

TI DSP, MCU 및 Xilinx Zynq FPGA 프로그래밍 전문가 과정

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1. FFT 개념

2. cos_dft

3. sin_fft

cos_dft.c

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <time.h>
#include <math.h>

#include <GL/glut.h>

#define SLICE      4

void draw_omega_sin(void);
void draw_spectrum(void);

float common_angles[5] = {15.0, 30.0, 45.0, 60.0, 75.0};
float freq_table[5] = {1000.0, 2400.0, 5000.0, 24000.0, 77000.0};

float theta = 0.0;

typedef struct complex{
    float cosx[32][32];
    float isinx[32][32];
} c;

void display(void){
    glClearColor(0.0, 0.0, 0.0, 1.0);
    glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
    glLoadIdentity();

    //gluLookAt(0.0, 0.0, 3.0, 0.0, 0.0, 0.0, 0.0, 1.0, 0.0);

    glColor3f(1, 0, 0);

    glBegin(GL_LINE_LOOP);
    glVertex3f(100.0, 0.0, 0.0);
    glVertex3f(-100.0, 0.0, 0.0);
    glEnd();

    glColor3f(0.0, 1.0, 0.0);

    glBegin(GL_LINE_LOOP);
    glVertex3f(0.0, 100.0, 0.0);
    glVertex3f(0.0, -100.0, 0.0);
    glEnd();

    //draw_omega_sin();
    draw_spectrum();
    glutSwapBuffers();
}

void reshape(int w, int h){
```

```
GLfloat n_range = 100.0f;

if(h == 0)
    h = 1;

glViewport(0, 0, w, h);
glMatrixMode(GL_PROJECTION);
glLoadIdentity();

if(w <= h)
    glOrtho(-n_range, n_range, -n_range * h / w, n_range * h / w, -n_range, n_range);
else
    glOrtho(-n_range * w / h, n_range * w / h, -n_range, n_range, -n_range, n_range);

glMatrixMode(GL_MODELVIEW);
glLoadIdentity();
}

void keyboard(unsigned char key, int x, int y){
    switch(key)
    {
        case 27:
            exit(0);
            break;
    }
}

void set_rand_amplitude(float *amp){
    *amp = rand() % 3 + 3;}

void set_angle_with_common_angles(float *angle){
    *angle = common_angles[rand() % 5];}

void angle2radian(float *angle, float *radian){
    *radian = *angle * M_PI / 180.0;}

void radian2angle(float *angle, float *radian){
    *angle = *radian * 180.0 / M_PI;}

void set_rand_frequency(float *freq){
    *freq = freq_table[rand() % 5];}

void calc_period(float *freq, float *period){
    *period = 1 / (*freq);}

void calc_angular_velocity(float *freq, float *ang_vel){
    *ang_vel = 2 * M_PI * (*freq);}

float get_step(float slice, float period){
    return period / slice;}

void cos_sim(float amplitude, float ang_vel, float period){
    int cnt = 0;
    float step, t = 0.0;

    t = step = get_step(SLICE, period);
```

```
while(cnt++ < 36) {
    printf("%.1fcos(%f * %.8f) = %f\n", amplitude, ang_vel,
        t, amplitude * cos(ang_vel * t));
        t += step;
    }
}

void sin_sim(float amplitude, float ang_vel, float period){
    int cnt = 0;
    float step, t = 0.0;

    t = step = get_step(SLICE, period);

    while(cnt++ < 36) {
        printf("%.1fsin(%f * %.8f) = %f\n", amplitude, ang_vel,
            t, amplitude * sin(ang_vel * t));
            t += step;
        }
    }

void draw_spectrum(void){
    float x = 0, x2 = 0, y2, cx, cy;
    float t, step = 0.0;
    int i, j, cnt = 0, cache = 0;
    float period, freq = 100.0;
    float res_real[32] = {0};
    float res_image[32] = {0};
    float y[32] = {0};
    c exp = {0};

    calc_period(&freq, &period);
    step = get_step(SLICE, period);

