tone detectors is enabled (bits 0,1 of the detectors mask; see the description of SDET command).

The return value is unpredictable for any other value of *item*.

### Example

| GI 0           |   |    |    |    |    |
|----------------|---|----|----|----|----|
| Byte sequence: | Microcontroller   | 25 | 00 | AA | AA |
|                | CompactSPEECH   | 25 | 00 | 00 | 06 |
| Description:   | Get the duration of the last detected DTMF tone.<br>The CompactSPEECH responds:<br><b>60 ms</b> |    |    |    |    |

### GL Get Length

Returns the length of the current message in multiples of 32 bytes.

The returned value includes the message directory information (64 bytes for the first block and 32 bytes for every other block), message data, and the entire last block of the message, even if the message occupies only a portion of the last block. Since a flash block includes 4096 bytes, the returned length may be bigger than the actual message length by up to 4095 bytes.

The minimum length of a message is one block, i.e., an empty message occupies 4 kbytes (the message length is:  $4096/32 = 128$ ).

### Example

| GL             |   |    |    |    |  |
|----------------|---|----|----|----|--|
| Byte sequence: | Microcontroller   | 19 | AA | AA |  |
|                | CompactSPEECH   | 19 | 02 | 00 |  |
| Description:   | Get the length of the current message.<br>The CompactSPEECH responds:<br><b>512</b><br>i.e., the message occupies 16384<br>(512 * 32) bytes |    |    |    |  |

### GMS Get Memory Status type

Returns the estimated total remaining recording time in seconds as a 16-bit unsigned integer. This estimate assumes 5.2 kbit/s with no silence compression: a real recording may be longer, according to the amount of silence detected and compressed.

The return value is dependent on the value of the *type* parameter as follows:

- 0: The remaining recording time is returned.
- 1: Returns 0. (For compatibility only.)
- 2: Same as 0. (For compatibility only.)

The return value is unpredictable for any other value of *type*.

### Example

| GMS 0          |   |    |    |    |    |
|----------------|---|----|----|----|----|
| Byte sequence: | Microcontroller   | 12 | 00 | AA | AA |
|                | CompactSPEECH   | 12 | 00 | 01 | 40 |
| Description:   | Return the remaining recording time.<br>The CompactSPEECH responds:<br><b>320 seconds</b> |    |    |    |    |

### GMT Get Message Tag

Returns the 16-bit tag associated with the current message. If the current message is undefined, ERR\_VALID is reported.

### Example

| GMT            |   |    |    |    |  |
|----------------|---|----|----|----|--|
| Byte sequence: | Microcontroller   | 04 | AA | AA |  |
|                | CompactSPEECH   | 04 | 00 | 0E |  |
| Description:   | Get the current message tag.<br>In a system where the message tag is encoded as described in the DMS command, the CompactSPEECH return value indicates that the message is a new ICM in mailbox Number 6. |    |    |    |  |

### GNM Get Number of Messages tag\_ref tag\_mask

Returns the number of messages whose message tags match the *tag\_ref* parameter. Only bits set in *tag\_mask* are compared, i.e., a match is considered successful if:

message tag and *tag\_mask* = *tag\_ref* and *tag\_mask*

where *and* is a bitwise AND operation.

The *tag\_ref* and *tag\_mask* parameters are each two bytes; the return value is also 2-bytes long.

For example, if *tag\_ref* = 42<sub>16</sub>, and *tag\_mask* = 3F<sub>16</sub>, the number of existing old messages whose user-defined tag is 2 is returned. See Section 2.6.1 for a description of message-tag encoding. If *tag\_mask* = 0, the total number of all existing messages is returned, regardless of the *tag\_ref* value.

### Example

| GNM<br>FFFE 0003 |  |    |    |    |             |
|------------------|--|----|----|----|-------------|
| Byte sequence:   | Microcontroller  | 11 | FF | FE | 00 03 AA AA |
|                  | CompactSPEECH  | 11 | FF | FE | 00 03 00 05 |
| Description:     | Get the number of messages which have bit 0 cleared, and bit 1 set, in their message tags.<br>CompactSPEECH responds that there are five messages which satisfy the request. |    |    |    |             |

## 2.0 Software (Continued)

### GSW

### Get Status Word

Returns the 2-byte status word.

### THE STATUS WORD

The CompactSPEECH processor has a 16-bit status word to indicate events that occur during normal operation. The CompactSPEECH asserts the  $\overline{MWRQST}$  signal (clears to 0), to indicate a change in the status word. This signal remains active until the CompactSPEECH receives a GSW command.

The status word is cleared during reset, and by the GSW command.

|         |          |        |     |    |           |             |         |          |            |               |             |               |   |
|---------|----------|--------|-----|----|-----------|-------------|---------|----------|------------|---------------|-------------|---------------|---|
| 15      | 14       | 13     | 12  | 11 | 10        | 9           | 8       | 7        | 6          | 5             | 4           | 3             | 0 |
| EV_DTMF | EV_RESET | EV_VOX | Res |    | EV_MEMLOW | EV_DIALTONE | EV_BUSY | EV_ERROR | EV_MEMFULL | EV_NORMAL_END | EV_DTMF_END | EV_DTMF_DIGIT |   |

The bits in the status word are used as follows:

#### EV\_DTMF\_DIGIT

DTMF digit. A value indicating a detected DTMF digit. (See the description of DTMF code in the GT command.)

#### EV\_DTMF\_END

1 = Ended detection of a DTMF tone. The detected digit is held in EV\_DTMF\_DIGIT.

#### EV\_NORMAL\_END

1 = Normal completion of operation, e.g., end of message playback.

#### EV\_MEMFULL

1 = Memory is full.

#### EV\_ERROR

1 = Error detected in the last command. You must issue the GEW command to return the error code and clear the error condition.

#### EV\_BUSY

1 = Busy tone detected. Use this indicator for call progress and line disconnection.

#### EV\_MEMLOW

1 = Not enough memory. (See CMSG command for further detail.)

#### EV\_DIALTONE

1 = Dial tone detected. Use this indicator for call progress and line disconnection.

### EV\_VOX

1 = a period of silence (no energy) was detected on the telephone line during recording. (See VOX\_TIME\_COUNT in Table 2-2.)

### EV\_RESET

When the CompactSPEECH completes its power-up—sequence and enters the **RESET** state, this bit is set to 1, and the  $\overline{MWRQST}$  signal is activated (cleared to 0).

Normally, this bit changes to 0 after performing the INIT command. If this bit is set during normal operation of the CompactSPEECH, it indicates an internal CompactSPEECH error. The microcontroller can recover from such an error by re-initializing the system.

### EV\_DTMF

1 = Started detection of a DTMF tone.

### Example

|                |  |    |       |
|----------------|--|----|-------|
| <b>GSW</b>     |  |    |       |
| Byte sequence: | Microcontroller  | 14 | AA AA |
|                | CompactSPEECH  | 14 | 00 40 |
| Description:   | Get the CompactSPEECH Status Word (typically sent after the $\overline{MWRQST}$ signal is asserted by the CompactSPEECH which indicates a change in the status word).<br>The CompactSPEECH responds that the memory is full. |    |       |

### GT

### Generate Tone *tone*

Generates the tone specified by the 1-byte *tone* parameter, until an S command is received.

Specify the tone by setting the bits of *tone* as follows:

**Bit 0** 1

**Bits 1–4** DTMF code.

Where the DTMF code is encoded as follows:

| Value (Hex) | DTMF Digit |
|-------------|------------|
| 0 to 9      | 0 to 9     |
| A           | A          |
| B           | *          |
| C           | #          |
| D           | B          |
| E           | C          |
| F           | D          |

## 2.0 Software (Continued)

**Bits 5–7** 0

To generate a single-frequency tone encode the bits as follows:

**Bit 0** 0

**Bits 1–5** 3–30

The value in bits 1–5 is multiplied by 100 to generate the required frequency (300 Hz–3000 Hz).

**Bits 6, 7** 0

The CompactSPEECH does not check for the validity of the tone specification. Invalid specification yields unpredictable results.

### Example

|                |   |    |    |
|----------------|---|----|----|
| <b>GT 0D20</b> |   |    |    |
| Byte sequence: | Microcontroller                           | 0D | 20 |
|                | CompactSPEECH                             | 0D | 20 |
| Description:   | Generate a single-frequency 1600 Hz tone. |    |    |

### GTD Get Time and Day *time\_\_day\_\_option*

Returns the time and day as a 2-byte value. *time\_\_day\_\_option* may be one of the following:

- 0: Get the system time and day.
- 1: Get the current message time-and-day stamp.

Any other *time\_\_day\_\_option* returns the time-and-day stamp of the current message.

Time of day is encoded as follows:

**Bits 0–2** Day of the week (1 through 7).

**Bits 3–7** Hour of the day (0 through 23).

**Bits 8–13** Minute of the hour (0 through 59).

**Bits 14–15** 00: The time was not set before the current message was recorded.

11: The time was set, i.e., the SETD (Set Time of Day) command was executed.

