Winbond
Electronics Corporation America

ChipCorder®

ISD5008 Reference Design User's Guide

Low Power Telephone Answering Device

Version 1.0
ISD Part Number 101999RD5008

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ISD5008 TAD REFERENCE DESIGN DISTRIBUTION DISKETTE

There are 21 files on this diskette. The instructions provided on this page are also provided on the accompanying diskette in text format.

The **TAD2.ZIP** file contains the following:

- **Tad2.DSN:** the complete schematic in OrCAD Ver. 7.00 format.
- **Tad2.PPT:** the complete schematic in MS PowerPoint format.
- **Tad2-bom.TXT:** the parts BOM in text format.
- **Tad2-bom.XLS:** the parts Bill of Materials in MS Excel format.
- **V10files.ZIP:** the zipped copy of the firmware listings. This includes 14 files. Make sure that you have plenty of paper when you go to print as there are many pages in this file.
- **TAM2Guide.pdf:** the Users Guide in Adobe PDF 4.0 format.

INSTALLATION INSTRUCTIONS TO ACCESS FILES

1. Verify that your hard drive has at least 4MB of free space to hold the files on this diskette.
2. Copy TAD2.ZIP onto your hard drive in a separate folder (directory).
3. Use WINZIP to open TAD2.ZIP; then again to open V10FILES.ZIP.
4. Copy the .DSN file to your OrCAD project directory and print the schematics. If you do not have OrCAD Version 7.00 or higher, use the MS PowerPoint version of the schematics.

ISD Applications Department October 20, 1999

Please address all questions, via email, to chipcorder@isd.com.

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ISD5008 Reference Design User's Guide

Low Power Telephone Answering System

INTRODUCTION

The ISD5008 ChipCorder® Product provides high-quality, 3-volt, programmable sampling rate, single-chip record/playback solutions for 4- to 8-minute messaging applications. These messaging applications are ideal for cellular applications, automotive communications, telephone answering devices and portable communications products. The CMOS-based device integrates the sampling clock, anti-aliasing and smoothing filters, and the multi-level storage array on a single-chip. For enhanced voice features, the ISD5008 eliminates external circuitry by integrating automatic gain control (AGC), a power amplifier/speaker driver, volume control, summing amplifiers, analog switches, and a car kit interface. Software adjustable input level amplifiers are also included, providing a flexible interface for multiple applications.

The ISD5008 product is designed for use in a microprocessor- or microcontroller-based system. Addressing, control, and duration are enabled through a Serial Peripheral Interface (SPI) or Microwire™ serial interface to minimize pin count.

Recordings are stored in on-chip non-volatile memory cells, providing zero-power message storage. This unique solution is made possible through ISD's patented multilevel storage technology. Voice and audio signals are stored directly into memory in their natural, uncompressed form, providing superior quality voice reproduction.

In the ISD5008 TAD Reference Design, the 8-minute ISD5008 is combined with an ISD4004-12 for a total of 20 minutes storage time. Because the ISD5008 includes an on-board microphone and speaker amplifiers, adding the ISD4004-12 is easily done by simply connecting to the ANA IN and ANA OUT ports of the ISD5008.

FEATURES

The ISD5008 solid state TAD contains not only basic answering machine features, but also offers the following additional features:

- One-way call record (phone number, direction, voice mail)
- Two-way call record (complete conversions)
- Private one-way message playback (while on a call)
- Two-way message playback
- Voice memo record and playback (phone in standby)
- Private call screening
- Personal outgoing message (given CID info)
- Private call announce while on call (given CIDCW)
- In-terminal answering machine
- Storage of 8 minutes on single chip memory and an additional 12 minutes on the second chip
- Battery power backup that can record incoming messages during power failures
- LCD display for message status with support for caller ID

POWERING THE TAD2

The TAD2 system is powered from either 4 AA cells or a 4-12 VDC wall adapter, capable of 150 mA, through a 3.1 mm connector. The center pin is ground.

OPERATING THE TAD2

All of the keypad operations are menu driven. At the base menu, the "Up" and "Down" keys scroll through submenus.

Main Menu

Displays the number of saved and new messages in the TAD.

Play Messages

The "Box" symbol button will start the play messages routine. If new messages exist, the oldest new message is played first. If no new messages exist, the TAD2 will display a message telling the user that no new messages exist. Selecting the "Left" arrow will play the oldest stored message. While a message is playing, the "Left" arrow rewinds, the "Box" will stop message playing, the "Right" arrow causes it to skip ahead to the next message and the "Up" and "Down" arrows adjust the volume. When the message has finished playing, the menu changes to the "Box", plays the message again, "Left" arrow plays the previous message, the "Right" arrow skips to the next message, the "Down" arrow deletes the message, and the "Up" arrow exits back to the main menu. After a message has finished playing and no user operations are requested for 15 seconds, the message routine will end and the menu goes back to the Main menu. During the time that the message is playing, the CID data is alternately displayed with the menu information.

Record Memo

Records a memo message (without CID Data) from the microphone. The "Box" starts and stops the recording.

Record OGM

Records the outgoing message that is to be played when the phone line is answered. The "Box" starts and stops the recording.

Play OGM

Plays back the Outgoing message to the speaker.

Change Pass Code

Displays the currently set password. The "Left" and "Right" arrows move the cursor. The "Up" and "Down" arrows change the digit at the cursor location. The "Box" saves the password.

