Lab 6
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ECE 3710
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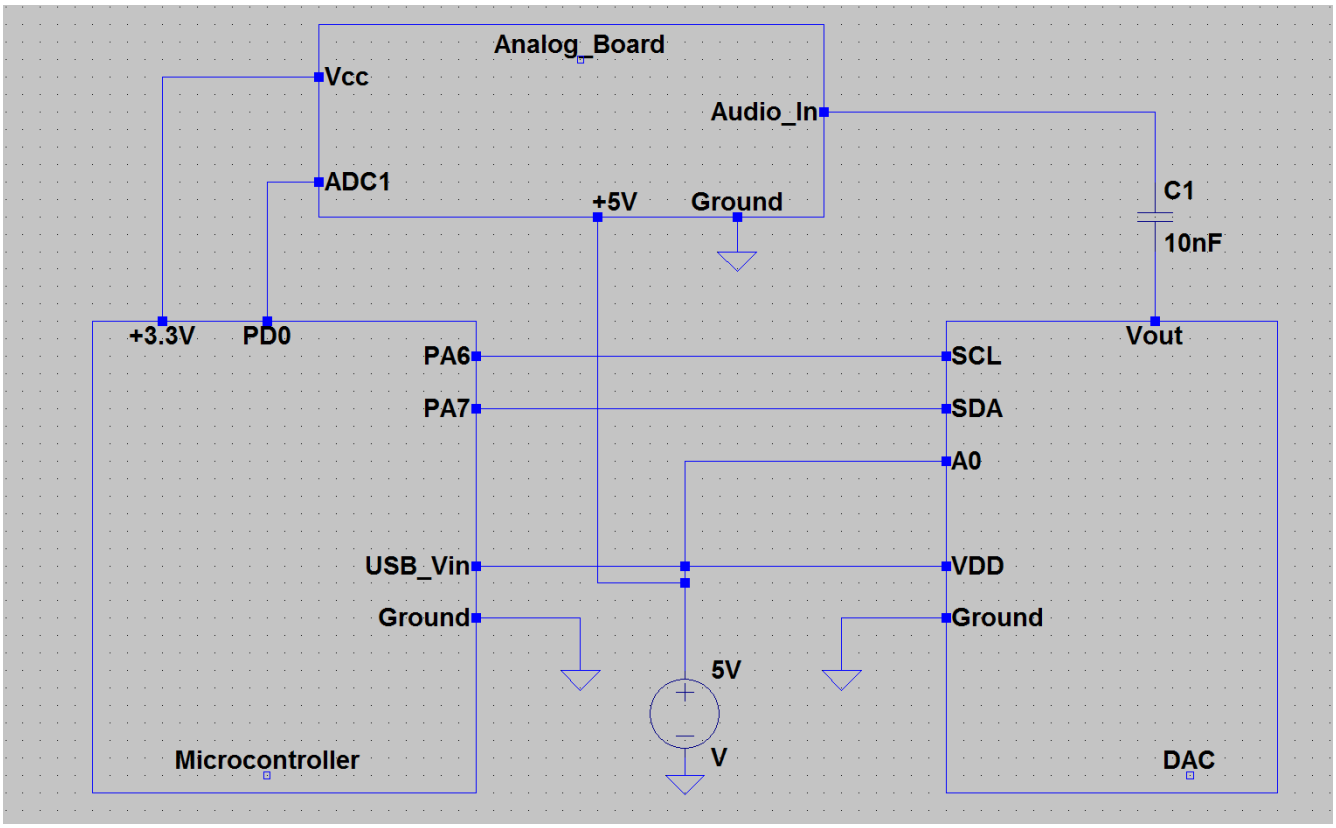
Overview:

The microcontroller outputs a digital sine wave to the DAC, which converts the values to analog and outputs them to the speaker. The speaker also has a potentiometer which sends a signal to the microcontroller that allows the user to alter the frequency of the sine wave to the speaker. This project requires:

- A 12-bit DAC
- A 5V voltage source
- A 10nF capacitor
- An analog board with both a potentiometer and speaker