**Note:** If the current message is undefined, and *time\_\_day\_\_option* is 1, an ERR\_INVALID error is reported.

### Example

|                |   |    |    |    |    |
|----------------|---|----|----|----|----|
| <b>GTD 1</b>   |   |    |    |    |    |
| Byte sequence: | Microcontroller   | 0E | 01 | AA | AA |
|                | CompactSPEECH   | 0E | 01 | E8 | 29 |
| Description:   | <p>Get the current message time-and-day stamp.</p> <p>The CompactSPEECH responds that the message was created on the first day of the week at 5:40 AM. The return value also indicates that the SETD command was used to set the system time and day before the message was recorded.</p> <p><b>Note:</b> If the SAS command is used to announce the time-and-day stamp, "Monday" is announced as the first day of the week. For an external vocabulary, the announcement depends on the vocabulary definition.</p> <p>(See the <i>IVS User's Manual</i> for more details.)</p> |    |    |    |    |

### GTM Get Tagged Message *tag\_\_ref tag\_\_mask dir*

Selects the current message, according to instructions in *dir*, to be the first, *n*<sup>th</sup> next or *n*<sup>th</sup> previous message which complies with the equation:

message tag and *tag\_\_mask* = *tag\_\_ref* and *tag\_\_mask*

where *and* is a bitwise AND operation.

*dir* is one of the following:

- 0: Selects the first (oldest) message.
- 128: Selects the last (newest) message.
- n*: Selects the *n*<sup>th</sup> next message starting from the current message.
- n*: Selects the *n*<sup>th</sup> previous message starting from the current message.

**Note:** To select the *n*<sup>th</sup> message with a given tag to be the current message you must first select the first message that complies with the above equation, and then issue another GTM command with *n* – 1 as a parameter, to skip to the *n*<sup>th</sup> message.

If a message is found, it becomes the current message and 1 (TRUE) is returned. If no message is found, the current message remains unchanged and 0 (FALSE) is returned.

If *dir* is not 0 and the current message is undefined, the return value is unpredictable. After the command execution the current message may either remain undefined or change to any existing message. The only exception is when the GTM command is executed just after the DM command. (See the DM command description for further detail.)

To access the *n*<sup>th</sup> message, when *n* > 127, a sequence of GTM commands is required.

## 2.0 Software (Continued)

### Example

| GTM FFCE 003F 0 |  |    |    |    |    |    |    |    |
|-----------------|--|----|----|----|----|----|----|----|
| Byte sequence:  | Microcontroller  | 09 | FF | CE | 00 | 3F | 00 | AA |
|                 | CompactSPEECH  | 09 | FF | CE | 00 | 3F | 00 | 01 |
| Description:    | <p>Select the oldest of the new ICMs, in mailbox number 6, to be the current message. For a system where the message tag is encoded as described in the example for the DMS command. The CompactSPEECH return value indicates that there is such a message.</p> <p>The following pseudo-code demonstrates how to play all new ICMs. The messages are marked after being played.</p> <p>In mailbox number 6:</p> <pre> Return_val = GTM (FFCE, 003F, 1) While (ReturnVal == TRUE)   Begin     P() /* Play */     Message_tag = GMT() /* get message tag */     SMT(FFF7) /* Mark the message as 'old' */     GTM(FFCE, 003F, 1) /* Get next with same tag */   End </pre> |    |    |    |    |    |    |    |

### INIT

### Initialize System

Execute this command after the CompactSPEECH has been configured (see CFG and GCFG commands).

Performs a soft reset of the CompactSPEECH as follows:

- Initializes the message directory information. Messages are not deleted. To delete the messages, use the DM and DMS commands.
- Sets the detectors mask to 0.
- Sets the volume level that is controlled by the VC command, to 0.
- Sets the playback speed to normal (0).
- Switches to the **IDLE** state.
- Initializes the tone detectors.

The current message is undefined after INIT execution.

The tunable parameters are not affected by this command. They are set to their default values only during RESET.

### Example

| INIT           |                               |    |
|----------------|-------------------------------|----|
| Byte sequence: | Microcontroller               | 13 |
|                | CompactSPEECH                 | 13 |
| Description:   | Initialize the CompactSPEECH. |    |

### INJ

### Inject IVS data $n$ byte<sub>1</sub> . . . byte <sub>$n$</sub>

Injects vocabulary data of size  $n$  bytes to good flash blocks. This command programs flash devices, on a production line, with IVS vocabulary data. It is optimized for speed; all CompactSPEECH detectors are suspended during execution of the command. Use the CVOC command to check whether programming was successful.

If there is not enough memory space for the vocabulary data, ERR\_PARAM is set in the error word, and execution stops.

Flash blocks that include IVS data cannot be used for recording, even if only one byte of the block contains IVS data (e.g., if the vocabulary size is  $4k + 100$  bytes, two blocks of the flash are not available for message recording).

### Example

| INJ 128 Data   |                                      |    |    |    |    |    |                 |
|----------------|--------------------------------------|----|----|----|----|----|-----------------|
| Byte sequence: | Microcontroller                      | 29 | 00 | 00 | 00 | 80 | Vocabulary Data |
|                | CompactSPEECH                        | 29 | 00 | 00 | 00 | 80 | Echo of Data    |
| Description:   | Inject 128 bytes of vocabulary data. |    |    |    |    |    |                 |

### MR

### Memory Reset

Erases all good flash blocks and initializes the CompactSPEECH (i.e., does exactly what the INIT command does). Bad blocks, and blocks which are used for IVS vocabularies, are not erased.

**Note:** The command erases all messages and should be used with care.

### Example

| MR             |                                |    |
|----------------|--------------------------------|----|
| Byte sequence: | Microcontroller                | 2A |
|                | CompactSPEECH                  | 2A |
| Description:   | Erase all Serial Flash blocks. |    |

### P

### Playback

Begins playback of the current message. The CompactSPEECH state changes to **PLAY**. When playback is complete, the CompactSPEECH sets the EV\_NORMAL\_END bit in the status word, and activates (clears to 0) the MWRQST signal. Playback can be paused with the PA command, and can be resumed later with the RES command.

If the current message is undefined, ERR\_INVALID is reported.

## 2.0 Software (Continued)

### Example

|                |                           |    |
|----------------|---------------------------|----|
| <b>P</b>       |                           |    |
| Byte sequence: | Microcontroller           | 03 |
|                | CompactSPEECH             | 03 |
| Description:   | Play the current message. |    |

### PA Pause

Suspends the execution of the current R, P, GT, SO, SW, SS or SAS command. The PA command does not change the state of the CompactSPEECH; execution can be resumed with the RES command.

**Note:** DTMF and tone detectors remain active during Pause.

### Example

|                |                                      |    |
|----------------|--------------------------------------|----|
| <b>PA</b>      |                                      |    |
| Byte sequence: | Microcontroller                      | 1C |
|                | CompactSPEECH                        | 1C |
| Description:   | Suspend playback of current message. |    |

### PDM Go To Power-down Mode

Switches the CompactSPEECH to power-down mode (see Section 1.2.3 for details). Sending any command while in power-down mode resets the CompactSPEECH detectors, and returns the CompactSPEECH to normal operation mode.

### Example

|                |   |    |
|----------------|---|----|
| <b>PDM</b>     |   |    |
| Byte sequence: | Microcontroller                           | 1A |
|                | CompactSPEECH                             | 1A |
| Description:   | Put the CompactSPEECH in power-down mode. |    |

### R Record tag

Records a new message with message tag *tag*. The CompactSPEECH state changes to **RECORD**. The R command continues execution until stopped by the S command. Recording can be paused with the PA command, and can be resumed later with the RES command.

If the memory becomes full, recording stops and EV\_MEMFULL is set in the status word.

### Example

|                |   |    |    |    |
|----------------|---|----|----|----|
| <b>R 000E</b>  |   |    |    |    |
| Byte sequence: | Microcontroller   | 0C | 00 | 0E |
|                | CompactSPEECH   | 0C | 00 | 0E |
| Description:   | Record a new ICM in mailbox Number 6 in a system where the message tag is encoded as described in the example of the DMS command. |    |    |    |

### RDET Reset Detectors *detectors\_\_reset\_\_mask*

Resets the CompactSPEECH tone and energy detectors according to the value of the *detectors\_\_reset\_\_mask* parameter. A bit set to 1 in the mask, resets the corresponding detector. A bit cleared to 0 is ignored.

The 1-byte *detectors\_\_reset\_\_mask* is encoded as follows:

**Bit 0** Reset the busy and dial tone detectors.

**Bits 1–4** Reserved. Must be cleared to 0.

**Bit 5** Reset the no energy (VOX) detector.

**Bit 6** Reset the DTMF detector.

**Bit 7** Reserved. Must be cleared to 0.

### Example

|                |                         |    |    |
|----------------|-------------------------|----|----|
| <b>RDET 20</b> |                         |    |    |
| Byte sequence: | Microcontroller         | 2C | 20 |
|                | CompactSPEECH           | 2C | 20 |
| Description:   | Reset the VOX detector. |    |    |

### RES Resume

Resumes the activity that was suspended by the PA, SF or SB commands.

### Example

|                |   |    |
|----------------|---|----|
| <b>RES</b>     |   |    |
| Byte sequence: | Microcontroller   | 1D |
|                | CompactSPEECH   | 1D |
| Description:   | Resume playback which was suspended by either the PA, SF or SB command. |    |

### RMSG Read Message *data*

Returns 32 bytes of *data* from the current position of the message pointer, and advances the message pointer by 32 bytes.

If the CompactSPEECH was in the **IDLE** state, the command opens the current message, switches the CompactSPEECH to the **MSG\_OPEN** state, sets the message pointer to the beginning of the message data, and returns the 32 bytes of *data*.

The microcontroller must issue an S command to close the message, and switch the CompactSPEECH to the **IDLE** state.

