Adding a Voice User Interface to M68HC05 Applications

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Introduction

As embedded microcontroller-based products become more sophisticated, additional emphasis is being placed on the design and implementation of their user interfaces. Visually based interfaces are commonly implemented with LCDs, LEDs, fluorescent displays, and lights. Many of these components can be controlled directly by an application’s processor without using additional components. Voice-based user interfaces, on the other hand, are often implemented with speech synthesizers, speech processors, sound generators, and digital signal processors which operate in conjunction with an application’s main processor. In addition to a processor dedicated to the generation of speech, designs frequently require a memory device to hold the data used by the processor, a loudspeaker, and audio amplification circuitry. The added cost for components and space has limited the implementation of speech-based user interfaces to higher end products and products for the visually impaired. This application note discusses adding a voice-based user interface to an application based on the Freescale MC68HC(7)05J1A microcontroller. In particular, interfacing members of the M68HC05 MCU Family to the Information Storage Devices (ISD) 1000 and 2500 family of voice record/playback devices is highlighted. The development of an audible thermometer application concludes the discussion.
Most applications that use speech as part or all of their user interface utilize any one of a number of speech processors and synthesizers on the market. The speech output by these devices usually is stored as noncompressed or compressed digital data in on-chip or external memory. In devices designed specifically for high-volume applications, speech data usually is stored in on-chip ROM.

However, most speech processors and synthesizers designed for the general market require more flexibility than can be offered by using on-chip ROM. Data for these processors is provided by a programmed external memory device. Depending on whether audio amplification is done by the speech processor or not, external circuitry may be needed to interface the processor to a loudspeaker. A block diagram of a typical speech system is illustrated in Figure 1.

**Figure 1. Typical Speech System Design**

The ISD 1000 and 2500 series of voice record/playback devices discussed in this application note integrate all the circuitry needed to record and play back audio signals on a single device. The speech processor, memory, and audio amplifier functional blocks needed to implement a speech interface are all integrated on this device. The members of the device family differ in the length of their recording times, ranging from 10 seconds to 90 seconds. The devices are designed to operate in a number of standalone recording and playback modes or under the control of an external microcontroller. The ease with which these devices can be interfaced with microcontrollers makes them ideal
for adding a voice-based user interface to an application based on a member of Motorola’s M68HC05 Family of MCUs. The remainder of this note discusses using one of these devices to add a voice-based user interface to a simple M68HC05 MCU-based application, namely a digital thermometer.

**Audible Thermometer Feature Definition**

The system design of the audible thermometer begins with the definition of the application’s feature set. The audible thermometer senses ambient temperature and outputs the temperature reading in a pre-recorded human voice. The thermometer is capable of sensing temperatures from –55 to +125 degrees Celsius in 0.5-degree increments. The thermometer powers up and remains in a low-power idle state until the user presses a button. Pushing the button wakes up the thermometer, causing it to acquire and output a temperature reading. After completing these tasks, the system returns to a low-power idle state.
Audible Thermometer Hardware Design

The system design of digital thermometers is a well-established paradigm in the design of embedded systems applications. The audible thermometer follows this model and its hardware design can be divided into two main functional blocks:

1. Temperature acquisition and conversion – Senses ambient temperature and converts the reading to the digital domain
2. Audio processing and output – Outputs the temperature reading in a human voice

To illustrate the ease with which a voice interface can be added to a Freescale M68HC05 MCU-based application, the Freescale MC68HC(7)05J1A microcontroller was chosen as the main system processor for this application. This device is the simplest and the most inexpensive member of Motorola’s M68HC05 Family of microcontrollers. The MC68HC(7)05J1A’s main on-chip peripherals include an 8-bit free-running timer and 14 bidirectional I/O pins. The MC68HC(7)05J1A’s simplicity constrains the role that it plays in the hardware implementation of these two blocks.

