Application Report
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Interfacing the DAC8811 to the MSP430F449

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ABSTRACT

This application report describes how to interface the DAC8811 multiplying digital-to-analog converter (MDAC) to the MSP430F449 mixed signal microcontroller.

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1 Introduction

The DAC8811 is a single-channel, low-power, low-noise, 16-bit resolution, current output MDAC, which features a fast serial interface and wide reference bandwidth of up to 10 MHz. The MDAC's communication port accepts 16 bits of serial input data, which can be interfaced with the MSP430F449 using the SPI protocol for this specific application report. The MDAC's power supply, V_{DD}, provides the power for both analog and digital sections and can range from a minimum of +2.7 V to a maximum of +5.5 V. Because the DAC8811 EVM and the HPA449 platform are used for this application report, the V_{DD} is fixed to +5 V. An external reference voltage is required to set the range of the full-scale current of this MDAC, which can be up to a maximum of ±15 Vdc or Vac.

The conventional way to use this MDAC is with a current-to-voltage topology, using an external operational amplifier. The amplifier selected for this application report is the OPA277, which provides the basis of the MDAC's settling time, linearity, and other operational factors. Therefore, the proper selection of the external I-to-V operational amplifier is crucial in the design.

2 Hardware Setup Configuration

This application report is based on an experiment using the HPA449 platform for the MSP430F449 and the DAC8811 EVM revision A. Once the HPA449 and the DAC8811 EVM are configured properly, they can be connected together easily. Figure 1 and Figure 2 show the hardware configuration setups for the HPA449 board and the DAC8811 EVM, respectively.

The HPA449 comes configured with the correct jumper settings from the factory (see Figure 1).

The hardware setup configuration for the DAC8811 EVM (see Figure 2) depicts the simple diagram of the interface connection between the DAC8811 and the MSP430F449 (see Figure 3).