If the current message is undefined, ERR\_INVALID is reported.

Trying to read beyond the end of the message will set the EV\_NORMAL\_END event and the CompactSPEECH will switch to the **IDLE** state. In this case, the return value is undefined and should be ignored.

### Example

|                  |  |    |                  |        |
|------------------|--|----|------------------|--------|
| <b>RMSG Data</b> |  |    |                  |        |
| Byte sequence:   | Microcontroller                                | 32 | AA               | AA ... |
|                  | CompactSPEECH                                  | 32 | 32 bytes of data |        |
| Description:     | Read 32 bytes from the current message memory. |    |                  |        |

### RRAM Read Memory

Exists for compatibility only. Use RMSG instead.

### S Stop

Stops execution of the current command and switches the CompactSpeech to the **IDLE** state. S may be used to stop the execution of all asynchronous commands.

## 2.0 Software (Continued)

### Example

|                |   |    |
|----------------|---|----|
| <b>S</b>       |   |    |
| Byte sequence: | Microcontroller   | 00 |
|                | CompactSPEECH   | 00 |
| Description:   | Stop current activity (e.g., playback, recording) and put the CompactSPEECH in <b>IDLE</b> state. |    |

### SAS Say Argumented Sentence *sentence\_n arg*

Announces sentence number *sentence\_n* of the currently selected vocabulary, and passes *arg* to it. *sentence\_n* and *arg* are each 1-byte long.

When playing is complete, the CompactSPEECH sets the EV\_NORMAL\_END bit in the status word, and activates the MWRQST signal.

If the current vocabulary is undefined, ERR\_INVALID is reported.

### Example

|                  |  |    |       |
|------------------|--|----|-------|
| <b>SAS 00 03</b> |  |    |       |
| Byte sequence:   | Microcontroller  | 1E | 00 03 |
|                  | CompactSPEECH  | 1E | 00 03 |
| Description:     | Announce the first sentence in the sentence table of the currently selected vocabulary with "3" as the actual parameter. |    |       |

### SB Skip Backward *time\_length*

Skips backward in the current message *time\_length* units, each of 0.2s duration, and causes message playback to pause. *time\_length* is a 2-byte parameter that can have any value up to 320, i.e., 64s. The skip accuracy is 5%. This command is meaningful only in the **PLAY** state. The RES command must be issued to continue playback.

If the beginning of the message is detected, during execution of the SB command, execution is terminated, the EV\_NORMAL\_END bit in the status register is set, the MWRQST signal is activated, and the CompactSPEECH switches to the **IDLE** state.

If *time\_length* is greater than 320, ERR\_PARAM is set in the error word.

Playback speed does not affect the behavior of this command.

### Example

|                |   |    |       |
|----------------|---|----|-------|
| <b>SB 19</b>   |   |    |       |
| Byte sequence: | Microcontroller   | 23 | 00 19 |
|                | CompactSPEECH   | 23 | 00 19 |
| Description:   | Skip back five seconds from the current position in the message being played. |    |       |

### SDET Set Detectors Mask *detectors\_mask*

Controls the reporting of detection for tones and VOX according to the value of the *detectors\_mask* parameter. A bit set to 1 in the mask, enables the reporting of the corresponding detector. A bit cleared to 0 disables the reporting. Disabling reporting of a detector does not stop or reset the detector.

The 1-byte *detectors\_mask* is encoded as follows:

**Bit 0** Report detection of a busy tone.

**Bit 1** Report detection of a dial tone.

**Bits 2–4** Reserved. Must be cleared to 0.

**Bit 5** Report detection of no energy (VOX) on the line. (The VOX attributes are specified with the tunable parameters VOX\_TIME\_COUNT and VOX\_ENERGY\_LEVEL.)

**Bit 6** Report the ending of a detected DTMF.

**Bit 7** Report the start of a detected DTMF (up to 40 ms after detection start).

### Example

|                |   |    |    |
|----------------|---|----|----|
| <b>SDET A3</b> |   |    |    |
| Byte sequence: | Microcontroller   | 10 | A3 |
|                | CompactSPEECH   | 10 | A3 |
| Description:   | Set reporting of all CompactSPEECH detectors, except for end-of-DTMF. |    |    |

### SE

#### Skip to End of Message

This command is valid only in the **PLAY** state. When invoked, playback is suspended (as for the PA command), and a jump to the end of the message is performed. Playback remains suspended after the jump.

### Example

|                |                                 |    |
|----------------|---------------------------------|----|
| <b>SE</b>      |                                 |    |
| Byte sequence: | Microcontroller                 | 24 |
|                | CompactSPEECH                   | 24 |
| Description:   | Skip to end of current message. |    |

### SETD

#### Set Time and Day *time\_and\_day*

Sets the system time and day as specified by bits 0–13 in the 2-byte *time\_and\_day* parameter. The *time\_and\_day* parameter is encoded as follows:

**Bits 0–2** Day of the week (1 through 7).

**Bits 3–7** Hour of the day (0 through 23).

**Bits 8–13** Minute of the hour (0 through 59).

**Bits 14–15** These bits must be set to 1.

If *time\_and\_day* value is not valid, ERR\_PARAM is set in the error word.

### Example

|                  |                                     |    |       |
|------------------|-------------------------------------|----|-------|
| <b>SETD 0E09</b> |                                     |    |       |
| Byte sequence:   | Microcontroller                     | 0F | 0E 09 |
|                  | CompactSPEECH                       | 0F | 0E 09 |
| Description:     | Set time and day to Monday 1:30 AM. |    |       |

## 2.0 Software (Continued)

### SF Skip Forward *time\_length*

Skips forward in the current message *time\_length* units, each of 0.2s duration, and causes message playback to pause. *time\_length* is a 2-byte parameter that can have any value up to 320, i.e., 64s. The skip accuracy is 5%. This command is meaningful only in the **PLAY** state. The RES command must be issued to continue playback.

If the end of the message is detected during execution of SF, execution of the command is terminated, the EV\_NORMAL\_END bit in the status register is set, the MWRQST signal is activated and the CompactSPEECH switches to the **IDLE** state.

If *time\_length* is greater than 320, ERR\_PARAM is set in the error word.

Playback speed does not affect the behavior of this command.

#### Example

|                |  |    |       |
|----------------|--|----|-------|
| <b>SF 19</b>   |  |    |       |
| Byte sequence: | Microcontroller  | 22 | 00 19 |
|                | CompactSPEECH  | 22 | 00 19 |
| Description:   | Skip forward five seconds from the current position in the message being played. |    |       |

### SMSG Set Message Pointer *num\_of\_pages*

Set the message pointer to (*num\_of\_pages* x 32) bytes from the beginning of the current message data.

If (*num\_of\_pages* x 32) is greater than the message length, EV\_NORMAL\_END is set in the status word, the message pointer is set to the end of the message, and the CompactSPEECH switches to the **IDLE** state.

#### Example

|                |   |    |       |
|----------------|---|----|-------|
| <b>SMSG 10</b> |   |    |       |
| Byte sequence: | Microcontroller   | 30 | 00 0A |
|                | CompactSPEECH   | 30 | 00 0A |
| Description:   | Set the message pointer to 32 bytes from the beginning of the current message data. |    |       |

### SMT Set Message Tag *message\_tag*

Sets the tag of the current message. The 2-byte *message\_tag* can be used to implement mailbox functions by including the mailbox number in the tag, or to handle old and new messages differently by using one bit in the tag to mark the message as old or new. See Section 2.6.1.

To change the tag of a message, we recommend that you read the message tag, modify it, and write it back.

**Note 1:** Message tag bits can only be cleared. Message tag bits are set only when a message is first created.

**Note 2:** If the current message is undefined, ERR\_INVALID is reported.

**Note 3:** Bit 15 of the message tag is used to select the voice compression algorithm and should not be modified after recording.

#### Example

|                  |  |    |       |
|------------------|--|----|-------|
| <b>SMT FF F7</b> |  |    |       |
| Byte sequence:   | Microcontroller  | 05 | FF F7 |
|                  | CompactSPEECH  | 05 | FF F7 |
| Description:     | Mark the current message as old in a system where the message tag is encoded as described in the example of the DMS command.<br>Note that the CompactSPEECH ignores bits in the tag which are set to 1; only bit 3 is modified in the message tag. |    |       |

### SO Say One Word *word\_number*

Plays the word number *word\_number* in the current vocabulary. The 1-byte *word\_number* may be any value from 0 through the index of the last word in the vocabulary.

When playback of the selected word has been completed, the CompactSPEECH sets the EV\_NORMAL\_END bit in the status word, and activates the MWRQST signal.

If *word\_number* is not defined in the current vocabulary, or if it is an IVS control or option code, ERR\_PARAM is set in the error word.

If the current vocabulary is undefined, ERR\_INVALID is reported.

#### Example

|                |   |       |
|----------------|---|-------|
| <b>SO 00</b>   |   |       |
| Byte sequence: | Microcontroller   | 07 00 |
|                | CompactSPEECH   | 07 00 |
| Description:   | Announce the first word in the word table of the currently selected vocabulary. |       |

### SPS Set Playback Speed *speed*

Sets the speed of message playback as specified by *speed*. The new speed applies to all recorded messages and synthesized messages (only if synthesized using external voice synthesis), until changed by another SPS command. If this command is issued while the CompactSPEECH is in the **PLAY** state, the speed also changes for the message currently being played.

*speed* may be one of 13 values, from -6 to +6. A value of 0 represents normal speed.