    for(i = 0; i < SLICE; i++)
    {
        for(j = 0; j < SLICE; j++)
        {
            exp.cosx[i][j] = cos(-(2 * M_PI * j * i) / SLICE);
            exp.isinx[i][j] = sin(-(2 * M_PI * j * i) / SLICE);
            printf("exp.cosx[%d][%d] = %f\n", i, j, exp.cosx[i][j]);
            //printf("exp.isinx[%d][%d] = %f\n", i, j, exp.isinx[i][j]);
        }
    }

    if(t > period)
        t = 0.0;

    i = 0;
    t = 0.0;
    for(; i < SLICE; t += step)
    {
        //if(t > 3 * period)
        if(t > period)
        {
            break;
            t = 0.0;
        }

        y[i] = 10 * cos(200 * M_PI * t);
```

```

        printf("y[%d] = %f\n", i++, y[i]);
        //printf("exp.cosx[%d] = %f\n", i, exp.cosx[i]);
        //printf("exp.isinx[%d] = %f\n", i, exp.isinx[i]);
        //printf("res_real[%d] = %f\n", i, res_real[i]);
        //printf("res_real = %f\n", res_real);
        //printf("res_image = %f\n", res_image);
    }

    for(i = 0; i < SLICE; i++)
        for(j = 0; j < SLICE; j++)
        {
            res_real[i] += y[j] * exp.cosx[i][j];
            res_image[i] += y[j] * exp.isinx[i][j];
            //printf("res_real[%d] = %f\n", i,
            printf("res_image[%d] = %f\n", i,
            res_real[i]);
            res_image[i]);
        }

    //printf("OK");

    for(i = 0; i < SLICE; i++)
    {
        glBegin(GL_POINTS);
        glVertex2f(i * 10, res_real[i] * 3);
        //glVertex2f(i * 10, res_image[i] * 3);
        glEnd();

        glBegin(GL_LINE_STRIP);
        glVertex2f(i * 10, res_real[i] * 3);
        glVertex2f(i * 10, 0);
        //glVertex2f(i * 10, res_image[i] * 3);
        //glVertex2f(i * 10, 0);
        glEnd();
    }

    #if 0
    glBegin(GL_LINE_STRIP);

    for(j = 0; j < SLICE; j++)
    {
        glVertex2f(j * 10, res_real[j] * 2);
        glVertex2f(j * 10, 0);
    }

    glEnd();

    #endif
    #if 0
    //if(cache && !(cnt % 16))
    if(cache)
    {
        glBegin(GL_POINTS);
        glVertex2f(cx * 4000, cy * 6);
        glVertex2f(t * 4000, y2 * 6);
        glEnd();

        glBegin(GL_LINE_STRIP);
        glVertex2f(t * 4000, y2 * 6);
        glVertex2f(t * 4000, 0);
    }

    glEnd();

    glEnd();

    cache = 1;
    cx = t;
    cy = y2;
    cnt++;
}

void draw_omega_sin(void){
    float amp, angle, period, freq, rad, omega, t, step = 0.0;
    float radius = 3.0;
    float x = 0, x2 = 0, y2, cx, cy;
    float tmp;
    int cnt = 0, cache = 0;

    srand(time(NULL));

    amp = 10;
    angle = 45.0;
    freq = 100.0;

    angle2radian(&angle, &rad);
    calc_period(&freq, &period);
    calc_angular_velocity(&freq, &omega);
    t = step = get_step(SLICE, period);

    printf("step = %f\n", step);

    if(t > period)
        t = 0.0;

    //glLineStipple(1, 0xFFEE);
    //glEnable(GL_LINE_STIPPLE);
    //glBegin(GL_POINTS);
    for(; ; t += step)
    {
        if(t > period)
            //if(t > 3 * period)
            {
                break;
                t = 0.0;
            }

        y2 = amp * sin(omega * t);

        if(cache && !(cnt % 16))
        {
            glBegin(GL_POINTS);
            glVertex2f(cx * 6000, cy * 6);
            glVertex2f(t * 6000, y2 * 6);
            glEnd();

            glBegin(GL_LINE_STRIP);
            //glVertex2f(cx * 4000, cy * 2);
            //glVertex2f(cx * 4000, 0);
            glVertex2f(t * 6000, y2 * 6);
        }

        glEnd();

        glVertex2f(t * 6000, 0);
    }

    glEnd();