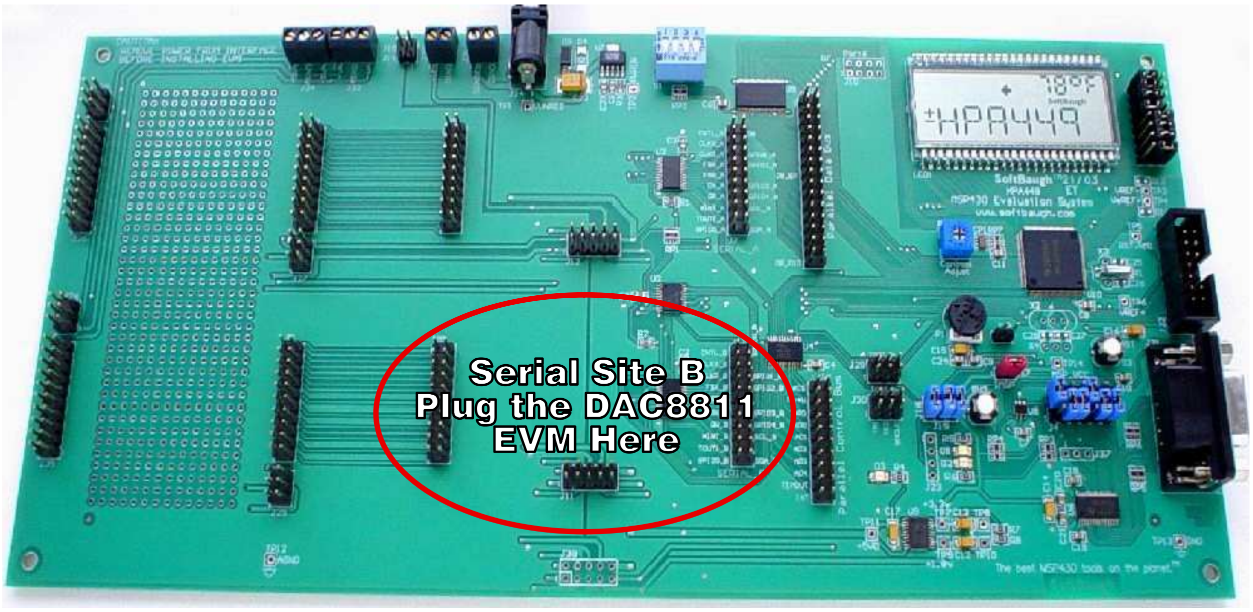

Figure 1. HPA449 Hardware Configuration

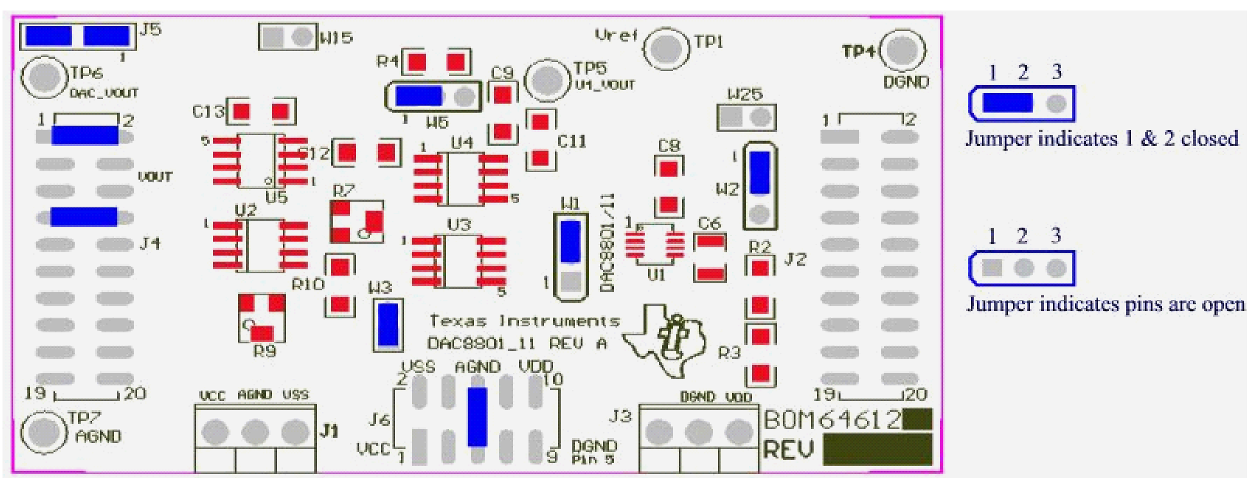

Figure 2. DAC8811 EVM Hardware Configuration

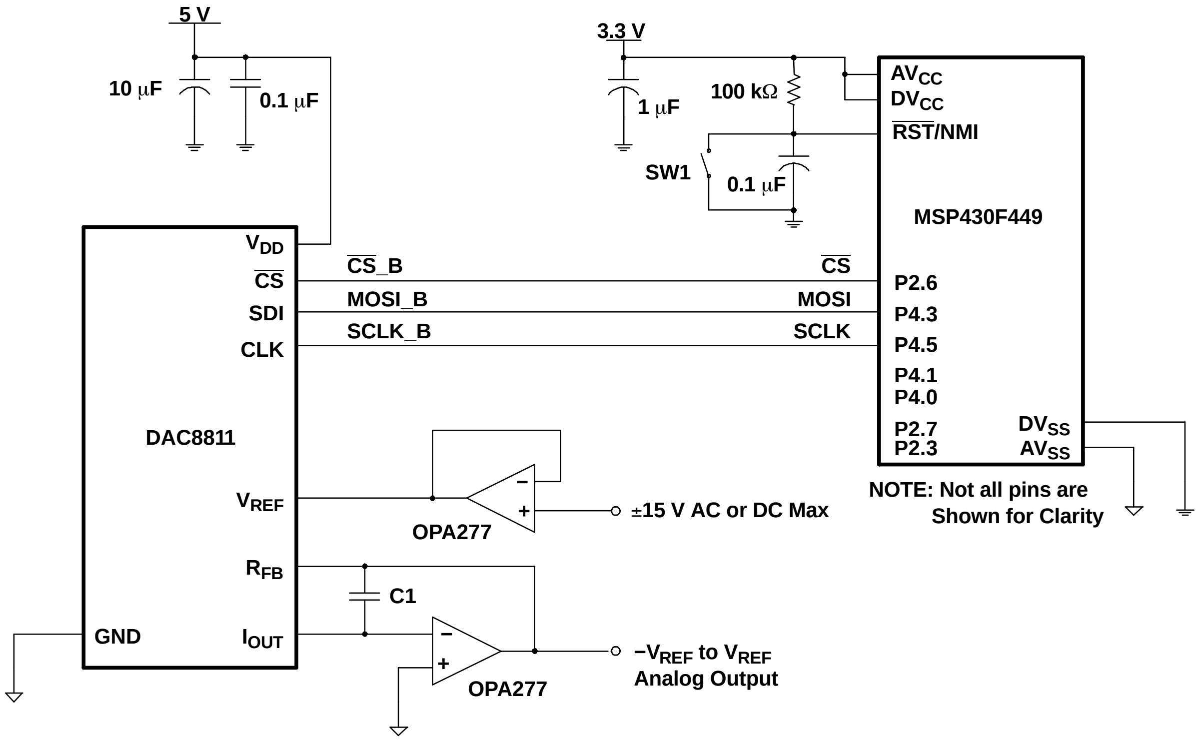

Figure 3. MSP430 and DAC8811 Circuit Diagram

3 Principle of Operation

The MSP430F449 microcontroller interfaces with the DAC8811 using the SPI serial data communication protocol via the MSP430 microcontroller 's USART1 port. Only two pins of the four-pin SPI mode of configuration are used. This is because there is no need for reading any data back from the DAC8811 or having the MSP430 microcontroller be slaved by another host peripheral for SPI purposes. Therefore, the STE and the MISO functions in SPI mode of the USART1 port are unused.

The $\overline{CS}$ function enables the SPI port and latches data into the DAC register. This function is accomplished using a GPIO pin, P2.6 of the MSP430 microcontroller. When $\overline{CS}$ is low, the digital input bits are advanced