Quadcopter
Teknologi og Forskningslære
Ullern VGS

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Abstract

Vi har i skoleåret 2014-15 designet, bygget og programmert et quadcopter. Denne teksten skal ta for seg prossessen, fra visjon til ferdig produkt, og gi en inngående forklaring i både fastvaren og programvaren.

1 Visjon

Målet med prosjektet var, fra starten av, å konstruere et quadcopter med passelige flyegenskaper. Det var derimot også motsetninger innad i gruppen, Martin og Karsten var hovedsakelig opptatt av de cinematografiske mulighetene, mens Thorvald ønsket å automatisere så mye som mulig.

2 Fremgangsmåte

Gruppen hadde mellom seg svært lite kunnskap om Arduino, fastvare og quadcoptre, det ble derfor brukt mye tid på research. Forum, Arduino Playground og YouTube ble flittig brukt, da man kan lære mye av andres erfaringer.

3 Produkt

3.1 Programvare

4 Innkjøps-prosess

Utgangspunktet ble fjorårets quadcoptergruppe. Men siden de ikke hadde et komplett sett med deler valgte vi å bruke en del tid på å finne ut av hvilke deler som ville passe vårt prosjekt best. De premissene som ble lagt til grunn var at det skulle være stort nok til å eventuellt kunne feste et GoPro på, ha kraftige nok motorer til å være stabilt, og være av en viss størrelse, for stabilitet.

4.1 Motorer og ESC

Gruppen året før hadde ikke et fult sett med motorer i tillegg hadde de ingen ESCer[1]. Motorene fra forrige år var umærkede, og det var vannskelig å finne spesifikasjoner. Vi klarte heller ikke å finne noe omtale om dem. På grunn av dette ble mye tid viet til å finne gode motorer og ESC.
Da vi ikke hadde noe kunnskap om elektronikk eller motorer, ble, som sagt, mye tid brukt på research. Vi konkluderte med at det var viktig å ha motorer med mye god omtale og stor brukergruppe, slik at det skulle bli lettere å løse eventuelle problemer. Vi ønsket allsidige motorer, som kunne fungere i mange ulike oppsett, da vi ikke hadde en klar formening om bruken av quadcopteret. Thorvald hadde lyst til at vi skulle kjøpe "Turnigy Aerodrive SK3 - 2822-1090kv", som høyere RPM(rounds per minute) som gjør at quadcopteret blir mer smidig og mer akselerasjon, mot å ofre litt løftekraft. Martin og Karsten ville heller gå for "NTM Prop Drive Series 28-26 1100kv / 252w" som er en kraftikere motor, men med lavere topphastighet og akselerasjon. Disse har derimot bedre løftekapasitet, som gjør dem egnet for filming. Vi kom til den konklusjonen at for vårt bruk ville ikke ESC være avgjørende, så her fokuserte vi på at de skulle ha god omtale og dokumentasjon, og så klart at de kunne håndtere den strømmen motorene trengte.

4.2 Batterier

Den forrige gruppen hadde overraskende mange batterier. De hadde blant annet to 1800mAh 7.4v LiPO batterer. Disse fungerte utmerket seriekoblet, da de har en spenning på 14.8v.

4.2.1 Batterilader

LiPo batterier er svært sensitive, og behøver riktig utstyr for å lades, noe vi først ikke hadde tilgang på. Etterhvert skaffet læreren vår en universallader som kunne lade mange forskjellige typer batterier. Vi fikk derfor i oppgave å finne ut hvordan denne laderen fungerte og hvordan man konfigurerte den for hvert enkelt batteri. Laderen er fra Hyperion og heter EOS0606i AC/DC.
Et problem var at batteriene bruker en xt60 kobling, noe vi ikke hadde, så det var ikke mulig å koble batteriene til laderen. Vi brukte en hack, der 3.5mm gullkoblinger blir brukt(figur 1).

[1] Electronic Speed Controller. Oversetter PPM signaler fra Arduino til analogt signal til motorene

Figure 1: 3.5mm gullkobling hack for xt60

4.3 Ramme

Det var ikke noe rammer fra tidligere år. Vi ville ha en ramme som var stor nok til at den kunne bære alle de komponentene vi hadde lyst til å ha på. I tillegg hadde vi lyst til å ha muligheten til å feste et kamera på undersiden, og vi trengte derfor en ramme hvor man kunne montere kamerafeste under. For å få mer stabilitet valgte vi også å ha en stor ramme. Vi gikk for DJI Flame Wheel F450, som er en veldig populær ramme som oppfyller våre kriterier.
En finesse med rammen er at den har et integrert strømfordelingssystem i selve rammen. Dette gjør at man slipper å lage et eget system med eksterne ledninger, noe som er rotete, tungt og plasskrevende, samt at det er tidskrevende og vannskelig å lodde et slikt oppsett.

4.3.1 Bestillingsproblematikk

Uheldigvis hadde ikke Hobby King mulighet til å fakturere skolen, slik at vi ikke kunne handle derfra. Vi fant en alternativ nettbutikk, Elefun, som hadde et bra utvalg av RC produkter; Elefun er også norsk, slik at frakt går fortere. F450 rammen var utsolgt i hele Norge, og da vi begynnte å få dårlig tid endte vi opp med å kjøpe en pakke med ramme, ESC og motorer. Til et annet prosjekt har vi lært at det er viktig få tak i deler tidligere, og ikke havne i den samme knipa som vi gjorde. Motorene vi endte opp med er betydelig dårligere enn de vi hadde sett oss ut, de er både tregere, har dårligere akselerasjon og mindre løftekraft. Planen var å eventuellt oppgradere dem sener om mulig, da koden og resten av oppsettet fortsatt ville være likt.

4.4 Fjernkontroll og mottager

Teknologi og Forskningslære hadde en veldig god 8 kanals fjernkontroll med mottager. Fjernkontrollen bruker PPM(pulse position modulation) og fjernkotrollen gjør det om til PWM(pulse width modulation) for de ulike kanalene(figur 2).