Note that a negative *speed* value represents an increase in speed, a positive value represents a decrease in speed.

The change in speed is approximate, and depends on the recorded data.

If *speed* is not in the -6 to +6 range, ERR\_PARAM is set in the error word.

#### Example

|                |                           |       |
|----------------|---------------------------|-------|
| <b>SPS FB</b>  |                           |       |
| Byte sequence: | Microcontroller           | 16 FB |
|                | CompactSPEECH             | 16 FB |
| Description:   | Set playback speed to -5. |       |

### SS Say Sentence *sentence\_n*

Say sentence number *sentence\_n* of the currently selected vocabulary. *sentence\_n* is 1-byte long.

If the sentence has an argument, 0 is passed as the value for this argument.

## 2.0 Software (Continued)

When playing has been completed, the CompactSPEECH sets the EV\_NORMAL\_END bit in the status word, and activates the MWRQST signal.

If *sentence\_n* is not defined in the current vocabulary, ERR\_PARAM is set in the error word.

If the current vocabulary is undefined, ERR\_INVALID is reported.

### Example

|                |   |    |    |
|----------------|---|----|----|
| <b>SS 00</b>   |   |    |    |
| Byte sequence: | Microcontroller   | 1F | 00 |
|                | CompactSPEECH   | 1F | 00 |
| Description:   | Announce the first sentence in the sentence table of the currently selected vocabulary. |    |    |

### SSM Set Speakerphone Mode *mode*

Sets the speakerphone to the *mode* mode of operation. The command is valid when the CompactSPEECH is in IDLE state. *mode* can be one of:

- 0 OFF  
Deactivate the speakerphone, and return the CompactSPEECH to normal operation mode.
- 1 ON  
Put the CompactSPEECH in speakerphone mode and activate speakerphone in full-duplex mode i.e., with full cancellation of both the acoustic and the electrical echoes. Tone detectors are not active. Gains in the Send and Receive paths are set by the relevant tunable parameters.
- 2 TRANSPARENT  
Activate the speakerphone with no echo cancellation. (This mode is used for system tuning.)
- 3 MUTE  
Activate speakerphone, while generating silence on the line. Tone detectors are not active.
- 4 LISTEN  
The line is audible on the speaker. Tone detectors are active.
- 5 Reserved
- 6 RESTART  
Restart the current speakerphone mode. This mode differs from ON; it does not require full initialization of the speakerphone. It should be used to resume the speakerphone operation after HOLD mode or to adjust to an environment change (e.g., parallel pickup).
- 7 HOLD  
Stop the codec interrupts. Neither side can hear each other.

### Example

|                |   |    |    |
|----------------|---|----|----|
| <b>SSM 1</b>   |   |    |    |
| Byte sequence: | Microcontroller   | 2F | 01 |
|                | CompactSPEECH   | 2F | 01 |
| Description:   | Put the CompactSPEECH into Speakerphone mode, and set the speakerphone to full-duplex mode. |    |    |

### SV

#### Set Vocabulary Type *type id*

Selects the vocabulary table to be used for voice synthesis. The vocabulary type is set according to the 1-byte *type* parameter:

- 0: For compatibility only
- 1: External vocabulary in ROM
- 2: External vocabulary in Serial Flash
- All others: Reserved

The host is responsible to select the current vocabulary, with SV, before using an SO, SW, SS or SAS command.

Each external vocabulary table has a unique *id* which is part of the vocabulary internal header (see the *IVS User's Manual* for more details). If *type* is 1 or 2, the CompactSPEECH searches for the one byte *id* parameter in each vocabulary table header until a match is found.

If the *id* parameter does not point to a valid IVS vocabulary ERR\_PARAM is set in the error word.

### Example

|                 |   |    |    |    |
|-----------------|---|----|----|----|
| <b>SV 02 03</b> |   |    |    |    |
| Byte sequence:  | Microcontroller   | 20 | 02 | 03 |
|                 | CompactSPEECH   | 20 | 02 | 03 |
| Description:    | Select the vocabulary with vocabulary-id 3, which resides on Serial Flash, as the current vocabulary. |    |    |    |

### SW

#### Say Words *n word<sub>1</sub> . . . word<sub>n</sub>*

Plays *n* words, indexed by *word<sub>1</sub>* to *word<sub>n</sub>*. On completion, the EV\_NORMAL\_END bit in the status word is set, and the MWRQST signal goes low.

If one of the words is not defined in the current vocabulary, or if it is an IVS control or option code, or if *n* > 8, ERR\_PARAM is reported.

If the current vocabulary is undefined, ERR\_INVALID is reported.

### Example

|                    |   |    |    |    |    |
|--------------------|---|----|----|----|----|
| <b>SW 02 00 00</b> |   |    |    |    |    |
| Byte sequence:     | Microcontroller   | 21 | 02 | 00 | 00 |
|                    | CompactSPEECH   | 21 | 02 | 00 | 00 |
| Description:       | Announce the first word, in the word table of the currently selected vocabulary, twice. |    |    |    |    |

### TUNE

#### Tune *index parameter\_\_value*

Sets the value of the tunable parameter identified by *index* (one byte) to the 2-byte value, *parameter\_\_value*. This command may be used to tune the DSP algorithms to a specific Data Access Arrangement (DAA) interface, or to change other parameters. If you do not use TUNE, the CompactSPEECH uses default values.

If *index* does not point to a valid tunable parameter, ERR\_PARAM is set in the error word.

**Note:** The tunable parameters are assigned with their default values on application of power. The INIT command does not affect these parameters.

Table 2-2 describes the tunable parameters, their index numbers and their default values.

## 2.0 Software (Continued)

**TABLE 2-2. Tunable Parameters**

| Index | Parameter Name          | Description  | Default |
|-------|-------------------------|--|---------|
| 0–3   | Reserved                |  | —       |
| 4     | __SIL__THRESHOLD        | Prevents speech from being interpreted as silence. The silence detection algorithm has an adaptive threshold, which is changed according to the noise level. This parameter is, therefore, only the initial threshold level.<br>Legal values: 9216 to 13824 in 512 (6 dB) steps.   | 11264   |
| 5     | __SIL__THRESHOLD__STEP  | Defines the adaptive threshold changes step.<br>If this threshold is too low, the threshold converges too slowly. If it is too high, silence detection is too sensitive to any noise.<br>Legal values: 3 to 48.  | 12      |
| 6     | __SIL__BURST__THRESHOLD | The minimum time period for speech detection during silence. As this threshold increases, the time period interpreted as silence increases.<br>If this threshold is too low, a burst of noise is detected as speech. If it is too high, words may be partially cut off.<br>Legal values: 1 to 3.   | 2       |
| 7     | __SIL__HANG__THRESHOLD  | The minimum time period for silence detection, during speech. As this threshold increases, the time period interpreted as silence decreases.<br>If this threshold is too low, words may be partially cut off. If it is too high, silence is detected.<br>Legal values: 8 to 31.  | 15      |
| 8     | __SIL__ENABLE           | Silence compression control.<br>0 turns silence compression off.   | 1       |
| 9     | __ENERGY__FACTOR        | Determines the energy level used to synthesize silence. For the default value, the energy levels of the synthesized silence and the recorded silence are the same.<br>If you divide (multiply) the default value by two, the synthesized silence is 6 dB less (more) than the level of the recorded silence.<br>Legal values: 1024 to 16384. | 8192    |
| 10    | VOX__ENERGY__THRESHOLD  | This constant determines the minimum energy level at which voice is detected. Below this level, it is interpreted as silence. If you divide (multiply) the value by 2 you get 3 dB decrease (increase) in the threshold.<br>Legal values: 0 to 65535.  | 12      |
| 11    | Reserved                |  |         |
| 12    | VOX__TIME__COUNT        | This constant, in units of 10 ms, determines the period of silence before the CompactSPEECH reports silence. The accuracy of the constant is $\pm 10$ ms.<br>Legal values: 0 to 65535.   | 700     |
| 13–15 | Reserved                |  |         |