Phone Answering

The TAD2 will answer the phone after two rings. The outgoing message is played first. If the # key is not pressed during the outgoing message, a new message is recorded and saved. If the # key is pressed, the DTMF commands are executed. When the calling party hangs up, the recording is ended. The "Box" will also end the recording.

If the slave phone is taken off-hook, the action that is currently taking place is immediately stopped and no message is saved.

DTMF Commands

When the "#" key is pressed while the outgoing message is played, the OGM is stopped. After the OGM has stopped, the user enters the pass code. If it is incorrectly entered, the TAD2 returns to the outgoing message after which the # can then be entered to try again. If the pass code is entered correctly, the oldest stored message begins playing. Three keys perform the following functions. The "1" key will back up ("rewind") the currently playing message. If the currently playing message is already at the beginning, the previous message will be played. The "2" key will save the currently playing message and the next message will begin playing. If the "3" key is pressed, the currently playing message will be deleted and then the next message will begin playing.

TONE BETWEEN MESSAGES

The next to the last row (1198) of the ISD5008 is played when the TAD2 interrupts (EOM or OVL) at the end of each message. There is a 1600 Hz tone recorded in the last two rows. Any desired audible indication could be recorded in these last two rows.

POWER MANAGEMENT

Power management is accomplished by using the two different power savings modes of the W78LE54 combined with the peripheral low power modes. The W91030 CID2 device, MT88L85 DTMF transceiver, ISD5008, and the ISD4004 all have sleep modes. The DAA, display, and the analog multiplex circuits are powered through PNP transistors and are turned off when not needed.

Doze Mode

When the microcontroller is still active but waiting for timer interrupts or user input, the processor is placed into the idle mode. In this mode the processor core clock input is stopped, leaving the timers, interrupts, etc. running and enabled. While in this mode, the microcontroller's power consumption is dropped by 80%. When an interrupt is received (from timer, etc.), the processor again begins to execute.

Suspend Mode

The firmware implements a 10 second inactivity timeout. When this timeout occurs, all sub-systems are powered down and the microcontroller is suspended. This is the lowest power mode.

When the suspend is executed, the subsystems are first powered off. Then the state of the microcontroller's internal registers are saved into internal RAM. Note that at reset, the RAM contents are preserved while the hardware registers are not. Next, the microcontroller is suspended. All activity ceases until the system is resumed.

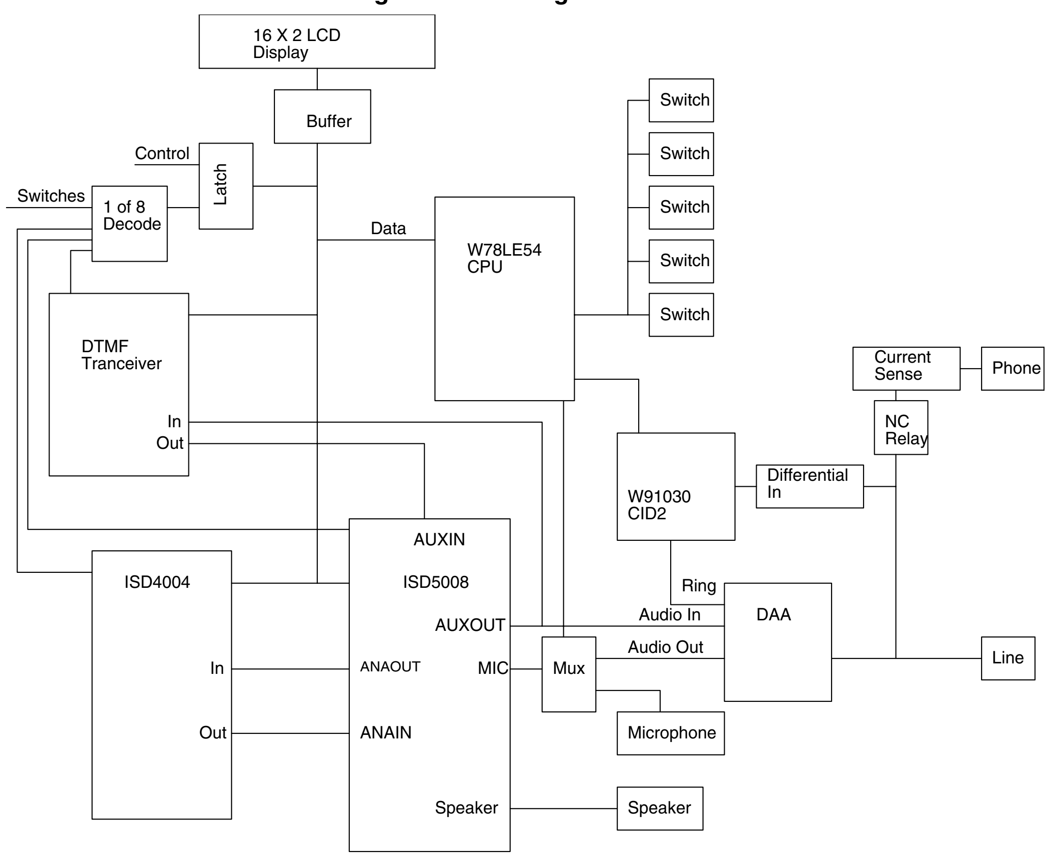
To resume, the microcontroller is reset. A latch is implemented to allow control of the reset. An output bit from the microcontroller is used to enable the reset latch. While enabled the latch will generate a reset upon the occurrence of a switch closure, ringing, or the slave phone going off-hook. When the microcontroller is reset, the same output bit disables the reset latch (all microcontroller port pins go HIGH at reset) once the microcontroller has actually reset.