5 Ferdig produkt

5.1 Monteringsplate av plast

For å enkelt kunne montere komponenter på rammen ble det montert på en plate av plast, som resten av komponentene enkelt kan skrus fast til, se figur 3. Denne plata ble festet til rammen ved at to plastskiver står i klem på hver sin side av topplata på rammen.

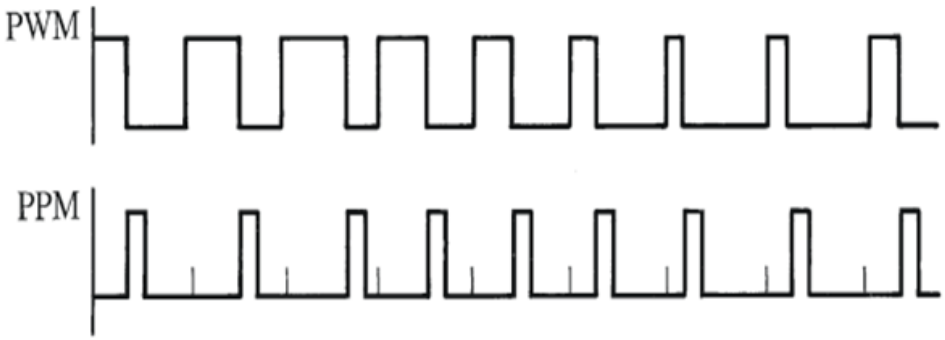

Figure 2: Samme signal i PPM og PWM
http://forum.arduino.cc/index.php?topic=254599.0

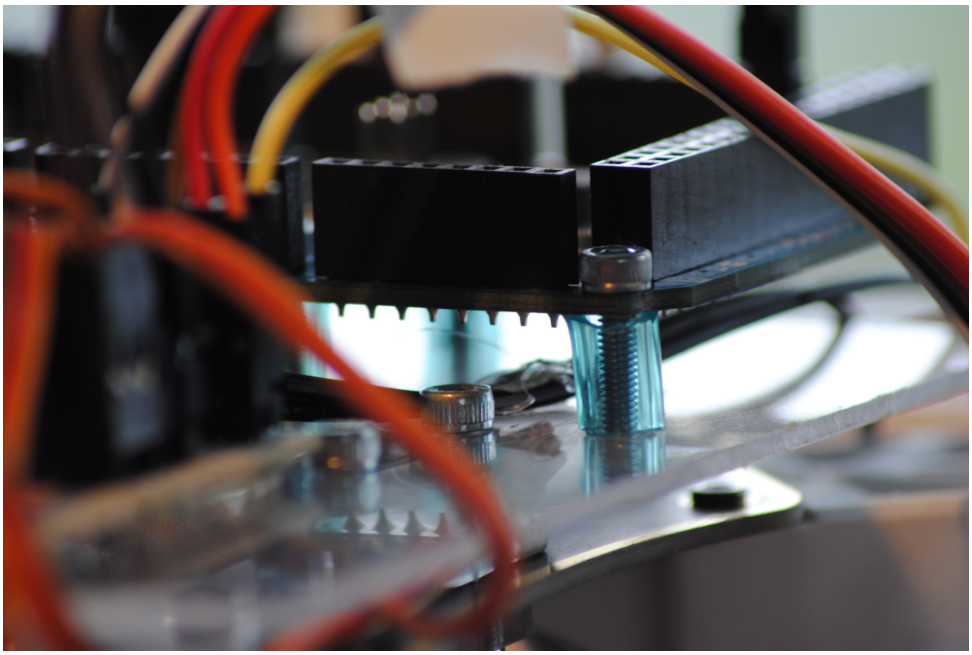

Figure 3: Arduino festet med vibrasjonsdemper i monteringsplate.

5.2 Fastvare

6 Vedlegg

6.1 Quadcopter kildekode

```
#define SAFE
//#define DEBUG

//----------ESC's config----------

//PWM values
#define MOTOR_ZERO_LEVEL 1100
#define MOTOR_ARM 140
#define MOTOR_MAX_LEVEL 2250

//Motor pins
#ifdef _DUE_BOARD
#define MOTOR_FR 2
#define MOTOR_FL 5
#define MOTOR_BR 4
#define MOTOR_BL 3
#elif defined _UNO_BOARD
#define MOTOR_BR 10
```

```
#define MOTOR_BL 9
#define MOTOR_FR 3
#define MOTOR_FL 11
#endif

//----------Rx config--------------------
#define RX_TIMEOUT 2200
//------Pins------
#ifdef _DUE_BOARD
/*
#define RX_PIN_THROTTLE 10
#define RX_PIN_PITCH 9
#define RX_PIN_ROLL 8
#define RX_PIN_YAW 11
//Auxillary - button and knobs
#define RX_PIN_AUX1 12
#define RX_PIN_AUX2 NULL
*/

#define RX_PIN_THROTTLE 10
#define RX_PIN_PITCH 11
#define RX_PIN_ROLL 12 //8
#define RX_PIN_YAW 9 //11
//Auxillary - button and knobs
#define RX_PIN_AUX1 8
#define RX_PIN_AUX2 13

#elif defined _UNO_BOARD
#define RX_PIN_THROTTLE 2
#define RX_PIN_PITCH 1
#define RX_PIN_ROLL 4
#define RX_PIN_YAW 0

//Auxillary - button and knobs
#define RX_PIN_AUX1 5
#define RX_PIN_AUX2 NULL
#endif

//------KEY VALUES-
#define RX_THROTTLE_MIN 1028
#define RX_THROTTLE_MAX 1864
#define THROTTLE_MAX MOTOR_MAX_LEVEL -(PITCH_MAX + ROLL_MAX+YAW_MAX)
#define THROTTLE_MIN MOTOR_ZERO_LEVEL + 150

#define RX_PITCH_MIN 1196
#define RX_PITCH_MAX 1703
#define PITCH_MIN -150
#define PITCH_MAX 150
#define PITCH_MIN_DEG -30
#define PITCH_MAX_DEG 30

#define RX_ROLL_MIN 1194
#define RX_ROLL_MAX 1703
#define ROLL_MIN -150
#define ROLL_MAX 150

#define RX_YAW_MIN 1035
#define RX_YAW_MAX 1867
#define YAW_MIN -150
#define YAW_MAX 150

#define RX_AUX1_MIN 1040
#define RX_AUX1_MAX 1866
#define AUX1_MIN -150
#define AUX1_MAX 150

#define RX_AUX2_MIN 1060
#define RX_AUX2_MAX 1875
#define AUX2_MIN -15
#define AUX2_MAX 15
```