The temperature acquisition and conversion block consists of circuitry that senses the application’s ambient temperature and converts it to a suitable electrical signal for processing by the system’s microcontroller. This block typically consists of a temperature sensor, signal conditioning circuitry, and an A/D converter. The temperature sensor is capable of varying a voltage or current signal in proportion to its ambient temperature. The signal is then processed by some form of analog conditioning circuitry. The conditioning circuitry design is heavily dependent on the accuracy, sensitivity, and noise rejection parameters of the application’s specifications and its components. This circuitry may amplify, filter, and linearize the signal in preparation for its conversion to the digital domain by the A/D converter. Once in digital form, the signal can be processed by the microcontroller. In most M68HC05-based applications, the temperature sensor and conditioning circuitry generate and process an analog signal for use by the MCU’s on-chip A/D converter peripheral. However, since the MC68HC(7)05J1A does not
have an on-chip A/D converter, an external A/D converter is needed to implement this block completely. The added cost and space required by an external A/D converter led to the selection of the Dallas Semiconductor DS1820 One-Wire Digital Thermometer to implement the temperature acquisition and conversion block in this application. The DS1820 is a 3-pin device that integrates the temperature sensor, conditioning circuitry, and A/D converter needed to implement this block on a single device. In addition, the DS1820 also has nine bytes of scratchpad RAM and two bytes of EEPROM memory. Using this device results in substantial cost and space savings. The temperature sensed by this device is available to the microcontroller as a 9-bit binary number which can be read serially from a single pin.

The audio processing and output block in this application serves to output the temperature read in a human voice. As mentioned earlier, the ISD 1000 and 2500 series voice record/playback devices contain most of the circuitry needed to implement this block. The high degree of integration provided by this device allows this block to be implemented using this device, a few passive components, and a loudspeaker. The device selected for use in the audible thermometer is the ISD2560. This device is capable of recording and playing back 60 seconds of sound and/or speech. The ISD2560 records by sampling a speech or sound signal at 8 kHz and storing the samples as discrete analog levels in storage cells. The ISD2560 has 480 K of such cells mapped in a memory space that is divided into 600 addresses. Sound recording can be initiated at any one of the 600 addresses and is stopped either by the manipulation of device control signals or by reaching the end of the device’s memory space. To separate recordings, special end of message (EOM) markers are placed in memory at the end of each recording. This gives the ISD2560 the ability to record a number of separate recordings or messages and play them back as many times or in any sequence desired. The audible thermometer uses this feature of the ISD2560 to output a sequence of pre-recorded phrases that correspond to the temperature read by the DS1820. In the thermometer, the ISD2560 is pre-recorded with phrases for the numbers 0 through 19, the numbers 20 through 90 in increments of 10, and the words “one hundred,” “point,” “degrees,” “negative,” and “Celsius.” (See the Design Manual for ISD1000A Family for recording instructions.) These phrases
are recorded at addresses in the ISD2560’s memory space that are 16 units apart starting at address $0000$. This allots a time of 1.5 seconds per phrase. The ISD2560 signals encountering an EOM marker by pulsing the /EOM pin low and then high. The signal can be used by an external controller to concatenate a sequence of messages.

Although the ISD2560 is capable of operating in a number of standalone or operational modes, the MC68HC(7)05J1A interfaces with the device at its microcontroller interface.

The following describes the ISD2560’s microcontroller interface pins and their functions:

1. A0–A9 – Address lines 0–9: Inputs used to access the 600 addresses within the device’s memory space. Although the number of lines allows the selection of 1024 addresses, only addresses 00 to 257 hex are valid.
2. /CE – Chip Enable: An active low pin that enables recording and playback operations
3. PD – Powerdown: An active high pin that puts the device in a low-power idle state.
4. P/R – Playback/Record: A pin that enables device recording when it is high and enables playback operations when it is low.
5. /EOM – End of Message: An active low pin that pulses for 12.5 msec after the end of a message.
6. /OVF – Overflow: An active low pin that signals the end of the device’s memory space. This signal can be used to cascade more than one ISD device together for greater message storage capacity.
After defining the system’s hardware functional blocks of the audible thermometer and selecting the components that comprise the blocks, the system block diagram in Figure 2 was derived for the audible thermometer.

Schematics for the application’s hardware design are located in Audible Thermometer Schematics.

Figure 2. Audible Thermometer System Block Diagram
Audible Thermometer Software Design

The audible thermometer’s system software can be divided into the main program functions and the low-level functions that interface the MC68HC(7)05J1A to the DS1820 and the ISD2560. The low-level driver routines are discussed first, since the main program routines are built on them.