## 2.0 Software (Continued)

**TABLE 2-2. Tunable Parameters (Continued)**

| Index | Parameter Name               | Description  | Default |
|-------|------------------------------|--|---------|
| 16    | TONE__GENERATION__LEVEL      | Controls the energy level at which DTMF and other tones are generated. Each unit represents 3 dB. The default level is the reference level.<br><br>For example, if you set this parameter to 4, the energy level is 6 dB less than the default level. The actual output level is the sum of TONE__GENERATION__LEVEL and the VOL__LEVEL variable, controlled by the VC command. The tones are distorted when the level is set too high.<br><br>Legal values:<br>$0 \leq \text{TONE\_GENERATION\_LEVEL} + \text{VOL\_LEVEL} \leq 12$ .   | 6       |
| 17    | Reserved                     |  |         |
| 18    | TONE__TIME__COUNT            | Controls the duration of a tone before it is reported as a dial tone, in 10 ms units. The accuracy of the constant is $\pm 10$ ms.<br><br>Legal values: 0 to 65535.  | 700     |
| 19    | TONE__ON__ENERGY__THRESHOLD  | Minimum energy level at which busy and dial tones are detected as ON (after 700 Hz filtering). If you divide (multiply) the value by 2 you get a 3 dB decrease (increase) in the threshold.<br><br>The mapping between energy level and the parameter value is as follows (results were measured on the codec output when a 400 Hz tone was injected to the codec input):<br><br>Tunable value                      Energy threshold (dB-V)<br>10                                      -31.8<br>20                                      -28.6<br>100                                     -21.7<br>500                                     -14.7<br>8000                                  -2.5<br><br>Legal values: 0 to 65535. | 160     |
| 20    | TONE__OFF__ENERGY__THRESHOLD | Maximum energy level at which busy and dial tones are detected as OFF (after 700 Hz filtering). If you divide (multiply) the value by 2 you get a 3 dB decrease (increase) in the threshold.<br><br>The mapping between energy level and the parameter value is the same as for TONE__ON__ENERGY__THRESHOLD.<br><br>Legal values: 0 to 65535.  | 110     |
| 21    | VCD__LEVEL                   | Controls the energy during playback and external voice synthesis. Each unit represents 3 dB. The default level is the reference level.<br><br>For example, if you set this parameter to 4, the energy level is 6 dB less than the default level. The actual output level is the sum of VCD__LEVEL and the VOL__LEVEL variable, controlled by the VC command. Speech is distorted when the level is set too high.<br><br>Legal values:<br>$0 \leq \text{VCD\_LEVEL} + \text{VOL\_LEVEL} \leq 12$ .  | 6       |
| 22    | VOX__TOLERANCE__TIME         | Controls the maximum energy period, in 10 ms units, that does NOT reset the vox detector.<br><br>Legal values: 0 to 255.   | 3       |
| 23    | MIN__BUSY__DETECT__TIME      | Minimum time period for busy detection, in 10 ms units. The accuracy of the constant is $\pm 10$ ms.<br><br>Legal values: 0 to 65535.  | 600     |
| 24    | ECHO__DELAY                  | The near-echo delay in samples. The sampling rate is 8000 Hz (i.e., 125 $\mu$ s per sample).<br><br>Legal values: 0 to 16.   | 4       |
| 25    | Reserved                     |  |         |
| 26    | DTMF__REV__TWIST             | Controls the reverse twist level at which CompactSPEECH detects DTMF tones. While the normal twist is set at 8 dB, the reverse twist can be either 8 dB (default) or 4 dB (if this parameter is set to 1).   | 0       |

## 2.0 Software (Continued)

**TABLE 2-2. Tunable Parameters (Continued)**

| Index        | Parameter Name            | Description  | Default      |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
|--------------|---------------------------|--|--------------|-------------------|---|---|---|-------|---|-------|---|-------|---|-------|---|-------|---|-------|---|--------|------|--------|----|
| 27           | DTMF__TWIST__LEVEL        | <p>A one-byte value that controls the twist level of a DTMF tone, generated by the GT command, by controlling the energy level of each of the two tones (low frequency and high frequency) composing the DTMF tone. The Least Significant Nibble (LSN) controls the low tone and the Most Significant Nibble (MSN) controls the high tone. The energy level of each tone, as measured at the output of a TP3054 codec (before the DAA) connected to the CompactSPEECH is summarized in the following table:</p> <table border="1"> <thead> <tr> <th>Nibble Value</th> <th>Tone Energy (dBV)</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>0</td> </tr> <tr> <td>1</td> <td>-17.8</td> </tr> <tr> <td>2</td> <td>-14.3</td> </tr> <tr> <td>3</td> <td>-12.9</td> </tr> <tr> <td>4</td> <td>-12.4</td> </tr> <tr> <td>5</td> <td>-12.0</td> </tr> <tr> <td>6</td> <td>-11.9</td> </tr> <tr> <td>7</td> <td>-11.85</td> </tr> <tr> <td>8-15</td> <td>-11.85</td> </tr> </tbody> </table> <p>The volume of the generated DTMF tone during measurements was 6. (TONE__GENERATION__LEVEL + VOL__LEVEL = 6).<br/>For the default level, the high tone is -14.3 dBV and the low tone is -12.4 dBV, which gives a DTMF twist level of 1.9 dB.<br/>The energy level of a single generated tone is the level of the low tone.</p> | Nibble Value | Tone Energy (dBV) | 0 | 0 | 1 | -17.8 | 2 | -14.3 | 3 | -12.9 | 4 | -12.4 | 5 | -12.0 | 6 | -11.9 | 7 | -11.85 | 8-15 | -11.85 | 66 |
| Nibble Value | Tone Energy (dBV)         |  |              |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
| 0            | 0                         |  |              |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
| 1            | -17.8                     |  |              |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
| 2            | -14.3                     |  |              |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
| 3            | -12.9                     |  |              |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
| 4            | -12.4                     |  |              |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
| 5            | -12.0                     |  |              |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
| 6            | -11.9                     |  |              |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
| 7            | -11.85                    |  |              |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
| 8-15         | -11.85                    |  |              |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
| 28           | Reserved                  |  |              |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
| 29           | Reserved                  |  |              |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
| 31           | SP__AEC__PRIORITY__BIAS   | <p>Controls the bias in priority between the Send and Receive paths. If send priority-bias is preferred, the value should be greater than zero. For no priority bias, the value should be zero. For priority bias for the Receive path, the value should be negative. Steps are 3 dB each (e.g., +3 is 9 dB bias for the Send path, -2 is 6 dB bias for the Receive path).<br/>Legal values: -4 to 4.</p>  | 0            |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
| 32           | SP__DIAL__TONE__THRESHOLD | <p>The RMS level below which the speakerphone treats a dial tone as noise, and not as a dial tone. When the Speakerphone algorithm detects a dial tone above this threshold it does not attenuate the signal. A value of 32767 disables the dial tone detector.<br/>Example: if the value is 512 then dial tones with energy below the following are not detected as dial tones:<br/><math>20 \cdot \log_{10}(512/16017) = -29.9 \text{ dBm0}</math></p>   | 4096         |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
| 33           | SP__BLOCK__LEVEL          | <p>Controls the maximum attenuation level of the speakerphone suppressors. It affects the speakerphone stability and its subjective quality. The maximum attenuation is calculated according to:<br/><math>SP\_BLOCK\_LEVEL/2^{28}</math><br/>Legal values: 0 to 32000.</p>  | 10922        |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |
| 33           | SP__AEC__LR__LEVEL        | <p>Controls the speakerphone gain from the microphone to the line-out. The total attenuation, or gain, depends on both of the analog gains and this value. The gain is:<br/><math>K \cdot \text{signal}</math><br/>where:<br/><math>K = SP\_AEC\_LR\_LEVEL/4096</math>.<br/>Legal values: 0 to 16000.</p>  | 14000        |                   |   |   |   |       |   |       |   |       |   |       |   |       |   |       |   |        |      |        |    |

## 2.0 Software (Continued)

**TABLE 2-2. Tunable Parameters (Continued)**

| Index | Parameter Name     | Description   | Default |
|-------|--------------------|---|---------|
| 35    | SP__EEC__LR__LEVEL | Controls the speakerphone gain from the line-in to the speaker.<br>The total attenuation, or gain, depends on both of the analog gains and this value.<br>The gain is:<br>$K * \text{signal}$ where:<br>$K = (\text{SP\_EEC\_LR\_LEVEL} / 4096) * (2^{(6 + \text{VOL\_LEVEL} / 2)})$ Legal values: 0 to 400.  | 281     |
| 36    | SP__AEC__CLIP__POS | Specifies the positive peak-value at which the analog circuit of the line-out saturates. Codec analog full scale corresponds to $\mu$ LAW full scale values after expansion. Assume that positive saturation occurs at amplitudes higher than those of a sine wave at X [dBm0]. The SP__AEC__CLIP__POS value is set as:<br>$\text{SP\_AEC\_CLIP\_POS} = 32636 * 10^{((X - 3.17) / 20)}$ <b>Note:</b> a sine wave with amplitude $4 * 8159 = 32636$ corresponds to 3.17 dBm0.<br>Example:<br>For X = -6.2761 dBm0, the value is:<br>$\text{SP\_AEC\_CLIP\_POS} = 32636 * 10^{((-6.2761 - 3.17) / 20)}$ $= 0.3371 * 32636 = 11000;$ Legal values: 0 to 32767. | 16000   |
| 37    | SP__AEC__CLIP__NEG | Specifies the negative peak value at which the analog circuit of the line-out saturates. Codec analog full scale corresponds to $\mu$ LAW full scale values after expansion. The value of SP__AEC__CLIP__NEG is set as shown for SP__AEC__CLIP__POS, above.<br>Legal values: -32768 to 0.   | -16000  |
| 38    | SP__EEC__CLIP__POS | Specifies the positive peak value at which the analog circuit of the speaker saturates. Codec analog full scale corresponds to $\mu$ LAW full scale values after expansion. The value of SP__EEC__CLIP__POS is set as shown for SP__AEC__CLIP__POS, above.<br>Legal values: 0 to 32767.   | 16000   |
| 39    | SP__EEC__CLIP__NEG | Specifies the negative peak value at which the analog circuit of the line-out saturates. Codec analog full scale corresponds to $\mu$ LAW full scale values after expansion. The value of SP__EEC__CLIP__NEG is set as shown for SP__AEC__CLIP__POS, above.<br>Legal values: -32768 to 0.   | -16000  |
| 40    | SP__AEC__ENABLE    | Enables/disables the acoustic echo controller.<br>Legal values: 0 (disable), 1 (enable).  | 1       |
| 41    | SP__EEC__ENABLE    | Enables/disables the electrical echo controller.<br>Legal values: 0 (disable), 1 (enable).  | 1       |

## 2.0 Software (Continued)

### Example

|                    |   |    |    |    |    |
|--------------------|---|----|----|----|----|
| <b>TUNE 23 700</b> |   |    |    |    |    |
| Byte sequence:     | Microcontroller   | 15 | 17 | 02 | BC |
|                    | CompactSPEECH   | 15 | 17 | 02 | BC |
| Description:       | Set the minimum period for busy detection to seven seconds. |    |    |    |    |

### VC **Volume Control *vol\_Level***

Controls the energy level of all the output generators (playback, tone generation, and voice synthesis) and the speakerphone, with one command. The resolution is  $\pm 3$  dB.