one bit at a time on each rising edge of SCLK. The DAC8811 receives 16 bits of digital input word serially. Because the SPI provides only eight data clocks per transmission, two write cycles are required within the $\overline{CS}$ low period (seeFigure 4). The 16-bit data is transferred into the shift register starting with the MSB via the MOSI pin on P4.3 of the MSP430 microcontroller.

The DAC register is updated on the rising edge of the $\overline{CS}$ signal on transitioning from low to high after the 16^{th} SCLK cycle. Any extra clocks generated while $\overline{CS}$ is low corrupts the data.

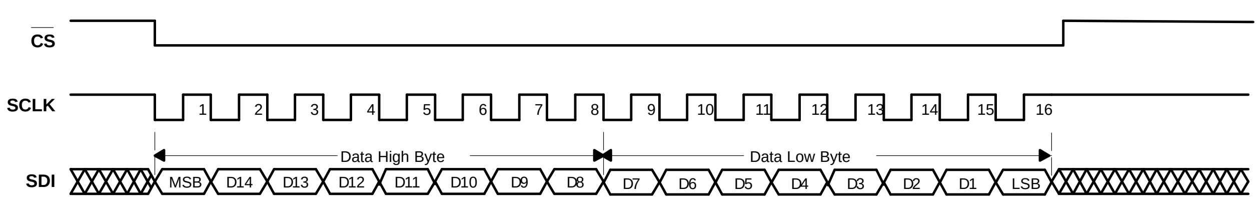

Figure 4. DAC8811 Serial Interface Timing

4 Generating the Sine-Wave Output

The actual timing diagram of the SPI serial interface is shown in Figure 5. Channel 1 shows the $\overline{CS}$ signal, and channel 2 shows the SCLK running at approximately 4 MHz. Channel 3 shows the MOSI line (Serial Data In) transmitting the 16-bit data word.