../Quadcopter/Quadcopter/config.h

```
void FlightController() {
  int motor[2][2]; //[F/B][R/L] motor[0][1]:motor front left
```

```
  float throttle, pitch, pitchSet, roll, rollSet, yaw, yawSet;

  //motor values are computed by adding throttle, roll, yaw and pitch
  throttle = map(rxThrottle, RX_THROTTLE_MIN, RX_THROTTLE_MAX, THROTTLE_MIN,
    THROTTLE_MAX);

  //xxSet er ønsket verdi, setpoint. Her i antall grader. xx er det som skal sendes
    til motor
  //  pitch = map(rxPitch, RX_PITCH_MIN, RX_PITCH_MAX, PITCH_MIN, PITCH_MAX);
  pitchSet = map(rxPitch, RX_PITCH_MIN, RX_PITCH_MAX, PITCH_MIN, PITCH_MAX); //Regner
     ut ønsket hellning på pitch
  rollSet  = map(rxRoll, RX_ROLL_MIN, RX_ROLL_MAX, ROLL_MIN, ROLL_MAX);
  yaw    = map(rxYaw, RX_YAW_MIN, RX_YAW_MAX, YAW_MIN, YAW_MAX);

  pitchPID.update( map(pitchSet, PITCH_MIN, PITCH_MAX, -10, 10));
  rollPID.update( map(rollSet, ROLL_MIN, ROLL_MAX, -10, 10));
  //  pitchPID.update(0);
  //  rollPID.update(0);

  pitch = pitchSet - pitchPID.evaluate(angles[0] - anglesInit[0]);
  roll = rollSet - rollPID.evaluate(angles[1] - anglesInit[1]);

  motor[0][0] = throttle - pitch + roll - yaw;
  motor[0][1] = throttle - pitch - roll + yaw;
  motor[1][0] = throttle + pitch + roll + yaw;
  motor[1][1] = throttle + pitch - roll - yaw;

  int i, j;
#ifdef SAFE
  if(rxAux1 < (RX_AUX1_MAX + RX_AUX1_MIN)/2 ) {
    for(i=0; i<2; i++) {
      for(j=0; j<2; j++) {
  motor[i][j] = MOTOR_ZERO_LEVEL;
      }
    }
  }
#endif

#ifdef STOP_MAX //Don't know if this will stay or not, if successfull, remove if
    for(i=0; i<2; i++) {
      for(j=0; j<2; j++) {
  if(motor[i][j] > MOTOR_MAX_LEVEL)
    motor[i][j] = MOTOR_MAX_LEVEL;

  if(motor[i][j] < MOTOR_ZERO_LEVEL)
    motor[i][j] = MOTOR_ZERO_LEVEL;
      }
    }
#endif

    for(i=0; i<2; i++) {
      for(j=0; j<2; j++) {
  motorS[i][j].writeMicroseconds(motor[i][j]);
      }
    }
}

byte zeroToMinus(bool n) {
  return n ? 1 : -1; //1 is 1 and 0 is -1
}
```

../Quadcopter/Quadcopter/FlightController.ino

```
void Gyro() {
  sixDOF.getRawValues(angles);
}

void gyroInit() {
  sixDOF.getRawValues(anglesInit);
}
```

../Quadcopter/Quadcopter/Gyro.ino

```
/*
Karsten Sebastian Stadler, Martin Due Andersen and Thorvald Molthe Ballestad
 Ullern VGS - 2015
```

```
Quadcopter.ino is the main file.
*/

#define _DUE_BOARD
//#define _UNO_BOARD

#define STOP_MAX //stop motor values to exeeding extremals
//#define DEBUG

#include "config.h"
#include <Servo.h>
#include <PID.h>
#include <Wire.h>
#include <FIMU_ADXL345.h>
#include <FIMU_ITG3200.h>
#include <FreeSixIMU.h>

volatile unsigned int rxThrottle, rxPitch, rxRoll, rxYaw, rxAux1, rxAux2;

Servo motorS[2][2];
FreeSixIMU sixDOF = FreeSixIMU();

PID pitchPID, rollPID;

int angles[6], anglesInit[6];

void setup() {
  rxInit();
  Wire.begin();
  sixDOF.init();
  delay(300);
  gyroInit(); //Must be after sixDOF init
#ifdef DEBUG
  Serial.begin(9600);
#endif
  motorS[0][0].attach(MOTOR_FR);
  motorS[0][1].attach(MOTOR_FL);
  motorS[1][0].attach(MOTOR_BR);
  motorS[1][1].attach(MOTOR_BL);

  pitchPID.updateParameters(0.5, 0, 1);
  rollPID.updateParameters(0.5, 0, 1);

  //  pitchPID.update(0);
  //  rollPID.update(0);
}

void loop() {
  Gyro();
  pitchPID.updateParameters(mapD(rxAux2, RX_AUX2_MIN, RX_AUX2_MAX, 0.05, 0.6), 1, 0);
  rollPID.updateParameters(mapD(rxAux2, RX_AUX2_MIN, RX_AUX2_MAX, 0.05, 0.6), 1, 0);
    //ole jacob
  FlightController(); //writes appropriate values to motors using PID
}

float mapD(float x, float in_min, float in_max, float out_min, float out_max)
{
  return (x - in_min) * (out_max - out_min) / (in_max - in_min) + out_min;
}
```