When given the proper command sequence, the Dallas Semiconductor DS1820 One-Wire Digital Thermometer is designed to acquire a temperature measurement within one second and convert it to a 9-bit digital word. The temperature measured is mapped into a range of 9-bit words that span from –55 to +125 degrees Celsius in 0.5-degree increments. The upper byte of a word indicates whether the temperature read is above or below 0 degrees Celsius. An upper byte value of $FF corresponds to a negative temperature and a value of $00 corresponds to a positive temperature. The lower byte values range from $01 to $FA for positive temperatures and from $FF to $92 for negative ones. When a temperature is read, the converted word is stored, least significant byte first, in the first two bytes of the DS1820’s scratchpad RAM memory. The device interfaces with a microcontroller over a single serial line using a half-duplex serial protocol. The protocol prescribes that the MCU initiate and sustain all communications with the DS1820. This protocol supports a full-featured command set that provides the microcontroller with complete control over the DS1820’s operation. The DS1820 command set includes commands to read and write scratchpad RAM memory, to read and write EEPROM memory, and to perform a temperature reading and conversion operation. Although the DS1820 is a multi-featured device, the audible thermometer only uses the commands required to perform a temperature reading and conversion operation and read the 9-bit data word from the DS1820. In this application, the DS1820 interfaces to the MC68HC(7)05J1A at its PB5 bidirectional input/output (I/O) pin. Since the DS1820’s protocol is not a standard, the MC68HC(7)05J1A must manipulate or “bit bang” the PB5 pin to communicate with a DS1820.

The DS1820’s serial protocol supports three communication functions: reset, read, and write.
A reset sequence initializes a DS1820 and prepares it to receive a command from the MCU. A DS1820 reset can be initiated only by the microcontroller and consists of a reset pulse from the microcontroller followed by an acknowledgment pulse from the DS1820. This requires that after driving the serial line to output the reset pulse, the MCU’s I/O pin must be changed from an output to an input to receive the acknowledgment pulse. Since setting the I/O line as an input threestates the serial line, a pullup resistor is needed to pull the serial line high while the microcontroller is not driving it. If an acknowledgment pulse is not received from the DS1820 within 15 to 60 microseconds from the rising edge of the reset pulse, the DS1820 is considered to be inoperative. Figure 3 illustrates the timing requirements for a DS1820 reset operation.

![Figure 3. DS1820 Reset Sequence](image)

**Figure 3. DS1820 Reset Sequence**

The MC68HC(7)05J1A sends commands and data to the DS1820 using the device’s write protocol. The microcontroller initiates a write cycle or time slot by pulling the serial line low. A write cycle must be a minimum of 60 microseconds long with a minimum recovery time of 1 microsecond between cycles. Data is output least significant bit first with each bit requiring one complete write cycle. Figure 4 illustrates the timing requirements for writing a 1 or 0 to the DS1820.
The MC68HC(7)05J1A reads data from the DS1820 using the device’s read protocol. The microcontroller initiates a read cycle or time slot by pulling the serial line low for a minimum of one microsecond. The DS1820 outputs a valid bit 15 microseconds after the start of the read cycle. Therefore, the MCU must change the I/O line driving the serial line from an output to an input before the DS1820 starts to output data. The pullup resistor on the serial line pulls up the line until the DS1820 is ready to output a bit. A read cycle must be a minimum of 60 microseconds with minimum recovery time of 1 microsecond between cycles. The DS1820 outputs data least significant bit first with each bit requiring one full read cycle. Figure 5 illustrates the timing requirements for reading a 1 or 0 from the DS1820.
The ISD2560 driver functions enable the device to play back a sequence of pre-recorded phrases under the direction of the MC68HC(7)05J1A. The MC68HC(7)05J1A performs this simple sequence of I/O port operations to cause the ISD2560 to output a single pre-recorded phrase:

1. Pulls the ISD2560’s PD low, taking the device out of powerdown mode
2. Sets the ISD2560’s P/R pin high, enabling playback operation
3. Places the starting address of the message on the ISD2560’s address bus
4. Pulses the ISD2560’s /CE pin low then high for a minimum of 100 nanoseconds
5. Waits for a falling edge on ISD2560’s /EOM pin, indicating that an EOM marker has been encountered
6. Waits for the rising edge on the ISD2560’s /EOM pin, indicating the end of the EOM pulse

**Figure 6** illustrates a timing diagram for the ISD2560’s signals.
The audible thermometer’s main program flow is:

1. Initialize the MC68HC705J1A’s I/O ports.
2. Put the MC68HC705 into low-power stop mode.
3. Wait for the user to press the pushbutton.
4. Acquire a temperature reading from the DS1820.
5. Output the reading to the ISD2560.
6. Return to stop mode and wait for the user to press the pushbutton.