    cache = 1;
    cx = t;
    cy = y2;
    cnt++;
}

int main(int argc, char **argv){
    float amplitude, angle, period, frequency, radian,
    angular_velocity;
    float step = 0.0;

    glutInit(&argc, argv);
    glutInitDisplayMode(GLUT_DOUBLE);
    glutInitWindowSize(1200, 800);
    glutInitWindowPosition(0, 0);
    glutCreateWindow("Digital Signal Processing");

    glutDisplayFunc(display);
    glutReshapeFunc(reshape);
    glutMainLoop();

    return 0;
}

```

sin_fft.c

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <time.h>
#include <math.h>

#include <GL/glut.h>

#define SLICE 8
#define HALF_SLICE (SLICE >> 1)

int glob = 4;
int count = 0;

#define TWID_FACTOR (SLICE >> 1) + 1

typedef struct complex
{
    double re;
    double im;
} c;

void draw_omega_sin(void);
void draw_spectrum(void);

float common_angles[5] = {15.0, 30.0, 45.0, 60.0, 75.0};
float freq_table[5] = {1000.0, 2400.0, 5000.0, 24000.0, 77000.0};

float theta = 0.0;

void display(void)
{
    glClearColor(0.0, 0.0, 0.0, 1.0);
    glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
    glLoadIdentity();

    //gluLookAt(0.0, 0.0, 3.0, 0.0, 0.0, 0.0, 0.0, 1.0, 0.0);

    glColor3f(1, 0, 0);

    glBegin(GL_LINE_LOOP);
    glVertex3f(100.0, 0.0, 0.0);
    glVertex3f(-100.0, 0.0, 0.0);
    glEnd();

    glColor3f(0.0, 1.0, 0.0);

    glBegin(GL_LINE_LOOP);
    glVertex3f(0.0, 100.0, 0.0);
    glVertex3f(0.0, -100.0, 0.0);
    glEnd();

    //draw_omega_sin();
    draw_spectrum();
    glutSwapBuffers();
}
```

```
void reshape(int w, int h)
{
    GLfloat n_range = 100.0f;

    if(h == 0)
        h = 1;

    glViewport(0, 0, w, h);
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();

    if(w <= h)
        glOrtho(-n_range, n_range, -n_range * h / w, n_range * h / w,
        -n_range, n_range);
    else
        glOrtho(-n_range * w / h, n_range * w / h, -n_range, n_range,
        -n_range, n_range);

    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();
}

void keyboard(unsigned char key, int x, int y){
    switch(key)
    {
        case 27:
            exit(0);
            break;
    }
}

void set_rand_amplitude(float *amp){
    *amp = rand() % 3 + 3;}

void set_angle_with_common_angles(float *angle){
    *angle = common_angles[rand() % 5];}

void angle2radian(float *angle, float *radian){
    *radian = *angle * M_PI / 180.0;}

void radian2angle(float *angle, float *radian){
    *angle = *radian * 180.0 / M_PI;}

void set_rand_frequency(float *freq){
    *freq = freq_table[rand() % 5];}

void calc_period(float *freq, float *period){
    *period = 1 / (*freq);}

void calc_angular_velocity(float *freq, float *ang_vel){
    *ang_vel = 2 * M_PI * (*freq);}

float get_step(float slice, float period){
    return period / slice;}

void cos_sim(float amplitude, float ang_vel, float period){
    int cnt = 0;
    float step, t = 0.0;
```

```
t = step = get_step(SLICE, period);

    while(cnt++ < 36) {
        printf("%.1fcos(%f * %.8f) = %f\n", amplitude, ang_vel,
            t, amplitude * cos(ang_vel * t));
        t += step;
    }
}

void sin_sim(float amplitude, float ang_vel, float period){
    int cnt = 0;
    float step, t = 0.0;

    t = step = get_step(SLICE, period);

    while(cnt++ < 36)
    {
        printf("%.1fsin(%f * %.8f) = %f\n", amplitude, ang_vel,
            t, amplitude * sin(ang_vel * t));
        t += step;
    }
}

void draw_spectrum(void){
    float t, step = 0.0;
    float period, freq = 100.0;

    c y[8] = {0};

    int ix;
    int ju;
    int iy;
    int i;
    double x[8] = {0};

    int tst;
    double temp_re;
    double temp_im;
    int iheight;
    int istart;
    int j;
    double twid_re;
    double dv0[5] = {0};

    double twid_im;
    double dv1[5] = {0};

    int ihi;

    calc_period(&freq, &period);
    step = get_step(SLICE, period);

    if(t > period)
        t = 0.0;

    i = 0;
    t = 0.0;
    for(; i < SLICE; t += step)
    {
        //if(t > 3 * period)
```

```

        if(t > period)
        {
            break;
            t = 0.0;
        }

        x[i] = 10 * sin(200 * M_PI * t);
        printf("x[%d] = %f\n", i++, x[i]);
        //printf("exp.cosx[%d] = %f\n", i, exp.cosx[i]);
        //printf("exp.isinx[%d] = %f\n", i, exp.isinx[i]);
        //printf("res_real[%d] = %f\n", i, res_real[i]);
        //printf("res_real = %f\n", res_real);
        //printf("res_image = %f\n", res_image);
    }

    t = 0;
    step = 2 * M_PI / SLICE;

    for(i = 0; i < 5; i++)
    {
        dv0[i] = cos(t);
        dv1[i] = -sin(t);
        t += step;
    }

    t = 0;

    ix = 0;
    ju = 0;
    iy = 0;
    printf("Before Reverse Order\n");
    for (i = 0; i < 7; i++) {
        y[iy].re = x[ix];
        y[iy].im = 0.0;

        printf("y[%d].re = %f\t", iy, y[iy].re);
        printf("y[%d].im = %f\n", iy, y[iy].im);

        iy = 8;
        tst = 1;
        while (tst) {
            iy >>= 1;
            ju ^= iy;
            tst = ((ju & iy) == 0);
        }

        iy = ju;
        ix++;
    }
    y[iy].re = x[ix];
    y[iy].im = 0.0;

    printf("\nAfter Reverse Order\n");
    for(i = 0; i < SLICE; i++)
    {
        printf("y[%d].re = %f\t", i, y[i].re);
        printf("y[%d].im = %f\n", i, y[i].im);
    }
    printf("\nN-2 First Butterfly\n");