../Quadcopter/Quadcopter/Quadcopter.ino

```
volatile int t[6];

void rxInit() {
  attachInterrupt(RX_PIN_THROTTLE, rxGoesUpThrottle, RISING);
  attachInterrupt(RX_PIN_PITCH, rxGoesUpPitch, RISING);
  attachInterrupt(RX_PIN_ROLL, rxGoesUpRoll, RISING);
  attachInterrupt(RX_PIN_YAW, rxGoesUpYaw, RISING);
  attachInterrupt(RX_PIN_AUX1, rxGoesUpAux1, RISING);
  attachInterrupt(RX_PIN_AUX2, rxGoesUpAux2, RISING);
}

//Not the most elegant solution, but it works(hopefully)
void rxGoesUpThrottle() {
```

```
  attachInterrupt(RX_PIN_THROTTLE, rxGoesDownThrottle, FALLING);
  t[0]=micros();
}

void rxGoesUpPitch() {
  attachInterrupt(RX_PIN_PITCH, rxGoesDownPitch, FALLING);
  t[1]=micros();
}

void rxGoesUpRoll() {
  attachInterrupt(RX_PIN_ROLL, rxGoesDownRoll, FALLING);
  t[2]=micros();
}

void rxGoesUpYaw() {
  attachInterrupt(RX_PIN_YAW, rxGoesDownYaw, FALLING);
  t[3]=micros();
}

void rxGoesUpAux1() {
  attachInterrupt(RX_PIN_AUX1, rxGoesDownAux1, FALLING);
  t[4]=micros();
}

void rxGoesUpAux2() {
  attachInterrupt(RX_PIN_AUX2, rxGoesDownAux2, FALLING);
  t[5]=micros();
}

void rxGoesDownThrottle() {
  rxThrottle = micros() - t[0];
  attachInterrupt(RX_PIN_THROTTLE, rxGoesUpThrottle, RISING);
}

void rxGoesDownPitch() {
  rxPitch = micros() - t[1];
  attachInterrupt(RX_PIN_PITCH, rxGoesUpPitch, RISING);
}

void rxGoesDownRoll() {
  rxRoll = micros() - t[2];
  attachInterrupt(RX_PIN_ROLL, rxGoesUpRoll, RISING);
}

void rxGoesDownYaw() {
  rxYaw = micros() - t[3];
  attachInterrupt(RX_PIN_YAW, rxGoesUpYaw, RISING);
}

void rxGoesDownAux1() {
  rxAux1 = micros() - t[4];
  attachInterrupt(RX_PIN_AUX1, rxGoesUpAux1, RISING);
}

void rxGoesDownAux2() {
  rxAux2 = micros() - t[5];
  attachInterrupt(RX_PIN_AUX2, rxGoesUpAux2, RISING);
}
```

../Quadcopter/Quadcopter/RX.ino

```
Class PID

int PID::evaluate(int error)
diff = _kd * (errorLast - errorNow)/(timeNow - timeLast)
return proportional + derivative + integral

PID::update(int setpoint)
PID::updateParameters(int kp, int ki, int kd)
```

../Quadcopter/Quadcopter/libraries/PID/keywords.txt

```
#include "Arduino.h" //Tillgang til Arduinos API, delay, digitalWrite osv.
#include "PID.h"

PID::PID() {
```

```
  _setpoint = 0;
  _lastError = 0;
  _sumError = 0;
  _lastTime = millis();
  _kp = 1;
  _ki = 1;
  _kd = 1;
}

int PID::evaluate(int value) {
  int error = _setpoint - value;
  int time = millis();

  _sumError+=error;
  int diff = (_lastError - error)/(_lastTime - time);

  _lastError = error;
  _lastTime = time;
  return _kp*error + _ki*_sumError + _kd*diff;
}

void PID::update(int setpoint) {
  _setpoint = setpoint;
}

void PID::updateParameters(float kp, float ki, float kd) {
  _kp = kp;
  _ki = ki;
  _kd = kd;
}
```

../Quadcopter/Quadcopter/libraries/PID/PID.cpp

```
class PID {
 public:
  PID();
  int evaluate(int value);
  void update(int setpoint);
  void updateParameters(float kp, float ki, float kd);

 private:
  int _setpoint;
  int _lastTime;
  int _lastError;
  int _sumError;
  float _kp;
  float _ki;
  float _kd;
};
```

../Quadcopter/Quadcopter/libraries/PID/PID.h

```
#include "CommunicationUtils.h"

void serialPrintFloatArr(float * arr, int length) {
  for(int i=0; i<length; i++) {
    serialFloatPrint(arr[i]);
    Serial.print(",");
  }
}


void serialFloatPrint(float f) {
  byte * b = (byte *) &f;
  for(int i=0; i<4; i++) {

    byte b1 = (b[i] >> 4) & 0x0f;
    byte b2 = (b[i] & 0x0f);

    char c1 = (b1 < 10) ? ('0' + b1) : 'A' + b1 - 10;
    char c2 = (b2 < 10) ? ('0' + b2) : 'A' + b2 - 10;

    Serial.print(c1);
    Serial.print(c2);
  }
}
```

```
26
27 void writeArr(void * varr, uint8_t arr_length, uint8_t type_bytes) {
28   byte * arr = (byte*) varr;
29   for(uint8_t i=0; i<arr_length; i++) {
30     writeVar(&arr[i * type_bytes], type_bytes);
31   }
32 }
33
34
35 // thanks to Francesco Ferrara and the Simplo project for the following code!
36 void writeVar(void * val, uint8_t type_bytes) {
37   byte * addr=(byte *)(val);
38   for(uint8_t i=0; i<type_bytes; i++) {
39     Serial.write(addr[i]);
40   }
41 }
```