Upon resume the internal registers are restored from the settings that were saved during the suspend routine. After the resume has completed, the required action will then complete. I.e. menu function, ringing, etc.

Slave Suspend Mode

Anytime the slave phone is off-hook, the W91030 (together w/MT88L85 due to the economy of using a common crystal) is powered up while the remainder of the system is suspended. If a CAS tone is detected, the system is resumed. The line is captured by placing the DAA off-hook, energizing K1 to disconnect the slave phone, and then the CID data is captured. After this, K1 is de-energized and the DAA is placed on-hook. The CID data is stored as well as displayed so that the user may switch-hook to answer the second call, if desired.

Figure 1: Block Figure of TAD2



Electrical Description

Power Supply

The board is supplied with 6 VDC from 4 AA cells or 4-12 VDC from a wall adapter, capable of 150 mA. The 3.1 mm connector's center pin is ground. The input voltage (4 – 12 VDC) supplies the 3 VDC regulator, as well as the display's contrast bias generator. The 3 VDC output supplies the majority of the TAD2's circuitry; some directly while others are powered through PNP transistor switches.

Digital Circuitry

U15 W78LE54 Microcontroller

The Winbond W78LE54 microcontroller contains 16K of code EEPROM, 256 bytes of data RAM, three timers, a UART, four I/O ports and a serial port.

Port 0

Port 0 is shared between U11 74HC574 8-bit latch, U12 MT88L85AN - DTMF transceiver, U10 74HC245, U5 ISD5008, and U8 ISD4004. The port drives the input of the latch. Port 0, bits 0..6 are used to communicate with the DTMF transceiver. The buffer interfaces with the display. Bits 5..6 are used for data in and data out to the ISD components.

0	DTMF Q1.	Latch/buffer – D1 input.
1	DTMF Q2.	Latch/buffer – D2 input.
2	DTMF Q3.	Latch/buffer – D3 input.
3	DTMF Q4.	Latch/buffer – D4 input.
4	DTMF DS.	Latch/buffer – D5 input.
5	DTMF R/W - ISD MISO.	Latch/buffer – D6 input.
6	DTMF RS0 - ISD MOSI.	Latch/buffer – D7 input.
7	Unused.	Latch/buffer – D8 input.

The 74HC574 is an 8-bit latch that drives several control signals:

0	FSKEN – HIGH enables the FSK decoder of the CID device.
1	358PDN - HIGH powers the DTMF decoder and CID devices down.
2	CIDMUT – HIGH mutes the phone connected to the second phone jack.
3	Unused.
4	MICEN – HIGH enables the Microphone input to the ISD input Mux.
5	138_0 – bit 0 of encoded input to the 74HC138 A input.
6	138_1 – bit 1 of encoded input to the 74HC138 B input.
7	138_2 – bit 2 of encoded input to the 74HC138 C input.

The 74HC138 is a 1 of 8 decoder. The outputs are used for chip selects and to select the switch inputs.

0	DTMFCS\ – LOW selects the DTMF device.
1	IS2SS\ – LOW selects the ISD4004 device.
2	IS1SS\ – LOW selects the ISD5008 device.
3	S0 – LOW selects switch 0.
4	S1 – LOW selects switch 1.
5	S2 – LOW selects switch 2.
6	S3 – LOW selects switch 3.
7	S4 – LOW selects switch 4.

Port 1

Port 1 is used as follows:

0	Unused.
1	SLEEP\ – LOW enables the resume-reset latch during suspend.
2	MEMCLK – drives the clock line of the NVRAM.
3	MEMDAT – In/out to data line of the NVRAM.
4	VAON\ – LOW powers up the VA rail.
5	OFFHK\ – LOW powers up the DAA and places it in the off-hook state.
6	DISP\ – LOW powers up the display.
7	ISDCLK – Drives the ISD serial data clock lines.

Port 2

Port 2 is used as follows:

0	OUTEN – Drives the clock line of the 74HC574 Latch. The latch is updated on rising edge.
1	DECEN\ – LOW enables the 74HC138 decoded output.
2	DTMFINT\ – Input from DTMF encoder/decoder to signify the receipt of a DTMF tone.
3	DISDE\ – LOW enables the display data buffer.
4	DISRS – Register select signal to the display port.
5	DISE - E signal to the display port.
6	RING – Active HIGH input from the CID device to signify the receipt of ringing.
7	OHK – Active HIGH input from the DAA to signify that the phone connected to the slave phone jack is in the Off-hook state.

Port 3

Port 3 is used as follows:

0	CIDDAT – Serial input from CID Device into the UART.
1	KEY – Active LOW input from the switch input array.
2	ISDRAC\ - Active LOW from the RAC pins of the ISD devices.
3	ISDINT\ – Active LOW interrupt from the wired ORed RAC's and INTs of the ISD devices.
4	CIDINT\ – Active LOW interrupt from the CID device to signify the receipt of carrier into the FSK decoder.
5	CASDET – Active HIGH input from the CID decoder to indicate the receipt of the CAS tone.
6	Not used.
7	Not used.

U12 MT88L85AN - DTMF Transceiver

The Mitel MT88L85AN is a DTMF Transceiver. It is powered down by the 358PDN signal. When enabled and a valid DTMF tone is detected, DTMFINT\ is driven LOW. The microcontroller then enables the data bus with DTMFCS\ and reads the binary encoded nibble through Port 0. The microcontroller may also send a nibble through Port 0 to transmit a DTMF tone to acknowledge the CAS during the Call Waiting Caller ID routine.