```

```

        for (i = 0; i <= 7; i += 2) {
            temp_re = y[i + 1].re;
            temp_im = y[i + 1].im;
            y[i + 1].re = y[i].re - y[i + 1].re;
            y[i + 1].im = y[i].im - y[i + 1].im;
            y[i].re += temp_re;
            y[i].im += temp_im;

            printf("y[%d].re = %f\t", i, y[i].re);
            printf("y[%d].im = %f\n", i, y[i].im);
            printf("y[%d].re = %f\t", i+1, y[i+1].re);
            printf("y[%d].im = %f\n", i+1, y[i+1].im);
        }

        iy = 2;
        ix = 4;
        ju = 2;
        iheight = 5;
        while (ju > 0) {
            // 0 ~ 4
            printf("\nN-%d Butterfly(처음은 짝수 오더)\n",
                glob);

            for (i = 0; i < iheight; i += ix) {
                temp_re = y[i + iy].re;
                temp_im = y[i + iy].im;
                y[i + iy].re = y[i].re - temp_re;
                y[i + iy].im = y[i].im - temp_im;
                y[i].re += temp_re;
                y[i].im += temp_im;
                printf("y[%d].re = %f\t", i, y[i].re);
                printf("y[%d].im = %f\n", i, y[i].im);
                printf("y[%d].re = %f\t", i+iy, y[i+iy].re);
                printf("y[%d].im = %f\n", i+iy, y[i+iy].im);
            }
            printf("\n");

            istory = 1;
            printf("\nN-%d Butterfly(처음은 홀수 오더)\n", glob);
            for (j = ju; j < 4; j += ju) {
                printf("twid_re = dv0 = cos(2 * pi * f * t / fftN 의절반)\n");
                printf("twid_im = dv1 = -sin(2 * pi * f * t / fftN 의절반)\n");
                twid_re = dv0[j];
                twid_im = dv1[j];
                i = istory;
                ihi = istory + iheight;
                while (i < ihi) {
                    temp_re = twid_re * y[i + iy].re - twid_im * y[i + iy].im;
                    temp_im = twid_re * y[i + iy].im + twid_im * y[i + iy].re;
                    y[i + iy].re = y[i].re - temp_re;
                    y[i + iy].im = y[i].im - temp_im;
                    y[i].re += temp_re;
                    y[i].im += temp_im;

                    printf("y[%d].re = %f\t", i, y[i].re / HALF_SLICE);
                    printf("y[%d].im = %f\n", i, y[i].im / HALF_SLICE);
                    printf("y[%d].re = %f\t", i+iy, y[i+iy].re / HALF_SLICE);
                    printf("y[%d].im = %f\n", i+iy, y[i+iy].im / HALF_SLICE);
                }
            }
        }
        #if 0