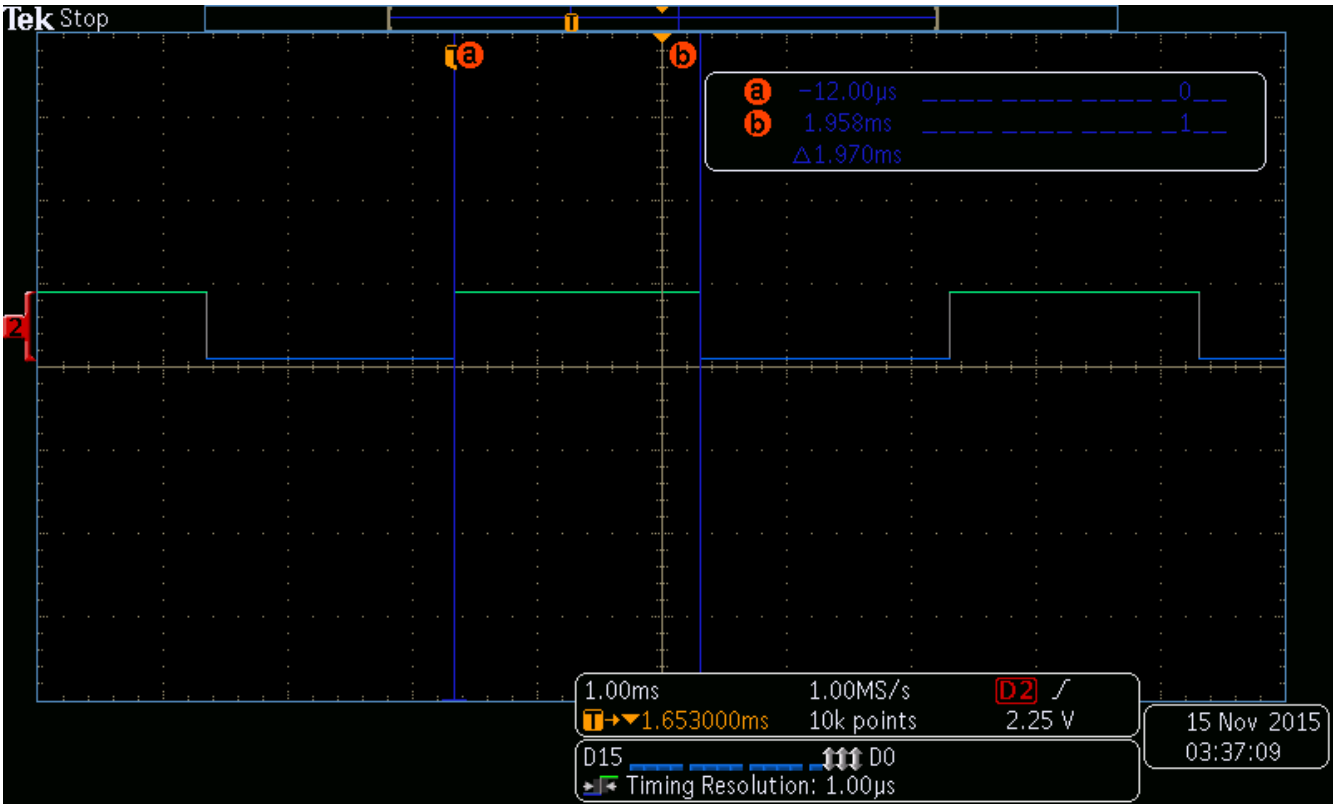
Hardware Details:

The microcontroller communicates with the DAC via I2C, requiring only 2 pins. For this, the I2C1 module was used on Port A. A0 was wired to power, making the address of the DAC 0x63 (instead of 0x62). The Vout pin of the DAC was the audio_in for the speaker, after the value went through the capacitor (which helped even out the rough edges of the waveform). ADC1 was used for the potentiometer and was input to the microcontroller on PD0. See schematic below:

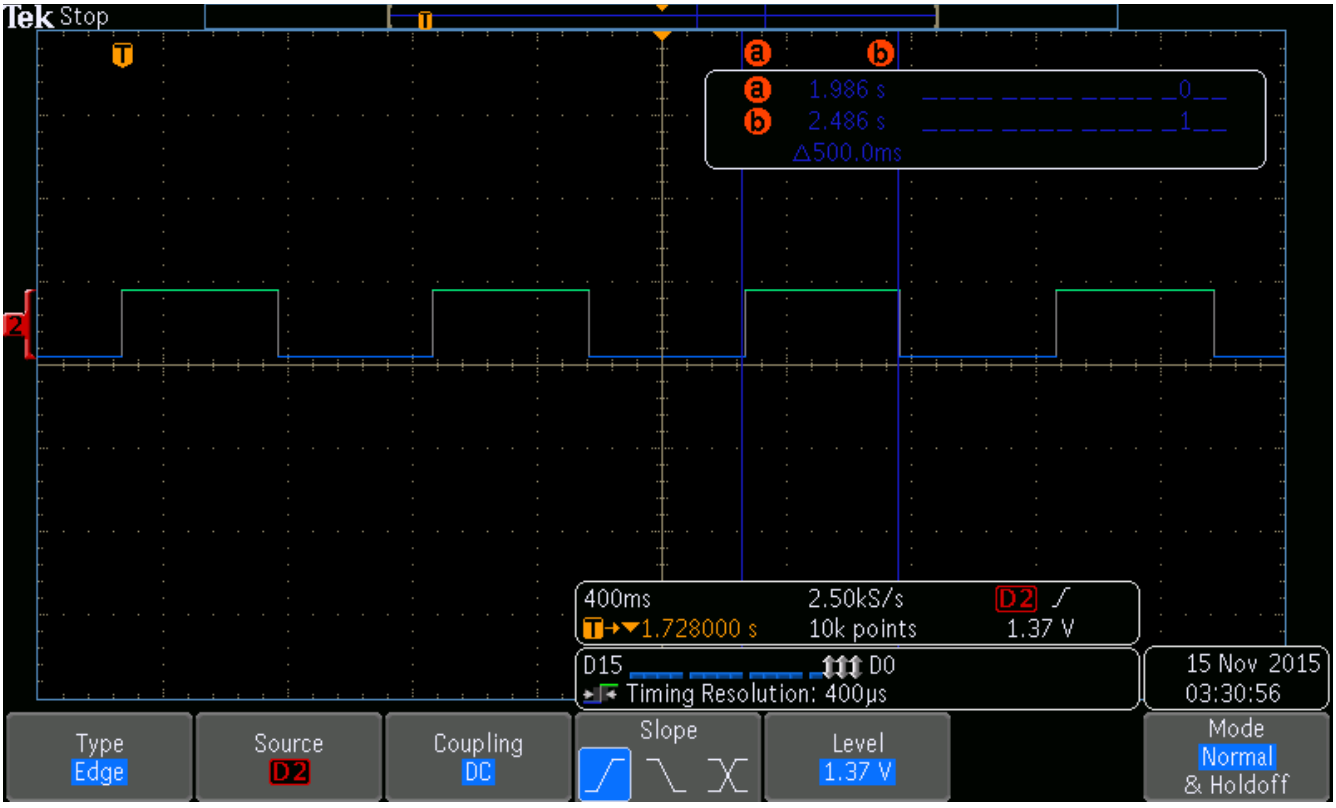


Software Details:

The sine wave was generated by creating a 40-element array. Each time timer C expired, the next value (circular) of the array was output to the DAC via I2C. Every 2ms, timer A expired and the current potentiometer value was read into the global value “VOLTAGE”. The logic analyzer verified that delay in this screenshot:

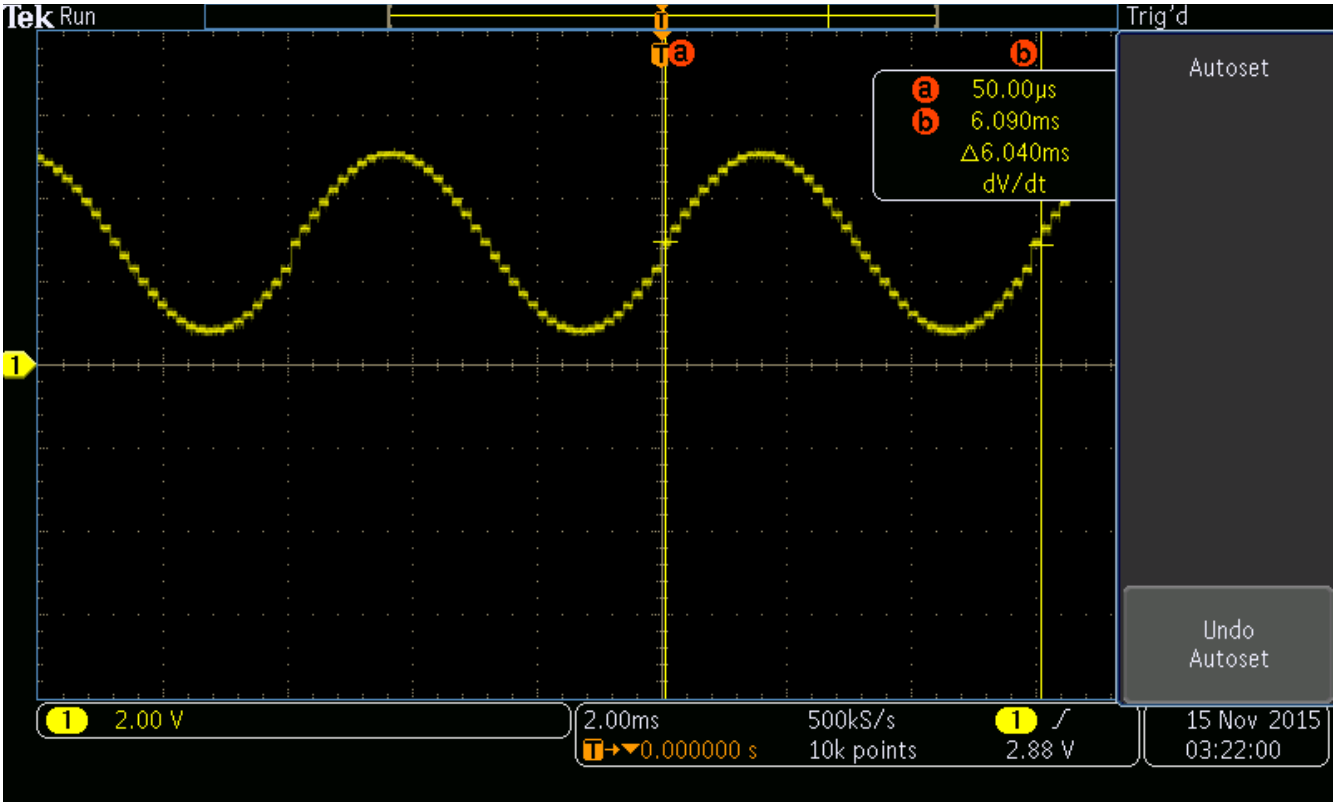


Every 500ms, the frequency of Timer C's expiration (the frequency of the sine wave) was checked to make sure it coincided with the value of the potentiometer. The logic analyzer verified that value below:

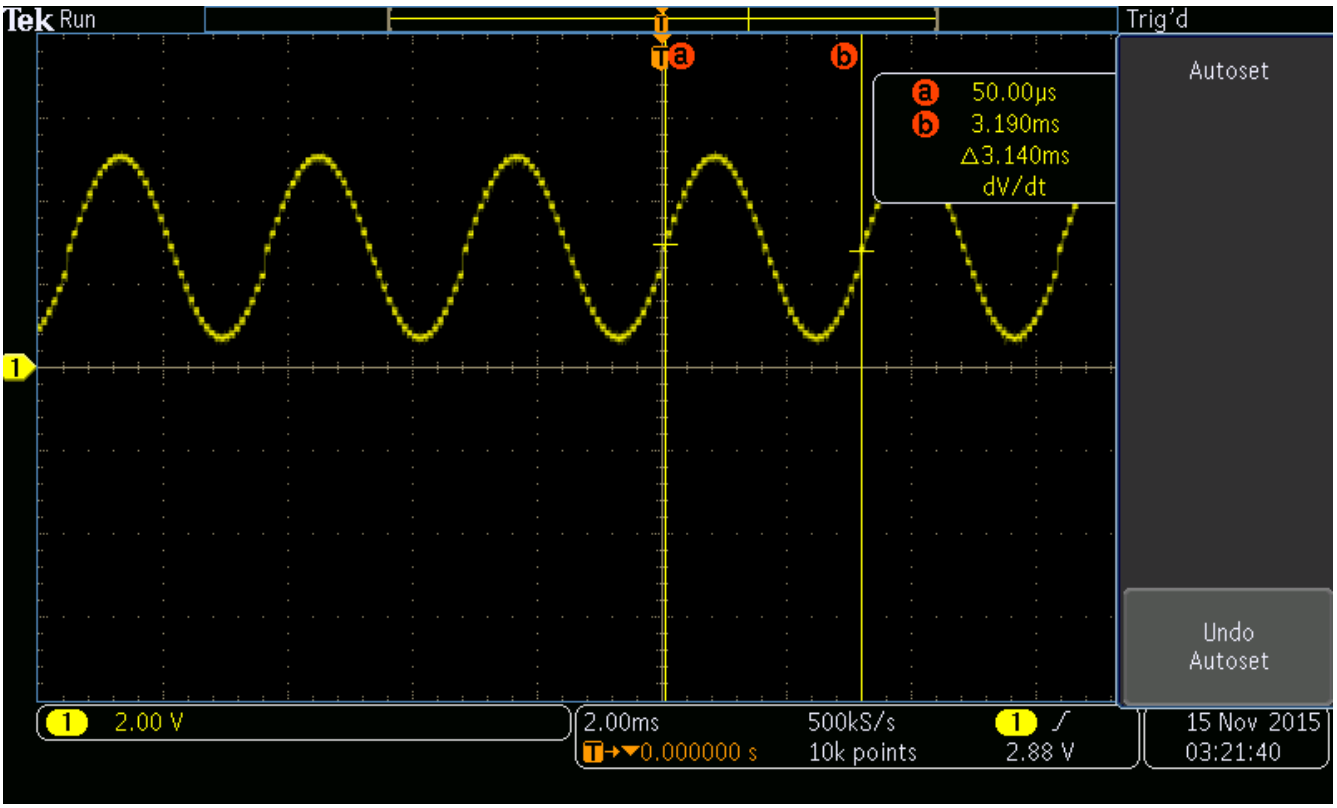


To determine the min and max frequencies of the sine wave, we looked at the frequency for middle C and made that our middle value. Using a slope of 1 (to prevent interger multiplication), that gave a minimum of 0x7D0 at 312.5 Hz (period of 1/312.5 = 3.2ms) and a max of 0x137F at 165.6 Hz (period of 1/165.6 = 6.03ms). Lower values gave higher frequencies.

The logic analyzer verified the lowest frequency:



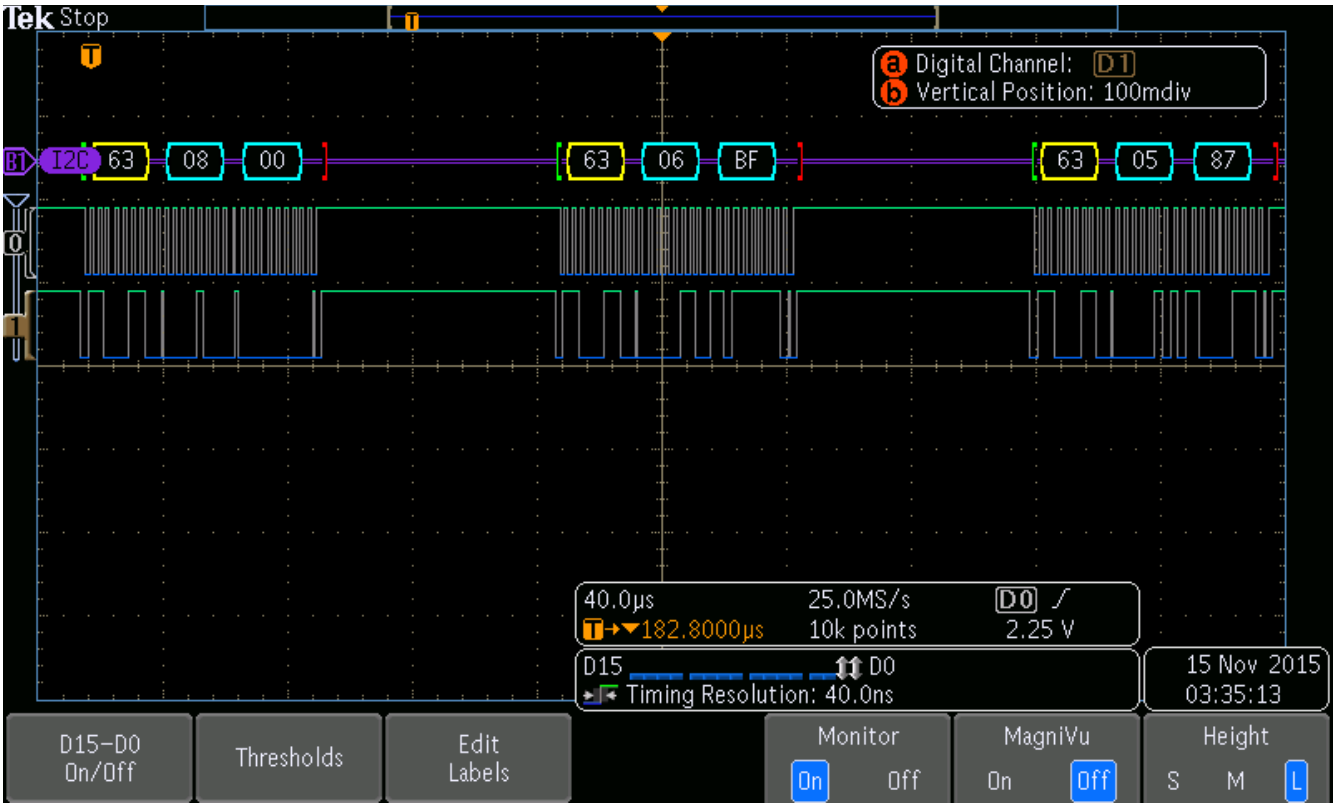
And the highest frequency:



There is a little bit of error between the theoretical and the exact from the logic analyzer, which is okay

considering the level of precision we used on the logic analyzer (low). Overall, it is clear to see everything is working properly and as expected within a very close margin.

And here is a screenshot of the I2C module sending 3 consecutive values of the sine table to the DAC (0x800,0x6bf,0x587):



Timers:

Although there were more efficient methods of working with the timers, we used a separate timers for each task. Timer 0 acted as timer A and was set to expire every 2ms, which triggered an interrupt to read the ADC module. Timer 1 acted as timer B and expired every 500ms, which triggered an interrupt to check the value read by timer A and configure the expire time for timer C. Timer 2 acted as timer C and expired with the min and max times specified above. During the interrupt, it transmitted the next value of the sine wave to the DAC.

Requirements:

1. The input voltage range for the DAC (Vss) is 2.7-5.5V (from datasheet).
2. The function of the A0 pin is the address of the DAC for I2C. We will use A0 = 1, so the I2C address for the DAC will be 0110 0011 (0x63).

Conclusion:

Although not a pleasant noise, the speaker does output a sound at apparently the correct frequencies, thanks to some very precise timing and a lot of frequent interrupts. Undoubtedly, this

system has a very practical and useful purpose, but at this level, it succeeded in only being very annoying to the other people in the lab. Using I2C was much easier than SPI and it is easy to see why it is so popular.

Code:

The rest of this document contains only code. Here it is:

GPIO.h

```
typedef struct{
	volatile unsigned int _0:1,_1:1,_2:1,_3:1,_4:1,_5:1,_6:1,_7:1,
	_8:1,_9:1,_10:1,_11:1,_12:1,_13:1,_14:1,_15:1,
	_16:1,_17:1,_18:1,_19:1,_20:1,_21:1,_22:1,_23:1,
	_24:1,_25:1,_26:1,_27:1,_28:1,_29:1,_30:1,_31:1;
}bitReg;

typedef struct{
	volatile unsigned char _0,_1,_2,_3;
}byteReg;

typedef struct{
	volatile unsigned short _0,_1;
}halfwordReg;

//access register via bit, byte, halfword, and word
typedef union{
	bitReg b;
	byteReg B;
	halfwordReg H;
	volatile unsigned int W;
}REG;

typedef struct{
	volatile unsigned char DATA_[1019]; //TI bit addresses
	REG DATA; //0x3FC
	REG DIR; //0x400
	REG IS; //0x404
	REG IBE; //0x408
	REG IEV; //0x40C
	REG IM; //0x410
	REG RIS; //0x414
	REG MIS; //0x418
	REG ICR; //0x41C
	REG AFSEL; //0x420
	volatile unsigned char RES[220]; //reserved
	REG DR2R; //0x500
	REG DR4R; //0x504
```

```
        REG DR8R; //0x508
        REG ODR; //0x50C
        REG PUR; //0x510
        REG PDR; //0x514
        REG SLR; //0x518
        REG DEN; //0x51C
        REG LOCK; //0x520
        REG CR; //0x524
        REG AMSEL; //0x528
        REG PCTL; //0x52C
}GPIO;
```