Consult **Main Program Flowchart** for a detailed flowchart of the main program’s operation.
After initializing the MC68HC(7)05J1A's I/O ports, the MCU is placed in stop mode. Pressing the pushbutton generates an MCU IRQ interrupt that wakes the processor out of stop mode. The processor then uses low-level driver routines to start a DS1820 temperature acquisition and conversion operation and read a 9-bit data word from the DS1820. (Consult Appendix B for a flowchart of the temperature acquisition routine.) If an error occurs during the acquisition of the word, the thermometer is placed into stop mode. Otherwise, the MC68HC(7)05J1A processes the word and determines the sequence of phrases to be output by the ISD2560. The processor then finds the address of each phrase from a series of tables. The address of each phrase is placed in the proper order in a phrase buffer. (Consult Appendix C for the flowchart of the audio processing routine.) The MCU then uses the ISD2560 low-level routines to output the sequence of phrases whose addresses are in the phrase buffer. After outputting the phrase sequence, the MCU returns to stop mode.
Summary

The ISD2560 1000 and 2500 series of voice record/playback devices permit the implementation of cost-effective, voice-based user interfaces in products based on Freescale's M68HC05 microcontrollers. The devices are designed with a microcontroller interface that easily interfaces with even the simplest member of the M68HC05 Family.

Bibliography

Freescale MC68HC705J1A Technical Data

ISD Information Storage Devices ISD2500 Series Preliminary Data Sheet

Design Manual for the ISD1000A Family

Dallas Semiconductor DS1820 One-Wire Digital Thermometer Data Sheet
Main Program Flowchart

1. INITIALIZE MC68HC(7)05J1A'S I/O PORTS.
2. ENTER STOP MODE. WAIT FOR THE USER TO PRESS THE PUSHBUTTON.
3. IF AN EXTERNAL INTERRUPT OCCURS, DELAY FOR 250 MSEC TO DEBOUNCE.
4. IS THE INTERRUPT VALID?
   - NO
   - YES
   - GET TEMPERATURE READING FROM THE DS1820. SEE TEMPERATURE READING PROCEDURE FLOWCHART.
5. WAS THE READING OPERATION SUCCESSFUL?
   - NO
   - YES
6. OUTPUT THE TEMPERATURE AUDIBLY. SEE AUDIO OUTPUT PROCEDURE FLOWCHART.
Temperature Reading Procedure Flowchart

1. **DS1820**
   - **RESET PROCEDURE**: Send a DS1820 reset pulse.
   - **WAS ACKNOWLEDGEMENT PULSE RECEIVED?**
     - **YES**: Send a DS1820 skip ROM ($CC) command.
     - **NO**: Set error bit in system status variable.

2. **Send a DS1820**
   - **CONVERT T ($44) COMMAND.**
   - **RESET THE DS1820**.

3. **Send a DS1820**
   - **SKIP ROM ($CC) COMMAND.**
   - **Send a DS1820**
     - **READ SCRATCHPAD ($BE) COMMAND.**
     - **READ 9-BIT TEMPERATURE DATA FROM THE DS1820.**
     - **RESET DS1820**.

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Audio Output Procedure Flowchart

CHECK THE TEMPERATURE WORD TO SEE IF IT IS AN ODD MULTIPLE OF 0.5.

IS THE MULTIPLE ODD?

NO

PLACE THE ADDRESS OF THE "NEGATIVE" PHRASE IN THE PHRASE BUFFER.

YES

IS THE TEMPERATURE NEGATIVE?

NO

IS THE TEMPERATURE > THAN OR =100 DEGREES C?

NO

PLACE THE ADDRESS OF THE "ONE HUNDRED" PHRASE IN PHRASE BUFFER.

YES

SUBTRACT THE DS1820'S VALUE FOR 100 FROM THE DATA.

IS THE TEMPERATURE > THAN 19 DEGREES C?

NO

NO

YES

A

DIVIDE THE DATA BY 10.
PLACE THE QUOTIENT IN A QUOTIENT VARIABLE.
PLACE THE REMAINDER IN A TEMPORARY VARIABLE.

FIND THE ADDRESS OF THE QUOTIENT'S PHRASE IN THE TBL20_90.

PLACE THE ADDRESS OF THE QUOTIENT'S PHRASE IN THE PHRASE BUFFER.

FIND THE ADDRESS OF THE PHRASE FOR THE NUMBER IN THE TBL0_19 TABLE.

PLACE THE ADDRESS OF THE PHRASE IN THE PHRASE BUFFER.

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Audio Output Procedure Flowchart (Continued)

A

FIND ADDRESS OF THE REMAINDER'S PHRASE IN THE TBL0_19 TABLE.

PLACE ADDRESS OF THE PHRASE IN THE PHRASE BUFFER.