The actual output level is composed of the tunable level variable, plus the *vol\_Level*. The valid range for the actual output level of each output generator is defined in Table 2-2. For example, if the tunable variable VCD\_LEVEL is 6, and *vol\_Level* is  $-2$ , then the output level equals  $VCD\_LEVEL + vol\_Level = 4$ .

### Example

|                |  |    |    |
|----------------|--|----|----|
| <b>VC 04</b>   |  |    |    |
| Byte sequence: | Microcontroller                            | 28 | 04 |
|                | CompactSPEECH                              | 28 | 04 |
| Description:   | Set the volume level to $VCD\_LEVEL + 4$ . |    |    |

### WMSG **Write Message *data***

Writes 32 bytes of *data* from the current position of the message pointer, and advances the message pointer by 32 bytes.

If the CompactSPEECH is in the **IDLE** state, the command opens the current message, switches the CompactSPEECH to the **MSG\_OPEN** state, sets the message pointer to the beginning of the message data, and writes the 32 bytes of *data*.

The command can lengthen a new message i.e., a message which was just created with the CMSG command, but was not yet closed by the S command. If this is the case, and if the message pointer points to the end of the last block used by the message, and WMSG command is issued, the message length increases by 4 kbytes. If the memory becomes full, EV\_MEMFULL is set in the status word, and the CompactSPEECH switches to the **IDLE** state.

Trying to lengthen an existing message, i.e., a message that was already closed, causes the CompactSPEECH to set the EV\_NORMAL\_END event in the status word, and switch to the **IDLE** state.

The microcontroller must issue a S command to close the message and switch the CompactSPEECH to the **IDLE** state.

**Notes:** When updating an existing message, bits can only be cleared, but not set.

If the current message is undefined, ERR\_INVALID is reported.

### Example

|                      |   |    |                           |
|----------------------|---|----|---------------------------|
| <b>WMSG 32 bytes</b> |   |    |                           |
| Byte sequence:       | Microcontroller   | 31 | 32 bytes of data to write |
|                      | CompactSPEECH   | 31 | echo 32 bytes of data     |
| Description:         | Create a message with tag = 01, and write 32 bytes in the message memory. |    |                           |

### WRAM **Write Memory *tag, data***

This command exists for compatibility only. Use WMSG instead.

# Appendix A

## SCHEMATIC DIAGRAMS

The following schematic diagrams are extracted from a CompactSPEECH demo unit, based on the NSV-AM266-SPAF board, designed by National Semiconductor.

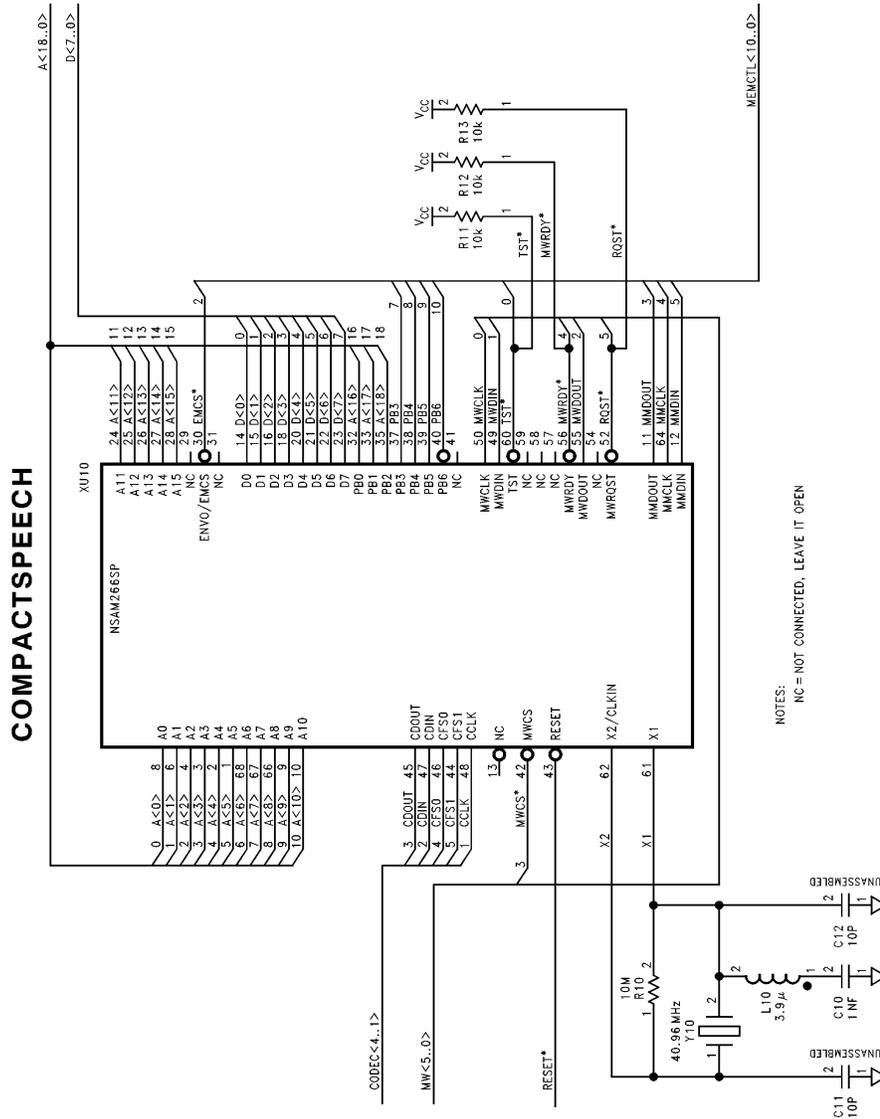
This demo includes three basic clusters:

- COP888EEG Microcontroller.
- CompactSPEECH cluster, including two TP3054 codec and an NSAM266SP controlling a Serial Flash device.

- User interface that includes one 16-digit LCD, and a 16-key (4 x 4) keypad.

For more details about the demo please refer to the *NS Digital Answering Machine Demo Operating Instructions*.

**Note:** If IVS resides in serial flash, and not in ROM, the address- and data-line connections are not required, and the layout is much simpler.