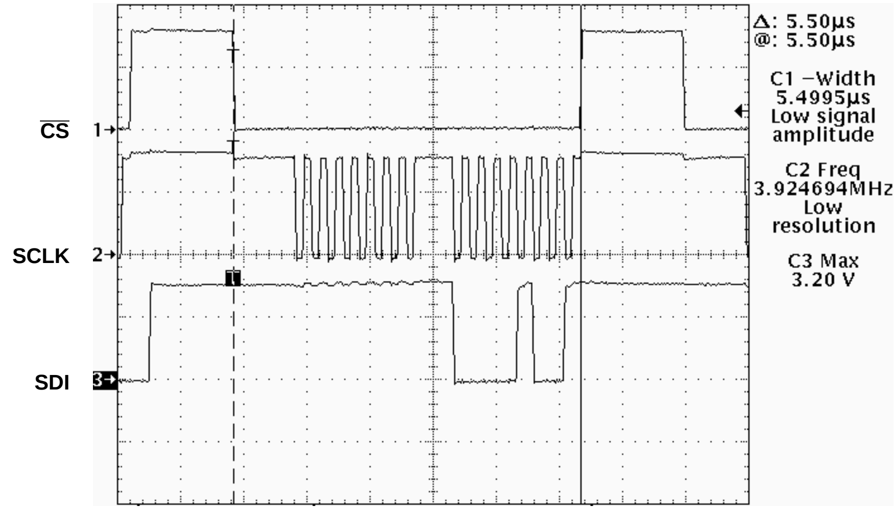

Figure 5. Actual Timing of the DAC8811 SPI Serial Interface

4.1 Positive DC Reference Source (V_{REF}) With Varying D_{CODE} (Sine Table)

The waveform in Figure 6 shows the reference voltage, V_{REF}, set to +10 Vdc as seen on channel 1. Channel 2 displays the sinusoidal waveform output from 0 V to –10 V, because the MDAC's output is the inverse of the reference input voltage, V_{REF}.

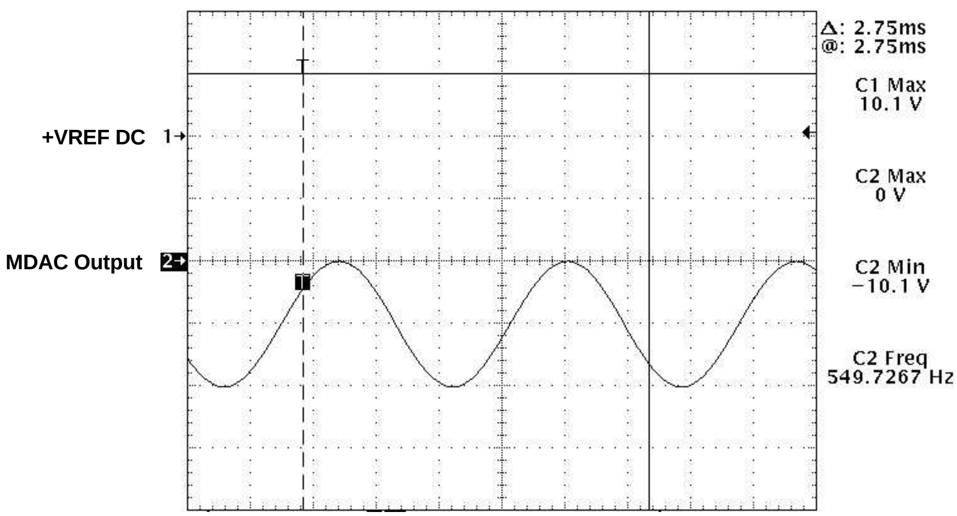

Figure 6. DAC8811 Reference and Output Waveform

4.2 Negative DC Reference Source (V_{REF}) With Varying D_{CODE} (Sine Table)

In like manner, if the reference voltage, V_{REF}, is changed to a negative polarity, as shown in Figure 7, then the MDAC's output becomes positive. Note that the amplitude has changed to 2.5 Vdc as well. Therefore, the MDAC's sinusoidal output is from 0 V to +2.5 V.