IS POINT FLAG VARIABLE SET?

YES

PLACE ADDRESSES OF THE "POINT" AND "FIVE" PHRASES IN PHRASE BUFFER.

NO

PLACE ADDRESS OF PHRASE "DEGREES" IN PHRASE BUFFER.

PLACE ADDRESS OF PHRASE "CELCIUS" IN PHRASE BUFFER.

PLACE AN $FF IN PHRASE BUFFER.

ISD2560 OUTPUTS SEQUENCE IN PHRASE BUFFER UNTIL A $FF IS ENCOUNTERED.
Source Code

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--------- SYSTEM EQUATES ----------

PORTA EQU $00 ; Port A register
PORTB EQU $01 ; Port B register
DDRA EQU $04 ; Port A Data Direction register
DDRB EQU $05 ; Port B Data Direction register
ERROR EQU 0 ; Error Bit
DQ EQU 5 ; 1820 DQ signal
DQ_CTRL EQU 5
SKIPROM EQU $CC ; 1820 Skip ROM command byte
CONVERT EQU $44 ; 1820 Temperature Convert command byte
READRAM EQU $BE ; 1820 Read RAM command byte
CE EQU $02 ; ISD2560 chip enable bit
PD EQU $03 ; ISD2560 powerdown bit
EOM EQU $04 ; ISD2560 end of message bit
DDRAMSK EQU $FF ; Port A Data Direction register mask
DDRBMSK EQU $2F ; Port B Data Direction register mask
PORTAMSK EQU $00 ; Port A mask
PORTBMSK EQU $2C ; Port B mask
POSITIVE_SIGN EQU $00 ; MSB of a positive temperature reading
NEGATIVE_SIGN EQU $FF ; MSB of a negative temperature reading
POSITIVE_LIMIT EQU $FA ; The highest LSB for a positive temperature.
NEGATIVE_LIMIT EQU $92 ; The lowest LSB for a negative temperature.

********** VARIABLES **********

ORG $C0

SYS_STATUS DS 1 ; System status variable
TEMP_HI DS 1 ; Stores the temperature reading high byte
TEMP_LO DS 1 ; Stores the temperature reading low byte
TEMP DS 1 ; Temporary storage space
TEMA DS 1 ; Register A temporary storage space
TEMPX DS 1 ; Register X temporary storage space

RAW_TEMP EQU TEMP_HI ; Storage space for converted reading
PHRASE_BUFFER DS $11 ; Stores addresses of phrases to be output
POINT_FLAG DS 1 ; Flag indicating a .5 increment in temperature
QUOTIENT DS 1 ; Storage space for the result of division
PHRASE_POINTER DS 1 ; Pointer to current address in phrase buffer

ORG $300

START: JSR INITIALIZE ; Initialize J1A's I/O ports
WAIT4INT STOP ; Stop
BRA WAIT4INT

IRQ_INT: CLR SYS_STATUS ; Clear the error bit
JSR DEBOUNCE ; Debounce the activation switch
BRSET ERROR,SYS_STATUS,IRQ_INT_EXIT ; If the error bit is
; set, the exit routine
JSR GET_TEMP ; Get a temperature reading from the 1820
BRSET ERROR,SYS_STATUS,IRQ_INT_EXIT ; If the error bit is
; set, the exit routine
JSR FORM_PHRASE ; Form table of addresses of the phrases to
; be output
JSR OUTPUT_TEMP ; Audibly output temperature
BCLR ERROR,SYS_STATUS ; Clear the error bit
RTI
Function Name: OUTPUT_TEMP
Function Inputs: None
Functions Outputs: None

Purpose: This function outputs the contents of the phrase_buffer to the ISD2560 which outputs them audibly.

OUTPUT_TEMP:  BCLR  PD,PORTB            ; Take the ISD2560 out of powerdown mode.
            LDX   #PHRASE_BUFFER      ; Point to the phrase buffer.
OUT_PHRASE:   LDA   PORTB
              AND   #$FC
              ORA   ,X
              STA   PORTB
              INCX
              LDA   ,X          ; Put the address of the next phrase to
              STA   PORTA       ; be output on the address bus of the ISD2560
              INCX
              BCLR  CE,PORTB    ; Pulse the ISD2560's chip enable pin to start
              BSET  CE,PORTB    ; outputting the current phrase.
EOM_H_WAIT:   BRSET EOM,PORTB,EOM_H_WAIT ; Wait for the ISD2560's End of Message
EOM_L_WAIT:   BRCLR EOM,PORTB,EOM_L_WAIT ; pulse before continuing
              LDA   ,X          ; Look for the end of the phrases to be output
              CMP   #$FF        ; if it is found exit the routine. Otherwise
              BNE   OUT_PHRASE  ; continue outputting phrases.
              BSET  PD,PORTB    ; Put the ISD2560 into powerdown mode.
              RTS
Function Name: FORM_PHRASE
Function Inputs: None
Functions Outputs: None

Purpose: This function converts the temperature read from the 1820 to the addresses of the phrases in the ISD2560 that match the individual digits in the reading. These addresses are stored in the phrase buffer.