U9 W91030 – Caller ID 2 Decoder

The Winbond W91030 is a Caller ID decoder. It contains a 1200 baud FSK decoder with carrier detect output. The decoded serial data stream is captured by the UART within the microcontroller. The device is powered down by 358PDN. The device also detects ringing and the CAS tone for call-waiting Caller ID. After the first ring detect, the microcontroller powers up the decoder and monitors CIDINT\. When carrier is detected (CIDINT\ = LOW), the microcontroller then configures the UART to 1200 baud and begins reading the data. After the preamble has been decoded, the data is stored into memory.

When the slave phone goes off-hook the current sensor (U1) detects the current and the W91030 is setup to detect the CAS tone. When the CAS tone is detected, it is acknowledged, and then the same routine is run to capture the CID data stream. Once all processing is completed, the microcontroller then puts the device back to sleep (358PDN = HIGH).

U17 24LC64 NVRAM

The 24LC64 NVRAM is an industry standard 64K (8K bytes) with an I2C 2 wire interface. The interface is implemented through Port 1 bits 2..3. The firmware auto-detects the RAM size. The NVRAM is used to store message mappings and CID data. It retains this data during power outages or while changing the batteries.

16 X 2 Alphanumeric LCD Display

The LCD display is comprised of the Optrex DMC-16249 LCD display and U10 74HC245 buffer. The display is powered down when not needed but U10 is always powered. The buffer drives the data bus into the display while the remaining control signals, RS and E, are driven by the microcontroller's P2.4 and P2.5.

Analog Circuitry

Analog input and level control

U5, the ISD5008, contains a differential analog input (MIC+ and MIC-), two single-ended analog inputs (AUXIN and ANAIN), a differential analog output (ANAOUT+ and ANAOUT-), a single-ended output (AUXOUT), and a speaker amplifier. The MIC inputs are multiplexed by the U6 [CD4066] analog switches. One pair of switches selects the microphone while the second pair selects the DAA. U8's, [ISD4004] output drives the ANAIN and U12's [MT88L85] TONE output drives the AUXIN. AUXOUT drives the DAA input; the ANAOUT drives U8's [ISD4004] input. The speaker is connected to the speaker outputs of the ISD5008.

The ISD5008 switches the selected inputs to their destination outputs. All level control and functions within the ISD5008 are manipulated through the serial bus.

DAA

The DAA is implemented discretely with U3A, U3B, U3C, LMC6484 Op amp, U4 CP Clare ITC117P integrated function device, and T1.

Isolation and ringer

U4 contains an opto-isolated relay, diode bridge, Darlington transistor, and ring detector. The Darlington is configured as a shunt regulator to allow for the use of a dry (no DC current) transformer. T1 is AC coupled to the phone line through the U4 relay. The ring signal is coupled through R5, C1, D3 and D4 into dual LEDs in U4.

2 Wire to 4 Wire Converter

U3C supplies a reference voltage while U3A and U3B are configured as a 2 wire to 4 wire converters. The secondary of T1 is DC coupled to the converter. One side of the secondary is supplied with the reference voltage. The other is driven through R28. U3B is configured as both an inverting and non-inverting amplifier. U3B is an inverting amplifier to the received signal and a non-inverting amplifier to the transmitted signal. The signals are summed at the tie point of T1 and R28. The result is that the transmitted signal output by U3B is a minimum of 10 dB below the received signal. Above approximately 400 Hz it is 20 dB below from the receive signal.

CID Interface

For Caller ID U9 is driven from tip and ring differentially through C13, C14, R34, R35, R43, and R47. D5, D6, D9, and D10 clamp the differential signal to be between the 3 VDC and ground rails.

Slave Phone

A slave phone may be connected to J2. K1 LCB110 is a NC relay and U1 LDA110 is an opto-isolator configured as a current sensor. When the slave phone goes off-hook, current flows through K1 and U1 to the phone. The opto-transistor turns on which also turns off Q1. When Q1 is turned off the OHK signal goes HIGH, indicating that the slave phone is off-hook. While the slave phone is off-hook, the micro-controller will monitor U9 W91030's CASDET signal. When CAS is detected, the DAA is taken off-hook and K1 is energized to break the current flow to the slave phone. After the CID data has been captured, K1 is turned back off and the DAA goes back on-hook.

FIRMWARE CODE

The firmware uses and maintains variables and data to manage the storing and play-back of messages in the ISD5008 and ISD4004. The TAD2 uses a Message Address Table (MAT) as described in ISD Application Notes combined with a variation on the actual structure. Two actual tables are maintained within the NVRAM. One stores all CID data. The other stores the actual audio message table combined with a status byte and a pointer into the CID table if the message is linked to a CID message.

NVRAM

The TAD2 has an NVRAM that is used to store all volatile data and tables. The NVRAM is an industry standard 24LC64 with a two wire I2C interface. The NVRAM manipulation is performed on a block basis with a maximum of 32 bytes per transfer.

Message Address Table Structure

The MAT is a list of tags and data. The tags identify the beginning of each message or class of data. The MAT tag is followed by the message status byte. The length byte following each tag (first follow for MatTag; second for all others) is the length of the data for that tag. The tag's data follows the length byte. At the end of each message is a MatEnd tag. At the end of the MAT is a TableEnd tag to indicate that there are no more messages.