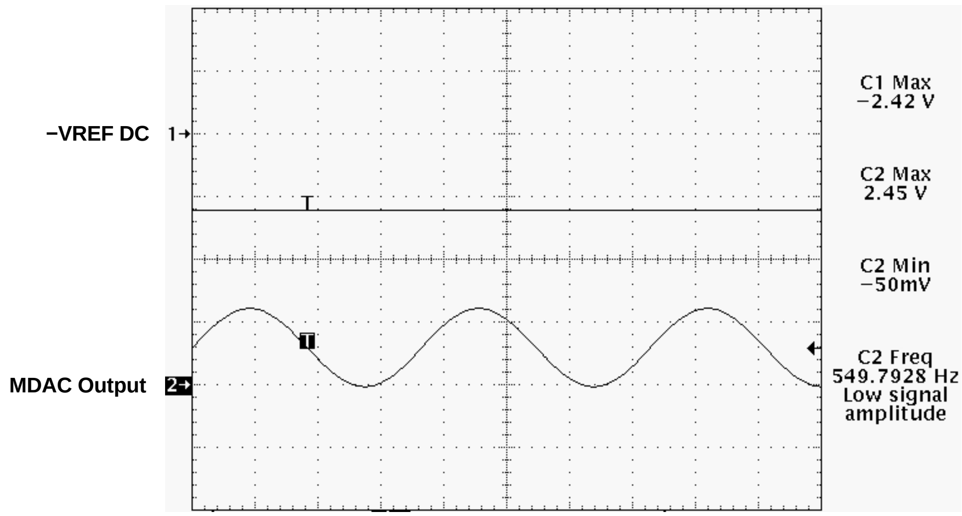

Figure 7. DAC8811 Reference and Output Waveform

4.3 AC Reference Source (V_{REF}) With Fixed D_{CODE} (0x8000)

The waveform of Figure 8 shows the reference voltage, V_{REF}, to be an ac source with amplitude of ±1 V (or 2 Vp-p). A fix D_{CODE} of 0x8000 is written to the MDAC; therefore, the subsequent output voltage is half the scale of the reference input voltage. The reference voltage can be a maximum of ±15 V.