Main.c

```
#include "GPIO.h"

GPIO *PA = (GPIO *) 0x40004000;
GPIO *PB = (GPIO *) 0x40005000;
GPIO *PC = (GPIO *) 0x40006000;
GPIO *PD = (GPIO *) 0x40007000;
GPIO *PE = (GPIO *) 0x40024000;
GPIO *PF = (GPIO *) 0x40025000;
unsigned char *SYSCTL = (unsigned char *) 0x400FE000;
unsigned char *CORE = (unsigned char *) 0xE000E000;
unsigned char *ADC0 = (unsigned char *) 0x40038000;
unsigned char *TM0 = (unsigned char *) 0x40030000;
unsigned char *TM1 = (unsigned char *) 0x40031000;
unsigned char *TM2 = (unsigned char *) 0x40032000;
unsigned char *I2C1 = (unsigned char *) 0x40021000;

unsigned char tabAdd = 0;
unsigned short SINTABLE[40] =
{
        0x800,0x940,0xa78,0xba1,0xcb3,
        0xda7,0xe78,0xf20,0xf9b,0xfe6,
        0xfff,0xfe6,0xf9b,0xf20,0xe78,
        0xda7,0xcb3,0xba1,0xa78,0x940,
        0x800,0x6bf,0x587,0x45e,0x34c,
        0x258,0x187,0xdf,0x64,0x19,
        0x0,0x19,0x64,0xdf,0x187,
        0x258,0x34c,0x45e,0x587,0x6bf
};

void enableClock(void);
void enablePortA(void);
void enablePortB(void);
void enablePortC(void);
void enablePortD(void);
```

```
void enablePortE(void);
void enablePortF(void);
void enableADC0(void);
void enableTM0(void);
void enableTM1(void);
void enableTM2(void);
void enableI2C1(void);
void configurePorts(void);

volatile unsigned int VOLTAGE = 0;

void ADC0SS0_Handler(void)
{
	ADC0[0x00C] |= 0x01;					//ack interrupt
	VOLTAGE = *(int*)&ADC0[0x48];		//Result FIFO
}

void TIMER1A_Handler(void)
{
	TM1[0x024] |= 0x1;					//ack

	TM2[0x00C] &= 0x00;
		//GPTMCTL
	*(int*)&TM2[0x028] = VOLTAGE + 0x7D0;			// change frequency
	TM2[0x00C] |= 0x1;
	//start timer
}

void TIMER2A_Handler(void)
{
	unsigned short Tx = SINTABLE[tabAdd++];
	unsigned char B1 = (Tx >> 8);
	unsigned char B2 = (Tx & 0xFF);

	if(tabAdd == 39){
		tabAdd = 0;
	}
	TM2[0x024] |= 0x1;					//ack

	while((I2C1[0x4] & 0x1) == 0x1);		//wait MCS BUSY
	I2C1[0x008] = B1;						//MDR
	while((I2C1[0x4] & 0x40) == 0x40);		// wait MCS BUSBSY
	I2C1[0x004] = 0x03;					//MCS
	while((I2C1[0x4] & 0x1) == 0x1);		//wait MCS BUSY

	I2C1[0x008] = B2;						//MDR
	I2C1[0x004] = 0x05;					//MCS
	while((I2C1[0x4] & 0x1) == 0x1);		//wait MCS BUSY
```

```
}

int main(void)
{
	configurePorts();

	while(1);
}

void configurePorts()
{
	enableClock();

	enablePortA();
	enablePortD();
	enableADC0();
	enableTM0();
	enableI2C1();
	enableTM1();
	enableTM2();
}

void enableClock(){
	unsigned int i;
//  *(int*)&SYSCTL[0x060] = 0x8E3D40;		//sysclk 16MHz
  *(int*)&SYSCTL[0x060] = 0x24E1540;		//sysclk 40 MHz
  for(i = 0; i < 0xFF; i++);
	SYSCTL[0x608] = 0x09;				//enable PA PD PF
	SYSCTL[0x638] |= 0x01;				//enable ADC0
	SYSCTL[0x604] |= 0x07;				//TM0 TM1 TM2
	SYSCTL[0x620] |= 0x02;				// I2C1

	*(int*)&CORE[0x100] = 0xA04000;					//NVIC interrupt
ADC0SS0 TM1A TM2A
}

void enablePortA(void)
{
	PA->AFSEL.B._0 = 0xC0;
	PA->DEN.B._0 = 0xC0;
	PA->DIR.B._0 = 0xC0;
	PA->PCTL.W = 0x33000000;
	PA->ODR.b._7 = 0x1;
	PA->PUR.B._0 |= 0xC0;
}

void enablePortD(void)
{
	PD->LOCK.W = 0x4C4F434B;				//GPIO Unlcok
```

```
	PD->CR.B._0 = 0x80;
	PD->DEN.B._0 = 0x00;
	PD->DIR.B._0 = 0x00;
	PD->AMSEL.b._0 = 0x1;
}

void enableADC0(void)
{
	ADC0[0x0] = 0x00;				//ADC0 disable
	ADC0[0x8] |= 0x01;				//SS0 interrupt enable
	ADC0[0x14] = 0x05;				//ADCEMUX trigger SS0 set timer
	ADC0[0x040] = 0x7;				//ADCSSMUX0 select AIN7
	ADC0[0x44] |= 0x06;				//ADCSSCTL0 interrupt enable, 1st
sample is end
	ADC0[0x0] |= 0x01;				//ADC SS0 enable
}

//Timer A
void enableTM0(void)
{
	TM0[0x00C] &= 0x00;				//GPTMCTL
	TM0[0x0] &= 0x00;			//GPTMCFG
	TM0[0x4] = 0x02;				//periodic
	*(int*)&TM0[0x028] = 0x13880;		// 2ms = INITIAL / 40 MHz
	TM0[0x00C] |= 0x21;				//start timer with ADC
}

//Timer B
void enableTM1(void)
{
	TM1[0x00C] &= 0x00;					//GPTMCTL
	TM1[0x0] &= 0x00;					//GPTMCFG
	TM1[0x4] = 0x02;					//periodic
	TM1[0x018] |= 0x1;				//enable interrupts GPTMIMR
	*(int*)&TM1[0x028] = 0x1312D00;		// 500ms = INITIAL / 40 MHz
	TM1[0x00C] |= 0x1;				//start timer
}

//Timer C
void enableTM2(void)
{
	TM2[0x00C] &= 0x00;					//GPTMCTL
	TM2[0x0] &= 0x00;					//GPTMCFG
	TM2[0x4] = 0x02;					//periodic
	TM2[0x018] |= 0x1;				//enable interrupts GPTMIMR
	*(int*)&TM2[0x028] = 0xFCF;			// .1ms = INITIAL / 40 MHz
	TM2[0x00C] |= 0x1;				//start timer
}
```

```
void enableI2C1(void)
{
	I2C1[0x004] = 0x00;		//I2C disable
	I2C1[0x020] |= 0x10; //master function enable
	I2C1[0x00C] = 0x4;		//TPR = 4
	I2C1[0x000] = (0x63 << 1);		// slave address = 0x63
}
```