../Quadcopter/Quadcopter/libraries/FreeSixIMU/CommunicationUtils.cpp

```
1 #ifndef CommunitationUtils_h
2 #define CommunitationUtils_h
3
4 #include "Arduino.h"
5
6 void serialPrintFloatArr(float * arr, int length);
7 void serialFloatPrint(float f);
8 void writeArr(void * arr, uint8_t arr_length, uint8_t type_bytes);
9 void writeVar(void * val, uint8_t type_bytes);
10
11
12 #endif // CommunitationUtils_h
```

../Quadcopter/Quadcopter/libraries/FreeSixIMU/CommunicationUtils.h

```
1  /*
2  DebugUtils.h - Simple debugging utilities.
3  Copyright (C) 2011 Fabio Varesano <fabio at varesano dot net>
4
5  Ideas taken from:
6  http://www.arduino.cc/cgi-bin/yabb2/YaBB.pl?num=1271517197
7
8  This program is free software: you can redistribute it and/or modify
9  it under the terms of the version 3 GNU General Public License as
10 published by the Free Software Foundation.
11
12 This program is distributed in the hope that it will be useful,
13 but WITHOUT ANY WARRANTY; without even the implied warranty of
14 MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
15 GNU General Public License for more details.
16
17 You should have received a copy of the GNU General Public License
18 along with this program.  If not, see <http://www.gnu.org/licenses/>.
19
20 */
21
22 #ifndef DEBUGUTILS_H
23 #define DEBUGUTILS_H
24
25 #ifdef DEBUG_V
26   #include <WProgram.h>
27   #define DEBUG_PRINT(str)    \
28     Serial.print(millis());     \
29     Serial.print(": ");    \
30     Serial.print(__PRETTY_FUNCTION__); \
31     Serial.print(' ');      \
32     Serial.print(__FILE__);     \
33     Serial.print(':');      \
34     Serial.print(__LINE__);     \
35     Serial.print(' ');      \
36     Serial.println(str);
37 #endif
38
39 #ifdef DEBUG
40   #define DEBUG_PRINT(str) \
41     Serial.println(str);
```

```
#endif

#ifndef DEBUG_PRINT
  #define DEBUG_PRINT(str)
#endif


#endif //DEBUGUTILS_H
```

../Quadcopter/Quadcopter/libraries/FreeSixIMU/DebugUtils.h

```
/***********************************************************************
 *                                                                     *
 * ADXL345 Driver for Arduino                                          *
 *                                                                     *
 ***********************************************************************
 *                                                                     *
 * This program is free software; you can redistribute it and/or modify*
 * it under the terms of the GNU License.                              *
 * This program is distributed in the hope that it will be useful,     *
 * but WITHOUT ANY WARRANTY; without even the implied warranty of      *
 * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the       *
 * GNU License V2 for more details.                                    *
 *                                                                     *
 ***********************************************************************/

#include "FIMU_ADXL345.h"
#include <Wire.h>

#define TO_READ (6)      // num of bytes we are going to read each time (two bytes
    for each axis)

ADXL345::ADXL345() {
  status = ADXL345_OK;
  error_code = ADXL345_NO_ERROR;

  gains[0] = 0.00376390;
  gains[1] = 0.00376009;
  gains[2] = 0.00349265;
}

void ADXL345::init(int address) {
  _dev_address = address;
  powerOn();
}

void ADXL345::powerOn() {
  //Turning on the ADXL345
  //writeTo(ADXL345_POWER_CTL, 0);
  //writeTo(ADXL345_POWER_CTL, 16);
  writeTo(ADXL345_POWER_CTL, 8);
}

// Reads the acceleration into an array of three places
void ADXL345::readAccel(int *xyz){
  readAccel(xyz, xyz + 1, xyz + 2);
}

// Reads the acceleration into three variable x, y and z
void ADXL345::readAccel(int *x, int *y, int *z) {
  readFrom(ADXL345_DATAX0, TO_READ, _buff); //read the acceleration data from the
    ADXL345

  // each axis reading comes in 10 bit resolution, ie 2 bytes.  Least Significat Byte
     first!!
  // thus we are converting both bytes in to one int
  //lite elegant aa caste til short
  *x = (short) (((int)_buff[1]) << 8) | _buff[0];
  *y = (short) (((int)_buff[3]) << 8) | _buff[2];
  *z = (short) (((int)_buff[5]) << 8) | _buff[4];
}

void ADXL345::get_Gxyz(float *xyz){
  int i;
  int xyz_int[3];
  readAccel(xyz_int);
```

```
63    for(i=0; i<3; i++){
        xyz[i] = xyz_int[i] * gains[i];
65    }
  }
67
  // Writes val to address register on device
69 void ADXL345::writeTo(byte address, byte val) {