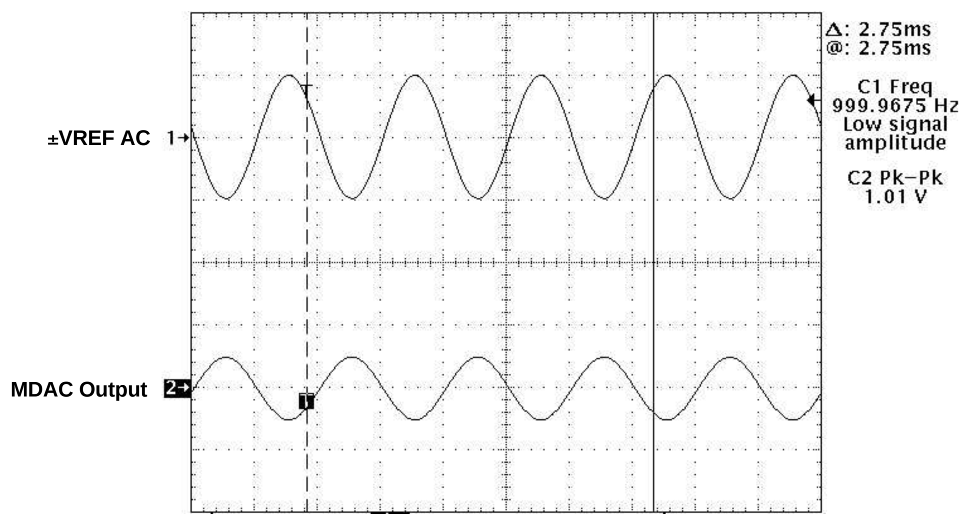

Figure 8. DAC8811 Reference and Output Waveform

4.4 AC Reference Source (V_{REF}) With Varying D_{CODE} (Sine Table)

The waveform of Figure 9 shows the reference voltage, V_{REF}, to be an ac source with amplitude of ±1 V (or 2 Vp-p). A varying D_{CODE} is written to the MDAC; therefore, the subsequent output voltage is the product of the D_{CODE} and the reference input voltage.

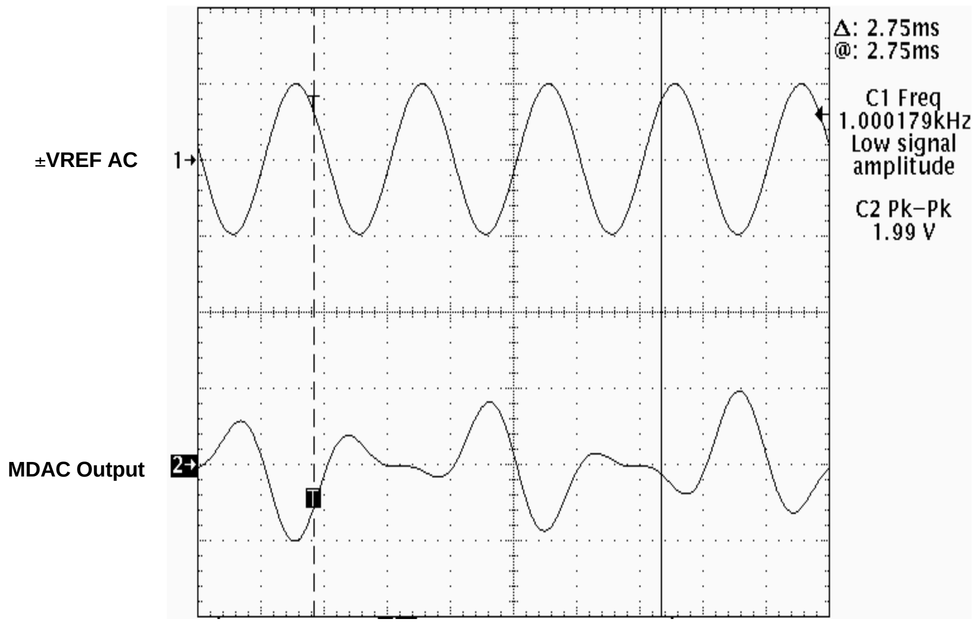

Figure 9. DAC8811 Reference and Output Waveform

5 Summary

This application report shows how easy it is to interface the DAC8811 to the MSP430F449 microcontroller using the SPI mode of serial communication. With the software program provided in this application report, a simple routine to generate a sinusoidal waveform or any multiplying function is achieved. Using the DAC8811 EVM along with the HPA449 evaluation system makes this task even easier. For detailed information regarding the DAC8811,see its data sheet SLAS411. For additional support, contact the TI Data Acquisition Product Group by sending an e-mail to dataconvapps@list.ti.com.

For questions or information regarding the HPA449 evaluation system, contact SoftBaugh, Inc. at e-mail address info@softbaugh.com, or call toll-free number (800) 794-5756 or commercial (770) 772-8111.