Tags

Below is a list of tag definitions:

0x80	MatTag.	Beginning of message string. The MatTag is followed by the MATLength. The message string is length bytes long plus 3; MatTag, length byte, and MATEnd.
0x81	CidTag.	Beginning of CID pointer field. The CidTag data is an integer offset into the CID table to the CID message with this audio message. If no CID message is associated with the audio message, the CidTag is not in the message string. The CidTag, if it exists, is followed by the CIDLength (always 2), and then one byte that is the CID message number in the CID message table.
0x82	MesTag.	Beginning of audio message string. The MesTag precedes the actual audio block map of the message. It is followed by the MesLength. The MesString is MesLength long. See Audio Blocks section for a definition of the actual audio block data.
0x8f	MatEnd.	End of the Message address table for this message. The Tag is always followed by another MatTag or the TableEnd tag.
0x9f	TableEnd	End of message table. There are no more audio messages.

Audio Message Blocks

Each of the ISD devices is divided into 128 audio blocks. Each ISD5008 audio block consists of 9 consecutive rows. Each ISD4004 audio block consists of 18 consecutive rows. The length of time for each row varies depending upon the sample rate. Block0 to Block127 (0h..07fh) point to the ISD5008 while Block128 to Block255 (080h..0ffh) point to the ISD4004.

Message Status

The message status byte follows the StatTag and StatLen bytes in the Message Table.

Status.	7	6	5	4	3	2	1	0
New Message - Set for New, Clear for message has been played.								X
OGM -this message is the OGM message.							X	

Used Block Table

The Used Block Table is a table of bits that represent the current used status of each audio block. The table is 32 bytes long (256 Audio Blocks / 8 bits per byte = 32 bytes). The UBT resides in RAM and is stored in the NVRAM at the offset UBTBlock

NVRAM Map

NVRAM Byte Address	Name.	Description.
0x00..0x0f	RootBlock	The root block is 16 bytes long. It holds the firmware version string and some variables needed at power up.
0x10 .. 0x2f	UBTBlock	The used block table block is 32 bytes long. It holds an image of the Used Block Table in case of power fail.
0x30 .. 0x17ff	AudioMessageTableBlock	The audio message table holds the message table for all audio messages.
0x1800 .. 0x1fff	CIDMessageTableBlock	The CID message table holds the CID messages.

Maximum audio message store capability

Almost 6 Kbytes of the NVRAM are assigned to the audio MAT. The actual number of audio messages that can be stored varies depending upon the number of audio blocks used within each message and the maximum available NVRAM storage. One message can be of any length limited only by available audio storage. The minimum length of the audio message is 11 bytes for a one block audio message with a CidTag field.

MatTag +	1
MatStatus +	1
MatLength +	2
CIDTag +	1
CIDLength +	1
CIDData +	1
MesTag +	1
MesLength +	1
MesData +	1
EndTag.	1

CID Table

2048 bytes of the NVRAM are allocated to store CID messages. Please refer to the MatTag, MatLength, MsgEnd, and MatEnd tags above for the definitions. A message combines these tags with the actual CID message received. The pointer store in the audio MAT is the sequential message number in the CID table. The length of each CID message varies. Using an average CID message length of 48, the Tad2 is capable of storing 41 CID messages. Note that this is a minimum and will vary depending upon how many no name or no number messages are stored.

SOURCE CODE OVERVIEW

The firmware provided with the TAD2 is compiled using seven source code files and their companion include (*.h) files. A general description is below while a detailed description is contained in the h files included with the source code zip file.

Tad2.c

Tad2 contains the main program loop. This is where the menu commands are located. All other procedures are called from this file.

Tadio.c

Tadio contains all of the hardware implementation specific routines. These procedures are called by the other routines when hardware related functions are needed. The actual I/O map is also defined here.

NVRam.c

The NVRAM related procedures are contained in this module. All NVRAM reads and writes are performed in this module.

ISD.c

ISD contains the command processor for the ISD devices. The interrupt routines for ISD operations are also here.

Mesman.c

The Message address table procedures are in the module. All routines for creating and retrieving audio messages are here. The ISD command processor makes calls to this module to obtain audio related data needed to execute the desired command.

Cid.c

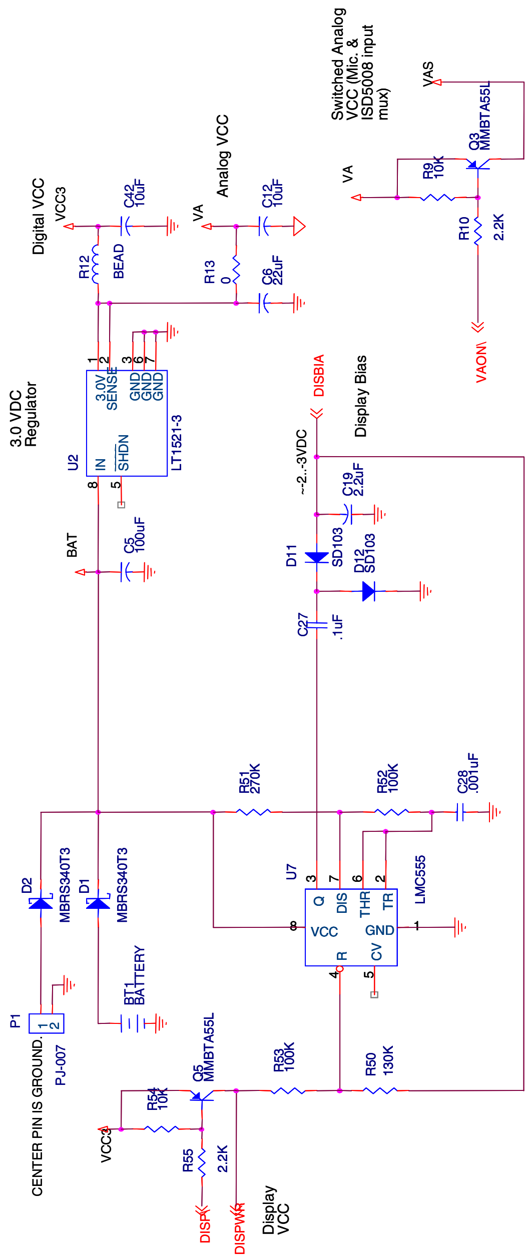
The caller ID routines are located in this module.