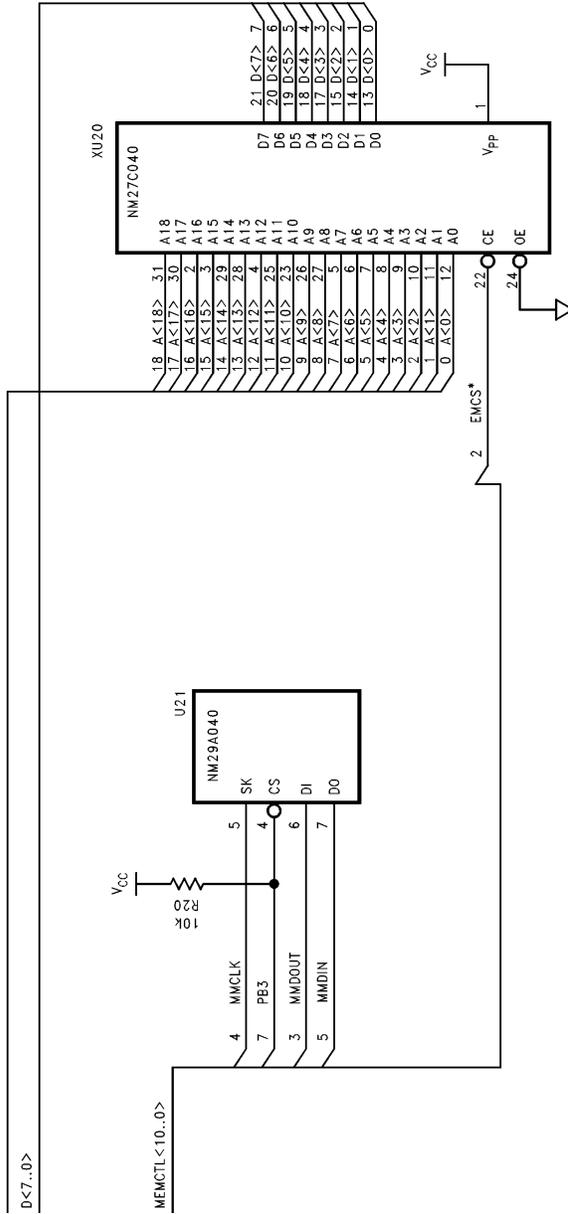


TL/EE/12868-02

**SERIAL FLASH**

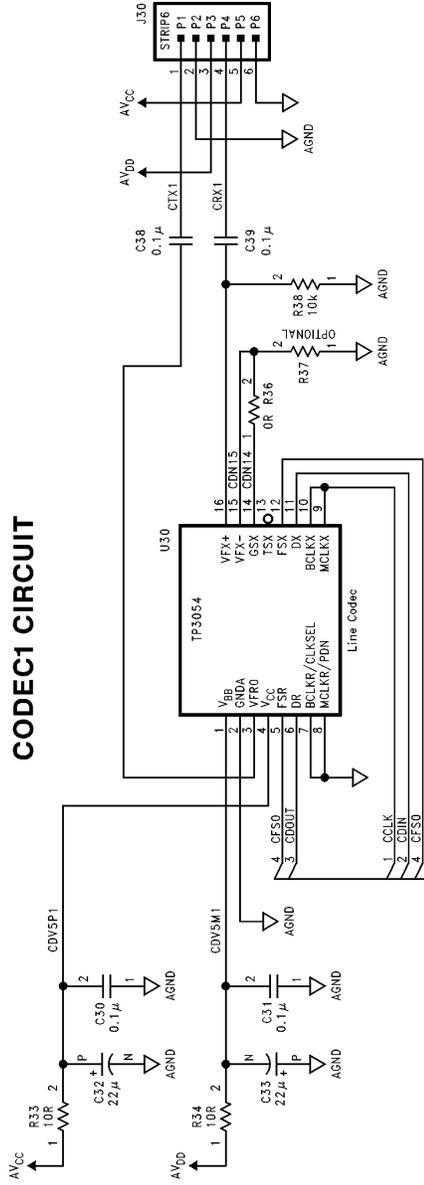
**IVS**

A<18..0>  
D<7..0>

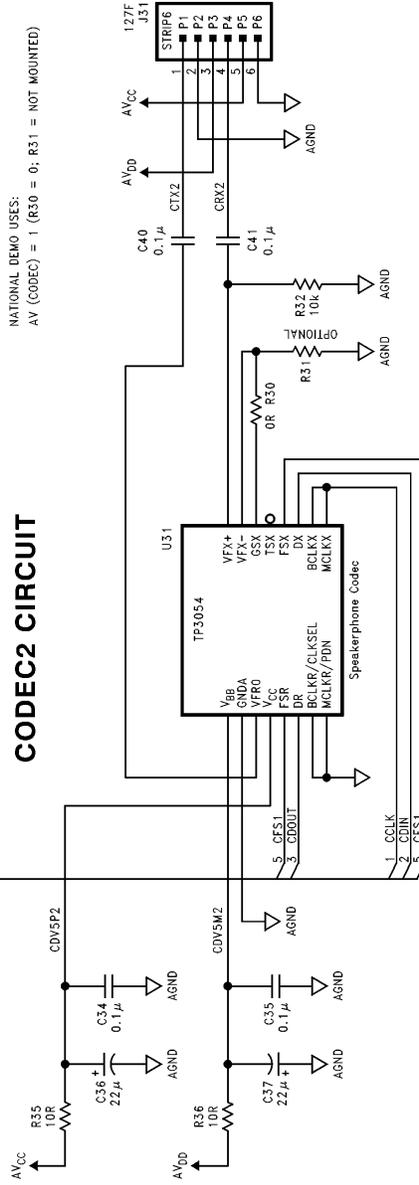


# Appendix A (Continued)

## CODEC1 CIRCUIT



## CODEC2 CIRCUIT

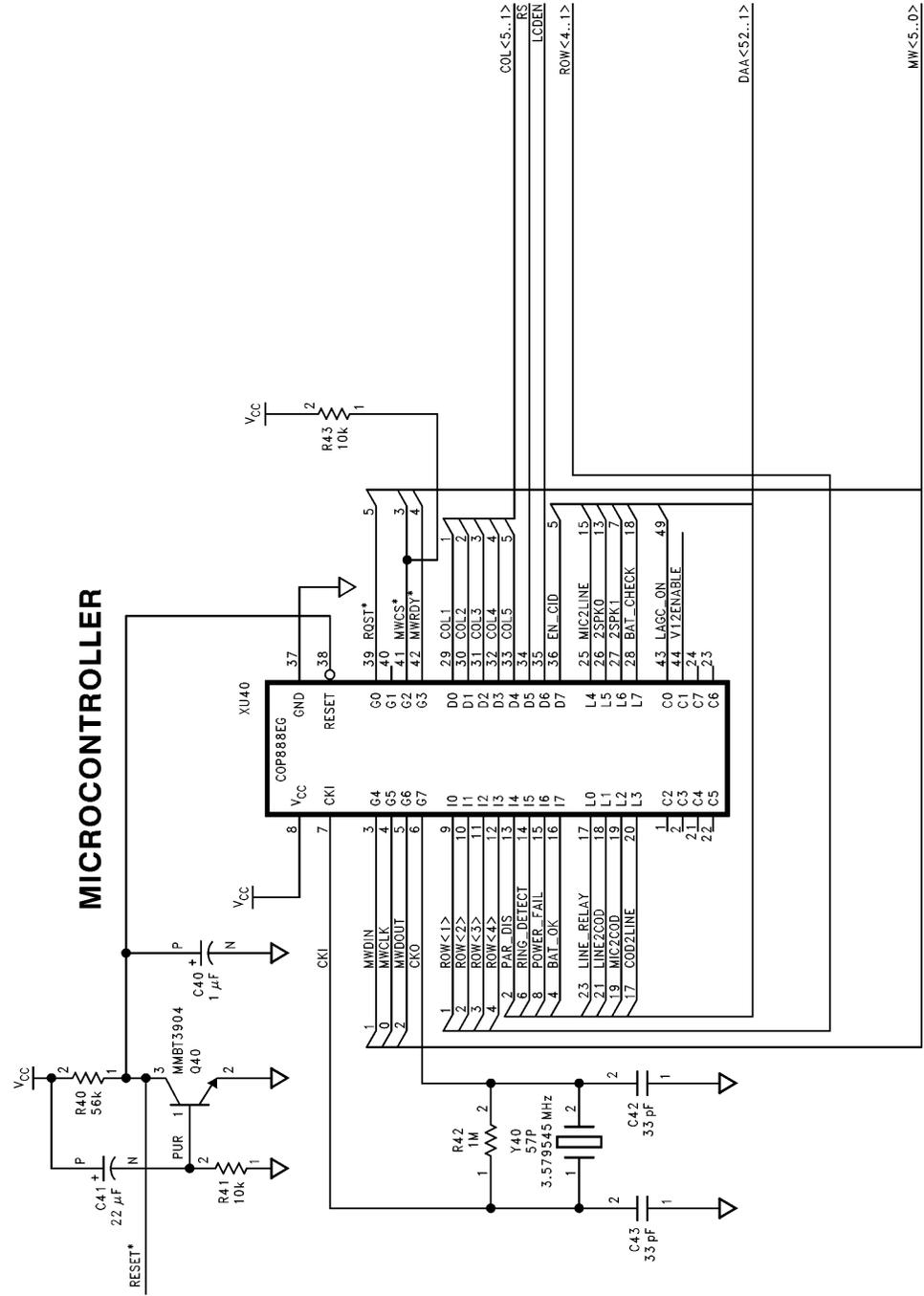


AV (CODEC) = 1 + R30/R31  
 NATIONAL DEMO USES:  
 AV (CODEC) = 1 (R30 = 0; R31 = NOT MOUNTED)