6 References

1. *DAC8811 16-Bit, Serial Input Multiplying Digital-to-Analog Converter* data sheet (SLAS411)
2. *DAC8801/11EVM User's Guide* (SLAU151)
3. *MSP430x43x, MSP430x44x Mixed Signal Microcontroller* data sheet (SLAS344)
4. *MSP430X4XX Family User's Guide* (SLAU056)
5. *MSP430F44X Evaluation System (HPA449) User's Guide (SoftBaugh, Inc.)*

Appendix A MSP430F449 Software Code

A.1 Main Code

```
;*******************************************************************************************
; MSP430F449 Demo - SPI Communication with DAC8811 SPI function
; using the HPA449 v1.1
;
; Assembled with IAR Embedded Workbench for MSP430 Kickstart
;
; Author:      Jojo Parguian
;              HPA/DAP
; Company:     Texas Instruments, Inc.
;
; Used:
;                HPA449 V1.1
;                DAC8811 EVM Rev 1
;
; Note:
;*******************************************************************************************
#include   "msp430x44x.h"         // Standard Equations
#include   "legal.asm"
#include   "readme.asm"
#define     DATASPI      R9
/************************************************************
* MSP430 Pin Assignment - GPIO Definitions
************************************************************/
/* J2 Connections */
#define CSb              0x40        /* P2.6 */
/************************************************************
* MSP430 USART1 Register Definitions
************************************************************/
#define SPI              0x038
;---------------------------------------------------------------------------
; 16-bit Unipolar Sine Lookup table with 256 steps
;---------------------------------------------------------------------------
          ORG   01000h
;---------------------------------------------------------------------------
Sin_tab
          DW   32768,33572,34376,35178,35980,36779,37576,38370,39161,39947
          DW   40730,41507,42280,43046,43807,44561,45307,46047,46778,47500
          DW   48214,48919,49614,50298,50972,51636,52287,52927,53555,54171
          DW   54773,55362,55938,56499,57047,57579,58097,58600,59087,59558
          DW   60013,60451,60873,61278,61666,62036,62389,62724,63041,63339
          DW   63620,63881,64124,64348,64553,64739,64905,65053,65180,65289
          DW   65377,65446,65496,65525,65535,65525,65496,65446,65377,65289
          DW   65180,65053,64905,64739,64553,64348,64124,63881,63620,63339
          DW   63041,62724,62389,62036,61666,61278,60873,60451,60013,59558
          DW   59087,58600,58097,57579,57047,56499,55938,55362,54773,54171
          DW   53555,52927,52287,51636,50972,50298,49614,48919,48214,47500,46778
          DW   46047,45307,44561,43807,43046,42280,41507,40730,39947,39161
          DW   38370,37576,36779,35980,35178,34376,33572,32768,31964,31160
          DW   30358,29556,28757,27960,27166,26375,25589,24806,24029,23256
          DW   22490,21729,20975,20229,19489,18758,18036,17322,16617,15922
          DW   15238,14564,13900,13249,12609,11981,11365,10763,10174,9598
          DW   9037,8489,7957,7439,6936,6449,5978,5523,5085,4663,4258,3870,3500
          DW   3147,2812,2495,2197,1916,1655,1412,1188,983,797,631,483,356,247
          DW   159,90,40,11,1,11,40,90,159,247,356,483,631,797,983,1188,1412,1655
          DW   1916,2197,2495,2812,3147,3500,3870,4258,4663,5085,5523,5978,6449
          DW   6936,7439,7957,8489,9037,9598,10174,10763,11365,11981,12609,13249
          DW   13900,14564,15238,15922,16617,17322,18036,18758,19489,20229,20975
          DW   21729,22490,23256,24029,24806,25589,26375,27166,27960,28757,29556
          DW   30358,31160,31964,32768
```

```
;----------------------------------------------------------------------------
            ORG     0F000h
;----------------------------------------------------------------------------
;**********************************************************************
;Program Code
;**********************************************************************
           RSEG CODE