    Wire.beginTransmission(_dev_address); // start transmission to device
71    Wire.write(address);              // send register address
    Wire.write(val);                  // send value to write
73    Wire.endTransmission();         // end transmission
  }
75
  // Reads num bytes starting from address register on device in to _buff array
77 void ADXL345::readFrom(byte address, int num, byte _buff[]) {
    Wire.beginTransmission(_dev_address); // start transmission to device
79    Wire.write(address);              // sends address to read from
    Wire.endTransmission();         // end transmission
81
    Wire.beginTransmission(_dev_address); // start transmission to device
83    Wire.requestFrom(_dev_address, num);    // request 6 bytes from device

85    int i = 0;
    while(Wire.available())         // device may send less than requested (abnormal)
87    {
      _buff[i] = Wire.read();    // receive a byte
89      i++;
    }
91    if(i != num){
      status = ADXL345_ERROR;
93      error_code = ADXL345_READ_ERROR;
    }
95    Wire.endTransmission();         // end transmission
  }
97
  // Gets the range setting and return it into rangeSetting
99 // it can be 2, 4, 8 or 16
  void ADXL345::getRangeSetting(byte* rangeSetting) {
101   byte _b;
    readFrom(ADXL345_DATA_FORMAT, 1, &_b);
103   *rangeSetting = _b & B00000011;
  }
105
  // Sets the range setting, possible values are: 2, 4, 8, 16
107 void ADXL345::setRangeSetting(int val) {
    byte _s;
109   byte _b;

111   switch (val) {
    case 2:
113     _s = B00000000;
      break;
115   case 4:
      _s = B00000001;
117     break;
    case 8:
119     _s = B00000010;
      break;
121   case 16:
      _s = B00000011;
123     break;
    default:
125     _s = B00000000;
    }
127   readFrom(ADXL345_DATA_FORMAT, 1, &_b);
    _s |= (_b & B11101100);
129   writeTo(ADXL345_DATA_FORMAT, _s);
  }
131 // gets the state of the SELF_TEST bit
  bool ADXL345::getSelfTestBit() {
133   return getRegisterBit(ADXL345_DATA_FORMAT, 7);
  }
135
  // Sets the SELF-TEST bit
137 // if set to 1 it applies a self-test force to the sensor causing a shift in the
      output data
```

```
// if set to 0 it disables the self-test force
void ADXL345::setSelfTestBit(bool selfTestBit) {
  setRegisterBit(ADXL345_DATA_FORMAT, 7, selfTestBit);
}

// Gets the state of the SPI bit
bool ADXL345::getSpiBit() {
  return getRegisterBit(ADXL345_DATA_FORMAT, 6);
}

// Sets the SPI bit
// if set to 1 it sets the device to 3-wire mode
// if set to 0 it sets the device to 4-wire SPI mode
void ADXL345::setSpiBit(bool spiBit) {
  setRegisterBit(ADXL345_DATA_FORMAT, 6, spiBit);
}

// Gets the state of the INT_INVERT bit
bool ADXL345::getInterruptLevelBit() {
  return getRegisterBit(ADXL345_DATA_FORMAT, 5);
}

// Sets the INT_INVERT bit
// if set to 0 sets the interrupts to active high
// if set to 1 sets the interrupts to active low
void ADXL345::setInterruptLevelBit(bool interruptLevelBit) {
  setRegisterBit(ADXL345_DATA_FORMAT, 5, interruptLevelBit);
}

// Gets the state of the FULL_RES bit
bool ADXL345::getFullResBit() {
  return getRegisterBit(ADXL345_DATA_FORMAT, 3);
}

// Sets the FULL_RES bit
// if set to 1, the device is in full resolution mode, where the output resolution
    increases with the
//   g range set by the range bits to maintain a 4mg/LSB scal factor
// if set to 0, the device is in 10-bit mode, and the range buts determine the
    maximum g range
//   and scale factor
void ADXL345::setFullResBit(bool fullResBit) {
  setRegisterBit(ADXL345_DATA_FORMAT, 3, fullResBit);
}

// Gets the state of the justify bit
bool ADXL345::getJustifyBit() {
  return getRegisterBit(ADXL345_DATA_FORMAT, 2);
}

// Sets the JUSTIFY bit
// if sets to 1 selects the left justified mode
// if sets to 0 selects right justified mode with sign extension
void ADXL345::setJustifyBit(bool justifyBit) {
  setRegisterBit(ADXL345_DATA_FORMAT, 2, justifyBit);
}

// Sets the THRESH_TAP byte value
// it should be between 0 and 255
// the scale factor is 62.5 mg/LSB
// A value of 0 may result in undesirable behavior
void ADXL345::setTapThreshold(int tapThreshold) {
  tapThreshold = min(max(tapThreshold,0),255);
  byte _b = byte (tapThreshold);
  writeTo(ADXL345_THRESH_TAP, _b);
}

// Gets the THRESH_TAP byte value
// return value is comprised between 0 and 255
// the scale factor is 62.5 mg/LSB
int ADXL345::getTapThreshold() {
  byte _b;
  readFrom(ADXL345_THRESH_TAP, 1, &_b);
  return int (_b);
}