Display.c

The display routines are located in this module.

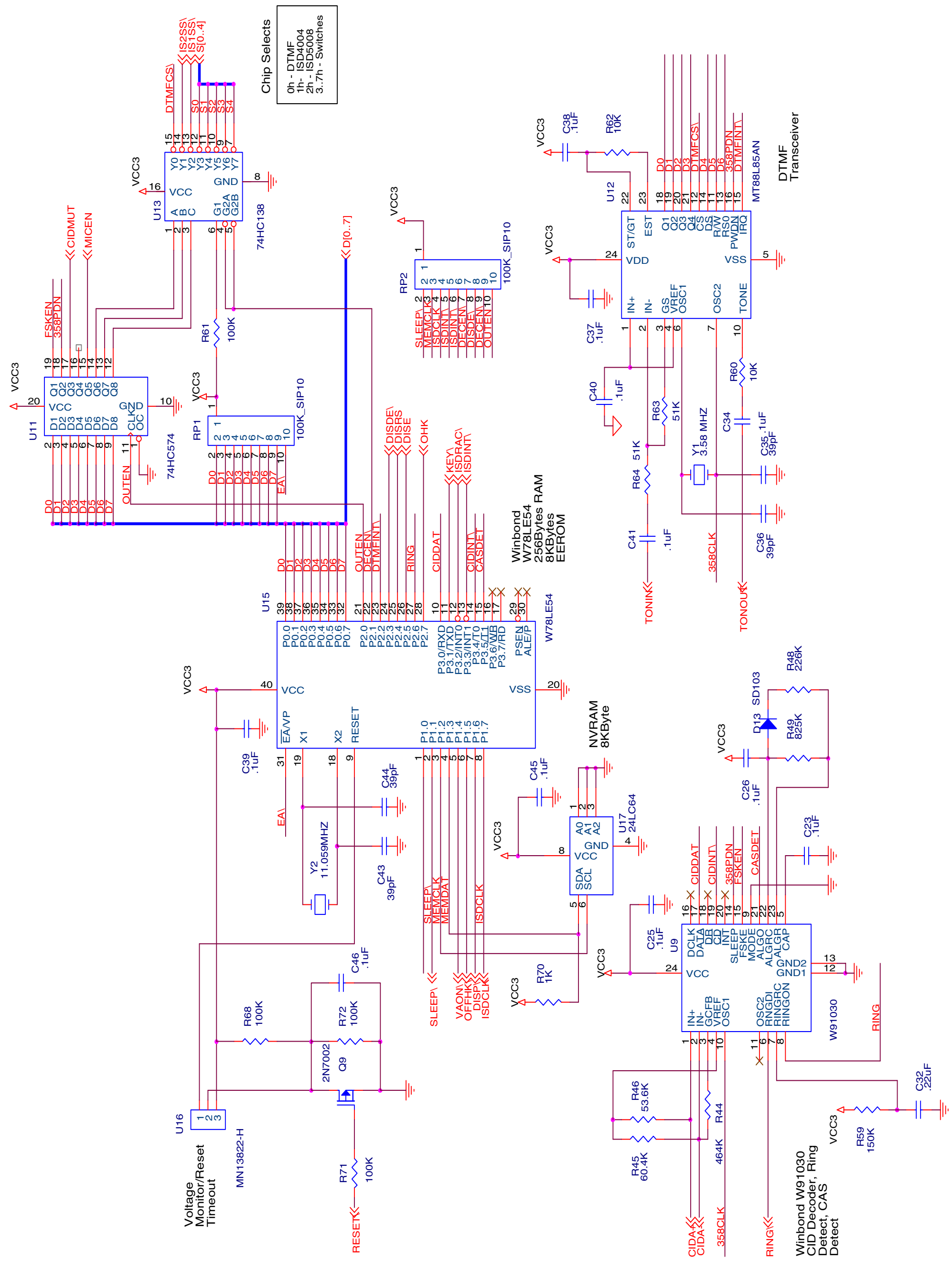
SCHEMATIC DIAGRAMS

Figure 2: Power Schematic



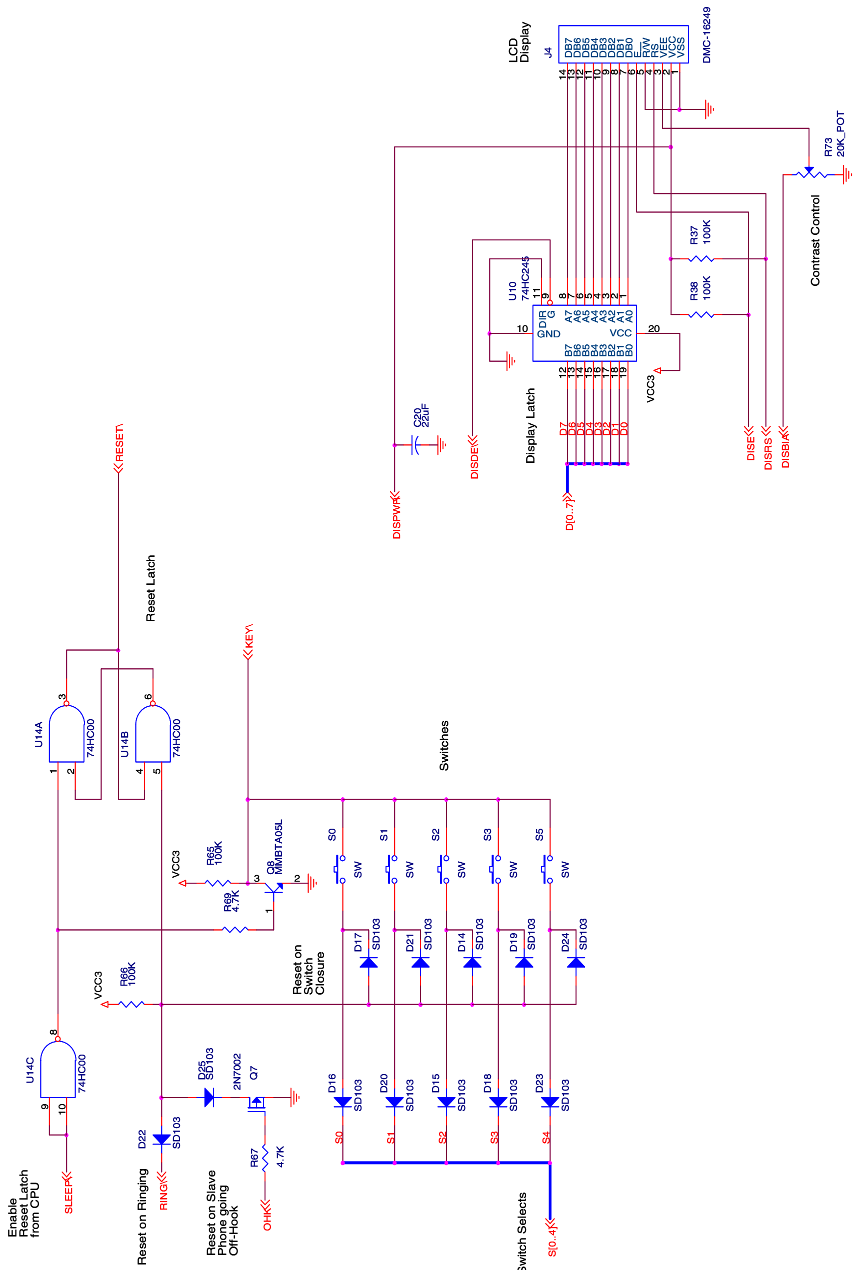