;**********************************************************************
RESET
            mov.w   #0A00h,SP                  ; Initialize stack-pointer
            call    #Init_Sys                  ; Initialize system
            clr.w   R6
            bic.b   #0FFh,&P1OUT
            Write_Data
            mov.w   #0FFh,R6                   ; 256 Sample Counter
            mov.w   #0,R5                      ; Table pointer
Again
            mov.w   Sin_tab(R5),DATASPI        ; Sine Table Data
            swpb    DATASPI                    ; MSB first
            bic.b   #CSb, &P2OUT               ; Assert CS_
            mov.b   DATASPI,&U1TXBUF           ; Transmit data
WaitXMT0
            bit.b   #UTXIFG1, &IFG2            ; TXBUF ready?
            jnc     WaitXMT0
            swpb    DATASPI                    ; LSB next
            mov.b   DATASPI,&U1TXBUF
WaitXMT1
            bit.b   #UTXIFG1, &IFG2            ; TXBUF ready?
            jnc     WaitXMT1
            incd.w  R5                         ; increment table pointer
            sub.w   #1,R6                      ; decrement sample counter
            bis.b   #CSb, &P2OUT               ; deassert CS_
            and.w   #0FFh,R6                   ; Check sample counter if 256
            jnz     Again                      ; Do another sample
            jmp     Write_Data                 ; Another cycle
;*******************************
; Clear TX Flag
;*******************************
CLEAR0
           bit.b #UTXIFG0,&IFG1                ; TXBUF ready?
           jnc CLEAR0                          ; 1 = ready
           bic.b #UTXIFG0,&IFG1
           ret
;*******************************
; Clear TX Flag
;*******************************
CLEAR1
           bit.b #UTXIFG1,&IFG2                 ; TXBUF ready?
           jnc CLEAR1                           ; 1 = ready
           bic.b #UTXIFG1,&IFG2
           ret
;**********************************************************************
Init_Sys;  Modules and Controls Registers set-up subroutine
;**********************************************************************
StopWDT
          mov.w    #WDTPW+WDTHOLD,&WDTCTL    ; Stop Watchdog Timer
SetupFLL2
          bis.b   #FN_4,&SCFI0                   ; x2 DCO, 8MHz nominal DCO
          bis.b   #DCOPLUS+XCAP14PF,&FLL_CTL0    ; DCO+, configure load caps
          mov.b   #121,&SCFQCTL                  ;(121+1) x 2 x 32768 = 7.99 Mhz
SetupPorts
; Port 2
```

```
          bis.b #CSb, &P2DIR
          bis.b #CSb, &P2OUT
; Port 4
          bis.b #SPI,&P4SEL                        ; P4.3,4,5 SPI option select

SetupSPI0
          bis.b #USPIE0,&ME1                       ; Enable SPI TX/RX
          mov.b #CHAR+SYNC+MM,&U0CTL               ; 8-bit SPI Master
          bis.b #SSEL0+SSEL1+STC,&U0TCTL
          mov.b #02h,&U0BR0
          mov.b #00h,&U0BR1
          mov.b #00h,&U0MCTL
          bis.b #UTXIE0, &P1IE

SetupSPI1
          bis.b #USPIE1,&ME2                       ; Enable SPI TX/RX
          mov.b #CHAR+SYNC+MM+SWRST,&U1CTL         ; 8-bit SPI Master
          bis.b #CKPL+SSEL0+SSEL1+STC,&U1TCTL      ; 3-pin SPI mode, SMCLK
          mov.b #002h,&U1BR0       ; CKPL+CKPH gives SCLK idle high and data
          mov.b #000h,&U1BR1       ; sampled on the falling edge of SCLK
          mov.b #000h,&U1MCTL      ; CKPL gives SCLK idle high and data
          bis.b #USPIE1,&ME2       ; sampled on the rising edge of SCLK
          bic.b #SWRST, &U1CTL     ; CKPH gives SCLK idle low and data
                                   ; sampled on the rising edge of SCLK
          ret
;*********************************************************************************
         COMMON  INTVEC            ; MSP430x44x Interrupt vectors
;*********************************************************************************
          ORG     RESET_VECTOR
RESET_VEC         DW   RESET       ; POR, ext. Reset, Watchdog
          ORG     PORT2_VECTOR
          END
```

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