FORM_PHRASE: CLR POINT_FLAG ; Check to see if the temperature reading is a .5 increment, if it is set the POINT_FLAG.
BRCLR 0,(RAW_TEMP+1),NOT_POINT
INC POINT_FLAG

NOT_POINT: LDX #PHRASE_BUFFER
LDA RAW_TEMP ; Check to see if the temperature is negative BEQ NOT_NEG ; if it is, place the address of the "Negative" phrase at the start of the phrase buffer.
Otherwise
STA ,X ; convert the temperature into its positive equivalent.
INCX
LDA (NEG_ADDR+1)
STA ,X
INCX
COM (RAW_TEMP+1)
INC (RAW_TEMP+1)

NOT_NEG: LSR (RAW_TEMP+1) ; Check for the temperature being lower than 100 degrees
LDA (RAW_TEMP+1) ; Celcius.
CMP #$64
BLO BELOW_100
SUB #$64
STA (RAW_TEMP+1)
LDA HUNDRED_ADDR ; If the temperature is greater than or equal to 100 degrees
STA ,X ; put the address of the "One hundred" phrase in the phrase
INCX ; buffer and subtract the equivalent value of 100 from the value.
LDA (HUNDRED_ADDR+1)
STA ,X
INCX
LDA (RAW_TEMP+1)
BEQ POINT
BELOW_100:   LDA (RAW_TEMP+1) ; Check to see if the remaining temperature value is less than 20
            CMP #$14  ; degrees. If it is, search for it in the TB0_19 table.
            BLO BELOW_20 ; Otherwise divide the data by ten. Store the
            CLR QUOTIENT ; quotient variable and the remainder in
            SUB #$14   ; (RAW_TEMP+1).
   DIV10        CMP #$A  
            BLO DIV_DONE
            INC QUOTIENT
            SUB #$A  
            BRA DIV10
   DIV_DONE     STA (RAW_TEMP+1)
            ASL QUOTIENT
            STX PHRASE_POINTER ; Find the address of the quotient's phrase in
            LDX QUOTIENT    ; the TBL20_90 table and store it in the phrase
            buffer.
            LDA TBL20_90,X
            INX
            STX TEMP
            LDX PHRASE_POINTER
            STA ,X
            INX
            STX PHRASE_POINTER
            LDX TEMP
            LDA TBL20_90,X
            LDX PHRASE_POINTER
            STA ,X
            INX
            LDA (RAW_TEMP+1)
            BEQ POINT
   BELOW_20     LDA (RAW_TEMP+1) ; Find the address of the remainder's phrase in
            ASLA ; TBL0_19 table and store it in the phrase
            STX PHRASE_POINTER
            TAX
            LDA TBL0_19,X
            INX
            STX TEMP
            LDX PHRASE_POINTER
            STA ,X
            INX
            STX PHRASE_POINTER
            LDX TEMP
            LDA TBL0_19,X
            LDX PHRASE_POINTER
            STA ,X
            INX
POINT TST POINT_FLAG ; If the temperature is a .5 increment reading
BEQ END_RAWTEMP ; load the phrase buffer with the addresses for
                  ; the
LDA POINT_ADDR ; "Point" and "Five" phrases.
STA ,X
INCX
LDA (POINT_ADDR+1)
STA ,X
INCX
LDA FIVE_ADDR
STA ,X
INCX
LDA (FIVE_ADDR+1)
STA ,X
INCX
END_RAWTEMP LDA DEGREE_ADDR ; Load the phrase buffer with the address for
STA ,X ; the "Degrees" phrase.
INCX
LDA (DEGREE_ADDR+1)
STA ,X
INCX
LDA CELCIUS_ADDR ; Load the phrase buffer with the address for
STA ,X ; the "Celcius" phrase.
INCX
LDA (CELCIUS_ADDR+1)
STA ,X
INCX
CLR ,X
DEC ,X
RTS