```

```
// set/get the gain for each axis in Gs / count
void ADXL345::setAxisGains(float *_gains){
  int i;
  for(i = 0; i < 3; i++){
    gains[i] = _gains[i];
  }
}
void ADXL345::getAxisGains(float *_gains){
  int i;
  for(i = 0; i < 3; i++){
    _gains[i] = gains[i];
  }
}


// Sets the OFSX, OFSY and OFSZ bytes
// OFSX, OFSY and OFSZ are user offset adjustments in twos complement format with
// a scale factor of 15,6mg/LSB
// OFSX, OFSY and OFSZ should be comprised between
void ADXL345::setAxisOffset(int x, int y, int z) {
  writeTo(ADXL345_OFSX, byte (x));
  writeTo(ADXL345_OFSY, byte (y));
  writeTo(ADXL345_OFSZ, byte (z));
}

// Gets the OFSX, OFSY and OFSZ bytes
void ADXL345::getAxisOffset(int* x, int* y, int*z) {
  byte _b;
  readFrom(ADXL345_OFSX, 1, &_b);
  *x = int (_b);
  readFrom(ADXL345_OFSY, 1, &_b);
  *y = int (_b);
  readFrom(ADXL345_OFSZ, 1, &_b);
  *z = int (_b);
}

// Sets the DUR byte
// The DUR byte contains an unsigned time value representing the maximum time
// that an event must be above THRESH_TAP threshold to qualify as a tap event
// The scale factor is 625us/LSB
// A value of 0 disables the tap/float tap funcitons. Max value is 255.
void ADXL345::setTapDuration(int tapDuration) {
  tapDuration = min(max(tapDuration,0),255);
  byte _b = byte (tapDuration);
  writeTo(ADXL345_DUR, _b);
}

// Gets the DUR byte
int ADXL345::getTapDuration() {
  byte _b;
  readFrom(ADXL345_DUR, 1, &_b);
  return int (_b);
}

// Sets the latency (latent register) which contains an unsigned time value
// representing the wait time from the detection of a tap event to the start
// of the time window, during which a possible second tap can be detected.
// The scale factor is 1.25ms/LSB. A value of 0 disables the float tap function.
// It accepts a maximum value of 255.
void ADXL345::setDoubleTapLatency(int floatTapLatency) {
  byte _b = byte (floatTapLatency);
  writeTo(ADXL345_LATENT, _b);
}

// Gets the Latent value
int ADXL345::getDoubleTapLatency() {
  byte _b;
  readFrom(ADXL345_LATENT, 1, &_b);
  return int (_b);
}

// Sets the Window register, which contains an unsigned time value representing
// the amount of time after the expiration of the latency time (Latent register)
// during which a second valud tap can begin. The scale factor is 1.25ms/LSB. A
// value of 0 disables the float tap function. The maximum value is 255.
void ADXL345::setDoubleTapWindow(int floatTapWindow) {
```

```
  floatTapWindow = min(max(floatTapWindow,0),255);
  byte _b = byte (floatTapWindow);
  writeTo(ADXL345_WINDOW, _b);
}

// Gets the Window register
int ADXL345::getDoubleTapWindow() {
  byte _b;
  readFrom(ADXL345_WINDOW, 1, &_b);
  return int (_b);
}

// Sets the THRESH_ACT byte which holds the threshold value for detecting activity.
// The data format is unsigned, so the magnitude of the activity event is compared
// with the value is compared with the value in the THRESH_ACT register. The scale
// factor is 62.5mg/LSB. A value of 0 may result in undesirable behavior if the
// activity interrupt is enabled. The maximum value is 255.
void ADXL345::setActivityThreshold(int activityThreshold) {
  activityThreshold = min(max(activityThreshold,0),255);
  byte _b = byte (activityThreshold);
  writeTo(ADXL345_THRESH_ACT, _b);
}

// Gets the THRESH_ACT byte
int ADXL345::getActivityThreshold() {
  byte _b;
  readFrom(ADXL345_THRESH_ACT, 1, &_b);
  return int (_b);
}

// Sets the THRESH_INACT byte which holds the threshold value for detecting
    inactivity.
// The data format is unsigned, so the magnitude of the inactivity event is compared
// with the value is compared with the value in the THRESH_INACT register. The scale
// factor is 62.5mg/LSB. A value of 0 may result in undesirable behavior if the
// inactivity interrupt is enabled. The maximum value is 255.
void ADXL345::setInactivityThreshold(int inactivityThreshold) {
  inactivityThreshold = min(max(inactivityThreshold,0),255);
  byte _b = byte (inactivityThreshold);
  writeTo(ADXL345_THRESH_INACT, _b);
}

// Gets the THRESH_INACT byte
int ADXL345::getInactivityThreshold() {
  byte _b;
  readFrom(ADXL345_THRESH_INACT, 1, &_b);
  return int (_b);
}

// Sets the TIME_INACT register, which contains an unsigned time value representing
    the
// amount of time that acceleration must be less thant the value in the THRESH_INACT
// register for inactivity to be declared. The scale factor is 1sec/LSB. The value
    must
// be between 0 and 255.
void ADXL345::setTimeInactivity(int timeInactivity) {
  timeInactivity = min(max(timeInactivity,0),255);
  byte _b = byte (timeInactivity);
  writeTo(ADXL345_TIME_INACT, _b);
}

// Gets the TIME_INACT register
int ADXL345::getTimeInactivity() {
  byte _b;
  readFrom(ADXL345_TIME_INACT, 1, &_b);
  return int (_b);
}

// Sets the THRESH_FF register which holds the threshold value, in an unsigned format
    , for
// free-fall detection. The root-sum-square (RSS) value of all axes is calculated and
// compared whith the value in THRESH_FF to determine if a free-fall event occured.
    The
// scale factor is 62.5mg/LSB. A value of 0 may result in undesirable behavior if the
     free-fall
// interrupt is enabled. The maximum value is 255.
```

```
void ADXL345::setFreeFallThreshold(int freeFallThreshold) {
  freeFallThreshold = min(max(freeFallThreshold,0),255);
  byte _b = byte(freeFallThreshold);
  writeTo(ADXL345_THRESH_FF, _b);
}

// Gets the THRESH_FF register.
int ADXL345::getFreeFallThreshold() {
  byte _b;
  readFrom(ADXL345_THRESH_FF, 1, &_b);
  return int(_b);
}