CODEC<5..1>

# Appendix A (Continued)

## MICROCONTROLLER



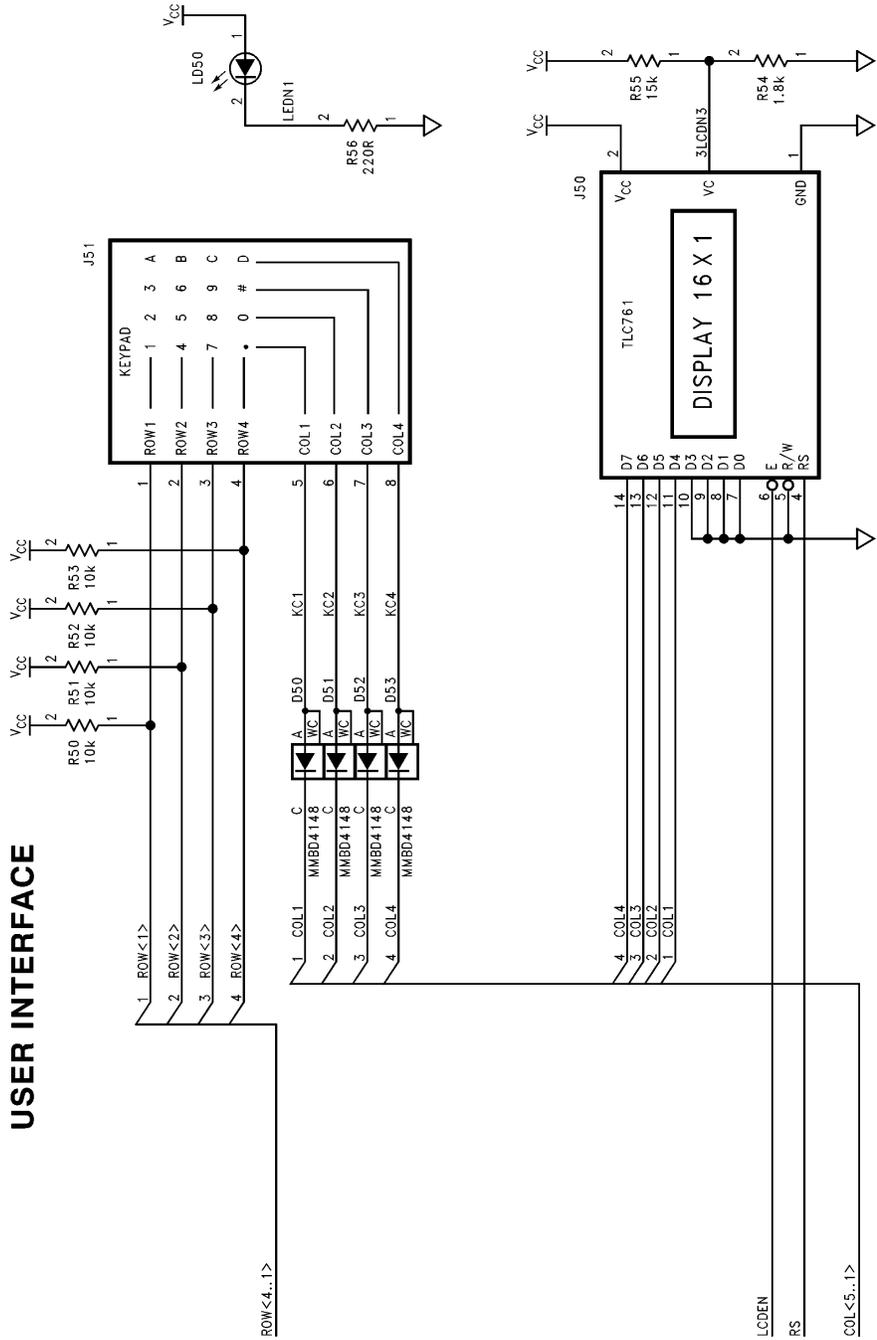
TL/EE/12668-35

MW<5..0>

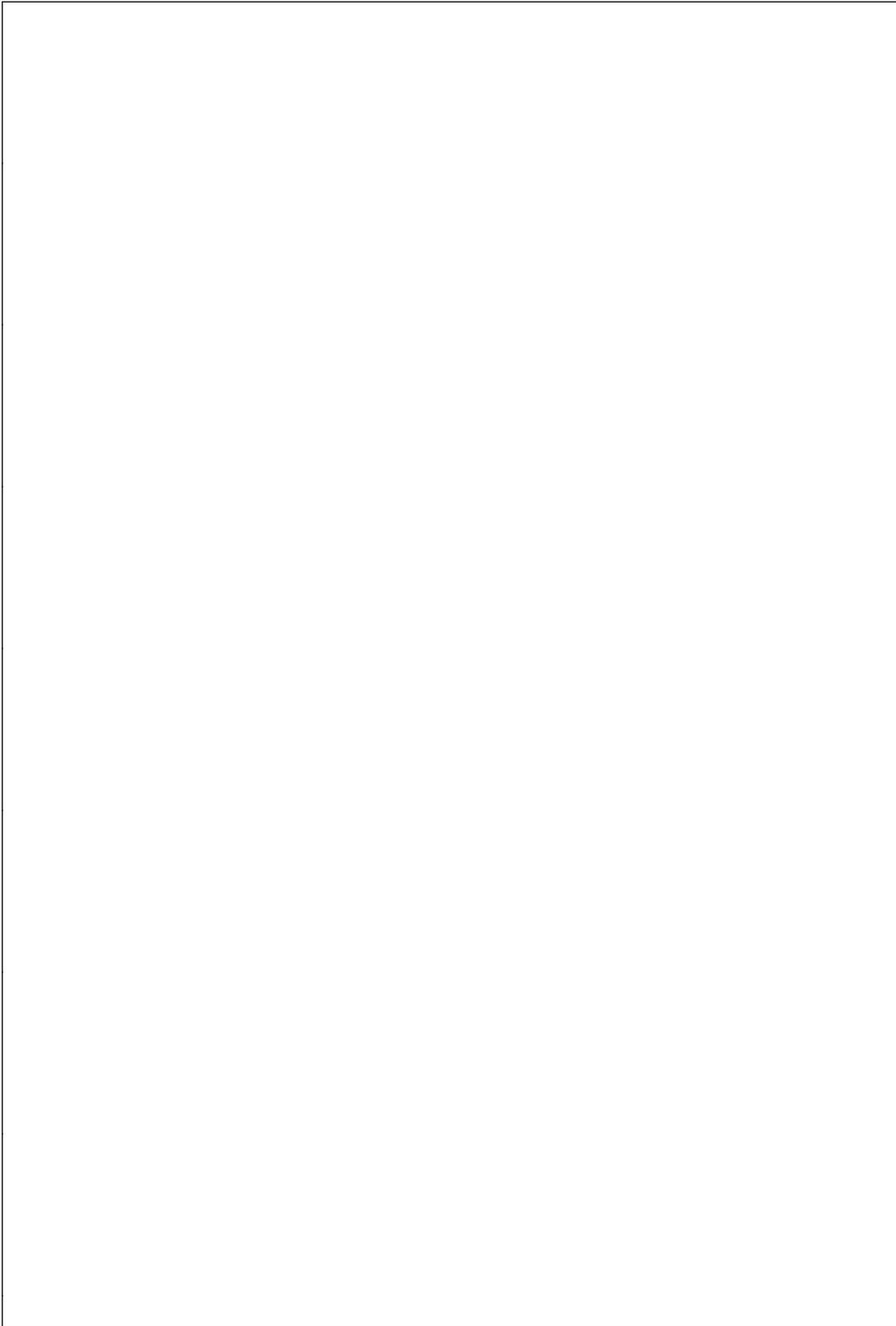
DAK<52..1>

# Appendix A (Continued)

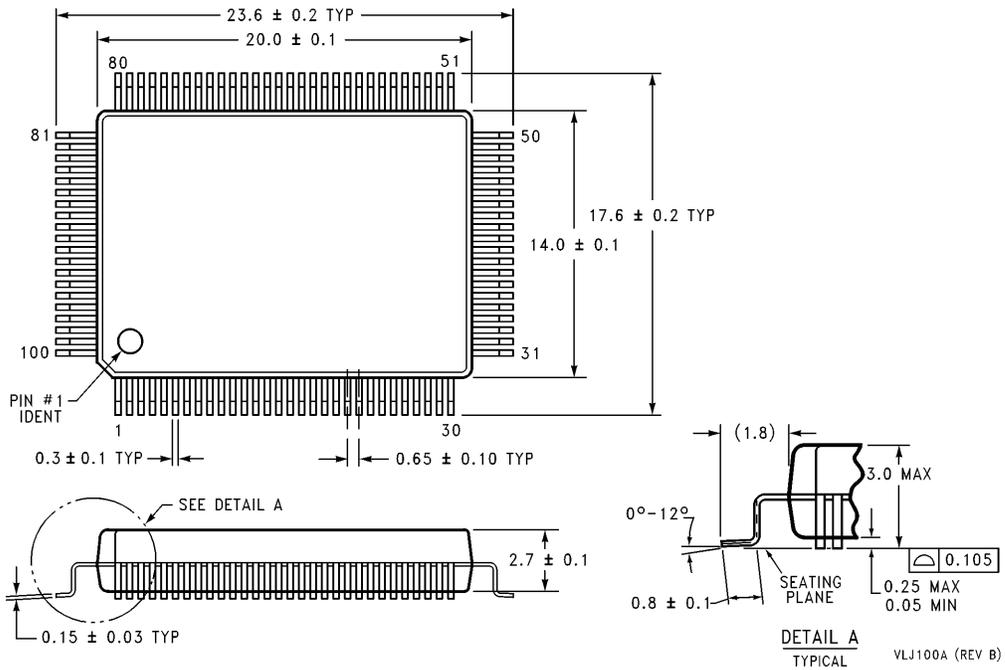
## USER INTERFACE



TL/EE/12688-36



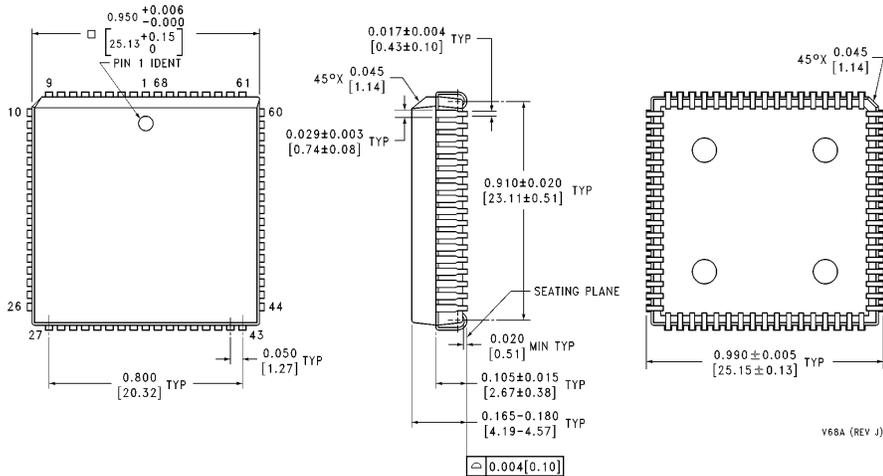
**Physical Dimensions** inches (millimeters) unless otherwise noted



**100-Pin Molded Plastic Quad Flatpak (EIAJ)**  
**Order Number NSAM266SPA/VLJ**  
**NS Package Number VLJ100A**

DETAIL A  
 TYPICAL VLJ100A (REV B)

**Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)



**68-Pin Plastic Leaded Chip Carrier (V)**  
**Order Number NSAM266SPA/V**  
**NS Package Number V68A**

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