************************************************************************************
*                                                                                 *
*  Function Name: INITIALIZE                                                          *
*  Function Inputs: None                                                              *
*  Functions Outputs: None                                                            *
*                                                                                 *
*  Purpose: This function configures PORT A and PORT B                              *
* and their data direction registers.                                               *
*                                                                                 *
************************************************************************************

INITIALIZE LDA #DDRAMSK
STA DDRA
LDA #PORTAMSK
STA PORTA
LDA #DDRBMSK
STA DDRB
LDA #PORTBMSK
STA PORTB
RTS
**Function Name:** GET_TEMP  
**Function Inputs:** None  
**Functions Outputs:** None  

**Purpose:** This function performs the required reads and writes to the 1820 to perform a temperature conversion and acquisition. The temperature read is returned in TEMP variable.

```assembly
GET_TEMP        JSR     RESET_1820                ; Reset the 1820.
BRSET   ERROR,SYS_STATUS,GET_ERROR
LDA     #SKIPROM        ; Send the 1820's SKIP ROM command.
STA     TEMP
JSR     WRITE_1820
LDA     #CONVERT        ; Send the 1820's CONVERT T command.
STA     TEMP
JSR     WRITE_1820
READ_LOOP       JSR     READ_1820
LDA     TEMP
CMP     #$FF
BNE     READ_LOOP
JSR     RESET_1820      ; Reset the 1820.
BRSET     ERROR,SYS_STATUS,GET_ERROR ; If the reset fails set the
LDA     #SKIPROM        ; error bit and exit the routine.
STA     TEMP
JSR     WRITE_1820
LDA      #READRAM vccccccccc; Read the 1820's RAM to get
STA     TEMP            ; the temperature
JSR     WRITE_1820
JSR     READ_1820
LDA     TEMP
CMP     [#POSITIVE_SIGN   ; Check for an invalid positive
BEQ     CHK_POSITIVE    ; data value.
CMP     [#NEGATIVE_SIGN   ; Check for an invalid negative
BNE     GET_ERROR       ; data value.
LDA     TEMP_LO
CMP     [#NEGATIVE_LIMIT
BLO     GET_ERROR
BRA     GET_EXIT
```
**Function Name:** RESET_1820  
**Function Inputs:** None  
**Functions Outputs:** None  

**Purpose:** This function resets the 1820. If the 1820 resets properly, it will return a response pulse. If a pulse is not received, the error bit is set in system status.

---

**RESET_1820**  
STA TEMPA  ; Save the CPU registers  
STX TEMPX  
BSET DQ,PORTB  ; Send a reset pulse to  
BSET DQ_CTRL,DDRB  ; the 1820  
BCLR DQ,PORTB  
JSR DELAY_500uS  
BSET DQ,PORTB  
BCLR DQ_CTRL,DDRB  ; Set the J1A to receive the response pulse from the 1820  
JSR DELAY_100uS  
BRSET DQ,PORTB,RESET_ERR  ; If the start of the pulse is not received, handle the error  
BRSET DQ,PORTB,RESET_EXIT  

**RESET_ERR**  
BSET ERROR,SYS_STATUS  ; Set the error bit  

**RESET_EXIT**  
BSET DQ,PORTB  ; Set the J1A for transmission  
BSET DQ_CTRL,DDRB  
LDA TEMPA  ; Restore CPU registers  
LDX TEMPX  
RTS
**Function Name: WRITE_1820**

**Function Inputs: None**

**Functions Outputs: None**

**Purpose: This function writes the data stored in the TEMP variable to the 1820.**

```assembly
WRITE_1820 STA TEMPA ; Save CPU registers.
STX TEMPX
LDX #8 ; Load X with count.
WRITE_SHIFT LSR TEMP ; Shift out the bit to be sent
BCS WRITE_ONE
WRITE_ZERO BCLR DQ,PORTB ; Send a zero to the 1820
JSR DELAY_80uS
BSET DQ,PORTB
BRA DEC_WRITE
WRITE_ONE BCLR DQ,PORTB ; Send a one to the 1820
NOP
NOP
NOP
BSET DQ,PORTB
JSR DELAY_80uS
DEC_WRITE DECX
BNE WRITE_SHIFT
LDA TEMPA ; Restore CPU registers
LDX TEMPX
RTS
```