Note: This diagram is available on the accompanying disk as power.sch.

Figure 3: Digital Schematic



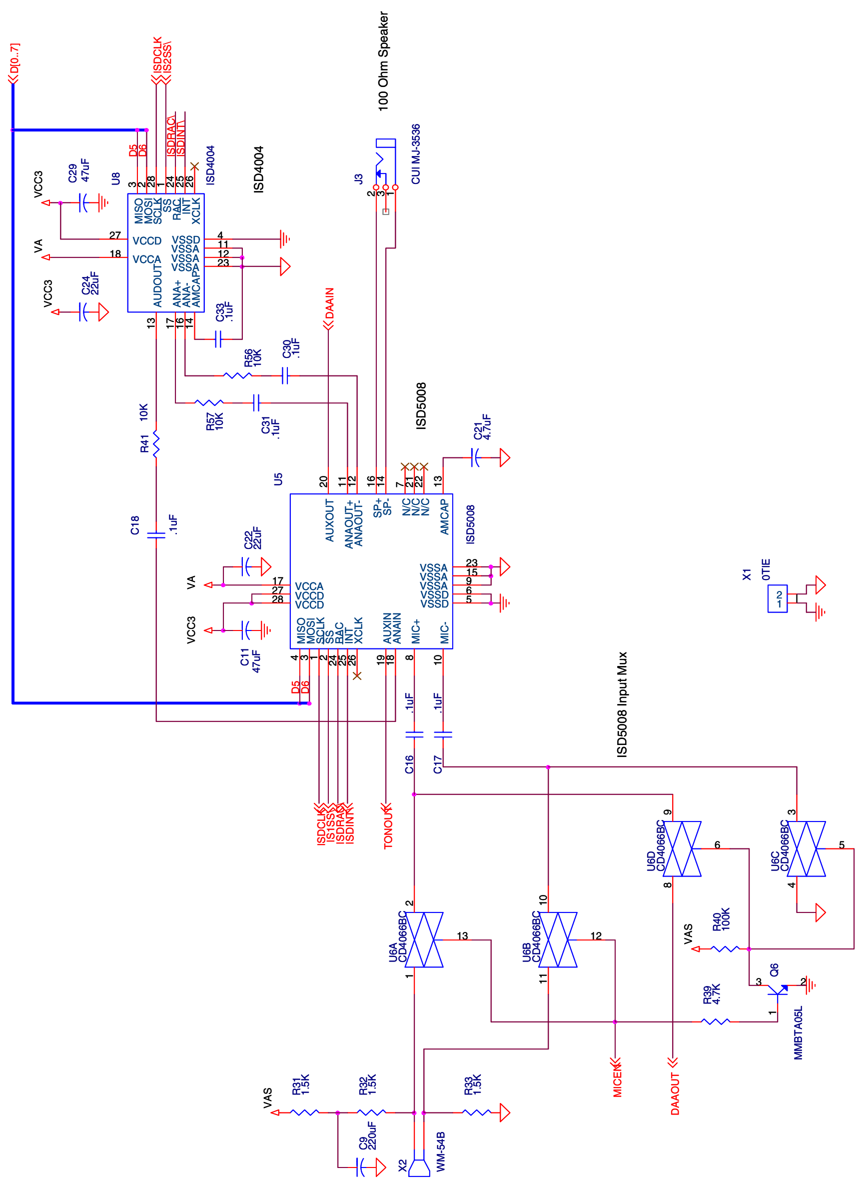
Note: This diagram is available on the accompanying disk as digital.sch.