```

```

            i += ix;
        }
        istory++;
    }
    ju /= 2;
    iy = ix;
    ix <= 1;
    iheight -= iy;

    if(ju > 0)
    {
        count++;
        printf("\nFinished N-%d Butterfly\nNow Starting N-%d Butterfly",
            glob, glob *= 2);
    }
    else
        printf("\nFinished N-%d Butterfly\n", glob);
    }
    //printf("OK");

    for(i = 0; i < SLICE; i++)
    {
        glBegin(GL_LINE_STRIP);

        if(y[i].re == 0 && y[i].im == 0)
            continue;

        glVertex2f(i * 10, y[i].re / HALF_SLICE);
        glVertex2f(i * 10, 0);

        glEnd();

        glBegin(GL_LINE_STRIP);

        glVertex2f(i * 10, y[i].im / HALF_SLICE);
        glVertex2f(i * 10, 0);

        glEnd();

        //if(cache && !(cnt % 16))
        if(cache)
        {
            glBegin(GL_POINTS);
            glVertex2f(cx * 4000, cy * 6);
            glVertex2f(t * 4000, y2 * 6);
            glEnd();

            glBegin(GL_LINE_STRIP);
            glVertex2f(t * 4000, y2 * 6);
            glVertex2f(t * 4000, 0);
            glEnd();
        }

        cache = 1;
    }

```

```

        cx = t;
        cy = y2;
        cnt++;
    }
#endif
}

void draw_omega_sin(void)
{
    float amp, angle, period, freq, rad, omega, t, step = 0.0;
    float radius = 3.0;
    float x = 0, x2 = 0, y2, cx, cy;
    float tmp;
    int cnt = 0, cache = 0;

    srand(time(NULL));

    amp = 10;
    angle = 45.0;
    freq = 100.0;

    angle2radian(&angle, &rad);
    calc_period(&freq, &period);
    calc_angular_velocity(&freq, &omega);
    t = step = get_step(SLICE, period);

    printf("step = %f\n", step);

    if(t > period)
        t = 0.0;

    //glLineStipple(1, 0xFFEE);
    //glEnable(GL_LINE_STIPPLE);
    //glBegin(GL_POINTS);
    for(; ; t += step)
    {
        if(t > period)
            //if(t > 3 * period)
            {
                break;
                t = 0.0;
            }

        y2 = amp * sin(omega * t);

        if(cache && !(cnt % 16))
        {
            glBegin(GL_POINTS);
            glVertex2f(cx * 6000, cy * 6);
            glVertex2f(t * 6000, y2 * 6);
            glEnd();

            glBegin(GL_LINE_STRIP);
            //glVertex2f(cx * 4000, cy * 2);
            //glVertex2f(cx * 4000, 0);
            glVertex2f(t * 6000, y2 * 6);
            glVertex2f(t * 6000, 0);
            glEnd();
        }
    }
}

```

```

        cache = 1;
        cx = t;
        cy = y2;
        cnt++;
    }
    //glEnd();
    //glDisable(GL_LINE_STIPPLE);
}

int main(int argc, char **argv)
{
    float amplitude, angle, period, frequency, radian,
    angular_velocity;
    float step = 0.0;

    glutInit(&argc, argv);
    glutInitDisplayMode(GLUT_DOUBLE);
    glutInitWindowSize(1200, 800);
    glutInitWindowPosition(0, 0);
    glutCreateWindow("Digital Signal Processing");

    glutDisplayFunc(display);
    glutReshapeFunc(reshape);
    glutMainLoop();

    return 0;
}

```