**Function Name: READ_1820**

**Function Inputs: None**

**Functions Outputs: None**

**Purpose: This function reads data from the 1820 and returns the date in the TEMP variable.**

```assembly
READ_1820 STA TEMPA ; Save CPU registers
STX TEMPX
LDX #8 ; Load X registers with count
```
READ_BIT        BSET    DQ,PORTB        ; Set up the DQ line for read
BSET    DQ_CTRL,DDRB
BCLR    DQ,PORTB
NOP
NOP
NOP
NOP
NOP
BCLR    DQ_CTRL,DDRB    ; Set the DQ line to receive data
BRSET   DQ,PORTB,READ_ONE ; Read bit
CLC
BRA     READ_SHIFT

READ_ONE        SEC
READ_SHIFT      ROR     TEMP            ; Rotate the bit in the TEMP variable
JSR     DELAY_80uS
DECX
BNE     READ_BIT
BSET    DQ,PORTB
BSET    DQ_CTRL,DDRB
LDA     TEMPA           ; Restore CPU registers
LDX     TEMPX
RTS

DEBOUNCE        LDX     #$FF
DEBOUNCE_LOOP   JSR     DELAY_500uS
DECX
BNE     DEBOUNCE_LOOP
BIL     DEBOUNCE_EXIT    ; If the interrupt is valid, exit
BSET    ERROR,SYS_STATUS ; If the interrupt is invalid, set
                   ; the error bit and exit
DEBOUNCE_EXIT   RTS

*********************************************************************************
*                                                                                  *
*  Function Name: DEBOUNCE                                                            *
*  Function Inputs: None                                                              *
*  Functions Outputs: None                                                            *
*                                                                                  *
*  Purpose: This function debounces the pushbutton switch.                         *
*                                                                                       *
*********************************************************************************

For More Information On This Product, 
Go to: www.freescale.com
**Application Note**

**Source Code**

```
*********************************************************************************
* Function Inputs: None
* Functions Outputs: None
* Purpose: This function provides delays.
* 
*********************************************************************************

DELAY_80uS      LDA     #$0C
BRA     DELAY_LOOP

DELAY_100uS     LDA     #$0F
BRA     DELAY_LOOP

DELAY_500uS     LDA     #$52
BRA     DELAY_LOOP

DELAY_LOOP      NOP
                NOP
                NOP
                DECA
                BNE     DELAY_LOOP
                RTS

*********************************************************************************
* PHRASE ADDRESS TABLE
* 
*********************************************************************************

org $700

TBL0_19:      DW  $0000         ; Address for the phrase "Zero".
              DW  $0010         ; Address for the phrase "One".
              DW  $0020         ; Address for the phrase "Two".
              DW  $0030         ; Address for the phrase "Three".
              DW  $0040         ; Address for the phrase "Four".
FIVE_ADDR:    DW  $0050         ; Address for the phrase "Five".
              DW  $0060         ; Address for the phrase "Six".
              DW  $0070         ; Address for the phrase "Seven".
              DW  $0080         ; Address for the phrase "Eight".
              DW  $0090         ; Address for the phrase "Nine".
              DW  $00A0         ; Address for the phrase "Ten".
              DW  $00B0         ; Address for the phrase "Eleven".
              DW  $00C0         ; Address for the phrase "Twelve".
              DW  $00D0         ; Address for the phrase "Thirteen".
              DW  $00E0         ; Address for the phrase "Fourteen".
              DW  $00F0         ; Address for the phrase "Fifteen".
              DW  $0100         ; Address for the phrase "Sixteen".
              DW  $0110         ; Address for the phrase "Seventeen".
```

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AN1292
DW $0120         ; Address for the phrase "Eighteen".
DW $0130         ; Address for the phrase "Nineteen".

TBL20_90:     DW  $0140         ; Address for the phrase "Twenty".
DW $0150         ; Address for the phrase "Thirty".
DW $0160         ; Address for the phrase "Forty".
DW $0170         ; Address for the phrase "Fifty".
DW $0180         ; Address for the phrase "Sixty".
DW $0190         ; Address for the phrase "Seventy".
DW $01A0         ; Address for the phrase "Eighty".
DW $01B0         ; Address for the phrase "Ninety".

HUNDRED_ADDR: DW  $01C0         ; Address for the phrase "One Hundred".
POINT_ADDR:   DW  $01D0         ; Address for the phrase "Point".
DEGREE_ADDR:  DW  $01E0         ; Address for the phrase "Degree".
NEG_ADDR:     DW  $01F0         ; Address for the phrase "Negative".
CELCIUS_ADDR: DW  $0200         ; Address for the phrase "Celcius".

ORG     $7FA
DW      IRQ_INT

ORG     $7FE
DW      START

END
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