Figure 4: Display/Keyboard Schematic



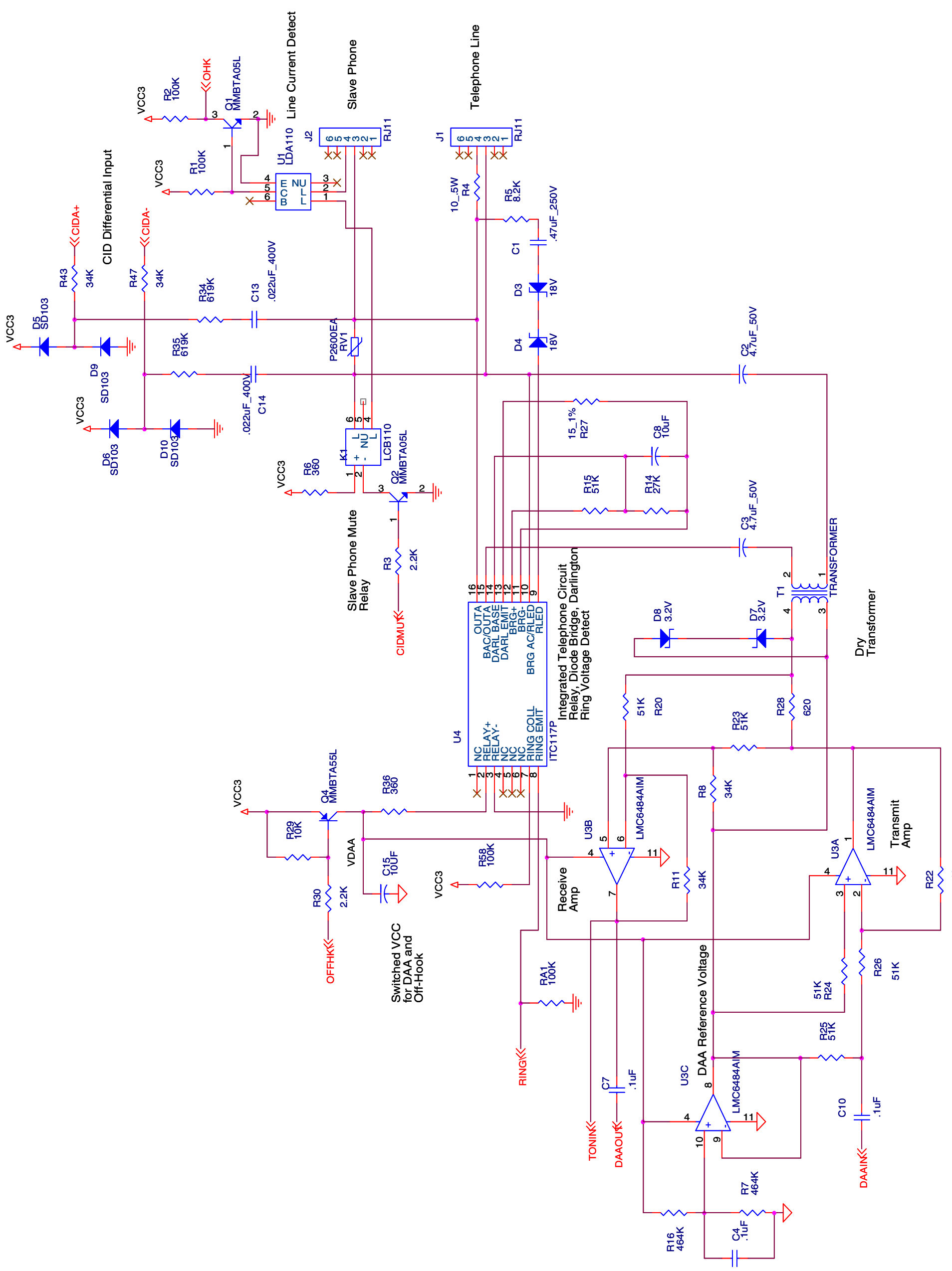
Note: This diagram is available on the accompanying disk as dsp_key.sch.

Figure 5: 5008 Schematic



Note: This diagram is available on the accompanying disk as 5008.sch.

Figure 6: DAA Schematic



Note: This diagram is available on the accompanying disk as daa.sch.

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