// Sets the TIME_FF register, which holds an unsigned time value representing the minimum
// time that the RSS value of all axes must be less than THRESH_FF to generate a free-fall
// interrupt. The scale factor is 5ms/LSB. A value of 0 may result in undesirable behavior if
// the free-fall interrupt is enabled. The maximum value is 255.
void ADXL345::setFreeFallDuration(int freeFallDuration) {
  freeFallDuration = min(max(freeFallDuration,0),255);
  byte _b = byte(freeFallDuration);
  writeTo(ADXL345_TIME_FF, _b);
}

// Gets the TIME_FF register.
int ADXL345::getFreeFallDuration() {
  byte _b;
  readFrom(ADXL345_TIME_FF, 1, &_b);
  return int(_b);
}

bool ADXL345::isActivityXEnabled() {
  return getRegisterBit(ADXL345_ACT_INACT_CTL, 6);
}
bool ADXL345::isActivityYEnabled() {
  return getRegisterBit(ADXL345_ACT_INACT_CTL, 5);
}
bool ADXL345::isActivityZEnabled() {
  return getRegisterBit(ADXL345_ACT_INACT_CTL, 4);
}
bool ADXL345::isInactivityXEnabled() {
  return getRegisterBit(ADXL345_ACT_INACT_CTL, 2);
}
bool ADXL345::isInactivityYEnabled() {
  return getRegisterBit(ADXL345_ACT_INACT_CTL, 1);
}
bool ADXL345::isInactivityZEnabled() {
  return getRegisterBit(ADXL345_ACT_INACT_CTL, 0);
}

void ADXL345::setActivityX(bool state) {
  setRegisterBit(ADXL345_ACT_INACT_CTL, 6, state);
}
void ADXL345::setActivityY(bool state) {
  setRegisterBit(ADXL345_ACT_INACT_CTL, 5, state);
}
void ADXL345::setActivityZ(bool state) {
  setRegisterBit(ADXL345_ACT_INACT_CTL, 4, state);
}
void ADXL345::setInactivityX(bool state) {
  setRegisterBit(ADXL345_ACT_INACT_CTL, 2, state);
}
void ADXL345::setInactivityY(bool state) {
  setRegisterBit(ADXL345_ACT_INACT_CTL, 1, state);
}
void ADXL345::setInactivityZ(bool state) {
  setRegisterBit(ADXL345_ACT_INACT_CTL, 0, state);
}

bool ADXL345::isActivityAc() {
  return getRegisterBit(ADXL345_ACT_INACT_CTL, 7);
}
bool ADXL345::isInactivityAc(){
  return getRegisterBit(ADXL345_ACT_INACT_CTL, 3);
```

```
}

void ADXL345::setActivityAc(bool state) {
  setRegisterBit(ADXL345_ACT_INACT_CTL, 7, state);
}
void ADXL345::setInactivityAc(bool state) {
  setRegisterBit(ADXL345_ACT_INACT_CTL, 3, state);
}

bool ADXL345::getSuppressBit(){
  return getRegisterBit(ADXL345_TAP_AXES, 3);
}
void ADXL345::setSuppressBit(bool state) {
  setRegisterBit(ADXL345_TAP_AXES, 3, state);
}

bool ADXL345::isTapDetectionOnX(){
  return getRegisterBit(ADXL345_TAP_AXES, 2);
}
void ADXL345::setTapDetectionOnX(bool state) {
  setRegisterBit(ADXL345_TAP_AXES, 2, state);
}
bool ADXL345::isTapDetectionOnY(){
  return getRegisterBit(ADXL345_TAP_AXES, 1);
}
void ADXL345::setTapDetectionOnY(bool state) {
  setRegisterBit(ADXL345_TAP_AXES, 1, state);
}
bool ADXL345::isTapDetectionOnZ(){
  return getRegisterBit(ADXL345_TAP_AXES, 0);
}
void ADXL345::setTapDetectionOnZ(bool state) {
  setRegisterBit(ADXL345_TAP_AXES, 0, state);
}

bool ADXL345::isActivitySourceOnX(){
  return getRegisterBit(ADXL345_ACT_TAP_STATUS, 6);
}
bool ADXL345::isActivitySourceOnY(){
  return getRegisterBit(ADXL345_ACT_TAP_STATUS, 5);
}
bool ADXL345::isActivitySourceOnZ(){
  return getRegisterBit(ADXL345_ACT_TAP_STATUS, 4);
}

bool ADXL345::isTapSourceOnX(){
  return getRegisterBit(ADXL345_ACT_TAP_STATUS, 2);
}
bool ADXL345::isTapSourceOnY(){
  return getRegisterBit(ADXL345_ACT_TAP_STATUS, 1);
}
bool ADXL345::isTapSourceOnZ(){
  return getRegisterBit(ADXL345_ACT_TAP_STATUS, 0);
}

bool ADXL345::isAsleep(){
  return getRegisterBit(ADXL345_ACT_TAP_STATUS, 3);
}

bool ADXL345::isLowPower(){
  return getRegisterBit(ADXL345_BW_RATE, 4);
}
void ADXL345::setLowPower(bool state) {
  setRegisterBit(ADXL345_BW_RATE, 4, state);
}

float ADXL345::getRate(){
  byte _b;
  readFrom(ADXL345_BW_RATE, 1, &_b);
  _b &= B00001111;
  return (pow(2,((int) _b)-6)) * 6.25;
}

void ADXL345::setRate(float rate){
  byte _b,_s;
  int v = (int) (rate / 6.25);
```

```
507   int r = 0;
      while (v >>= 1)
509   {
        r++;
511   }
      if (r <= 9) {
513     readFrom(ADXL345_BW_RATE, 1, &_b);
        _s = (byte) (r + 6) | (_b & B11110000);
515     writeTo(ADXL345_BW_RATE, _s);
      }
517 }

519 void ADXL345::set_bw(byte bw_code){
      if((bw_code < ADXL345_BW_3) || (bw_code > ADXL345_BW_1600)){
521     status = false;
        error_code = ADXL345_BAD_ARG;
523   }
      else{
525     writeTo(ADXL345_BW_RATE, bw_code);
      }
527 }

529 byte ADXL345::get_bw_code(){
      byte bw_code;
531   readFrom(ADXL345_BW_RATE, 1, &bw_code);
      return bw_code;
533 }

535 byte ADXL345::getInterruptSource() {
      byte _b;
537   readFrom(ADXL345_INT_SOURCE, 1, &_b);
      return _b;
539 }

541 bool ADXL345::getInterruptSource(byte interruptBit) {
      return getRegisterBit(ADXL345_INT_SOURCE,interruptBit);
543 }

545 bool ADXL345::getInterruptMapping(byte interruptBit) {
      return getRegisterBit(ADXL345_INT_MAP,interruptBit);
547 }

549 // Set the mapping of an interrupt to pin1 or pin2
    // eg: setInterruptMapping(ADXL345_INT_DOUBLE_TAP_BIT,ADXL345_INT2_PIN);
551 void ADXL345::setInterruptMapping(byte interruptBit, bool interruptPin) {
      setRegisterBit(ADXL345_INT_MAP, interruptBit, interruptPin);
553 }

555 bool ADXL345::isInterruptEnabled(byte interruptBit) {
      return getRegisterBit(ADXL345_INT_ENABLE,interruptBit);
557 }

559 void ADXL345::setInterrupt(byte interruptBit, bool state) {
      setRegisterBit(ADXL345_INT_ENABLE, interruptBit, state);
561 }

563 void ADXL345::setRegisterBit(byte regAdress, int bitPos, bool state) {
      byte _b;
565   readFrom(regAdress, 1, &_b);
      if (state) {
567     _b |= (1 << bitPos);  // forces nth bit of _b to be 1.  all other bits left alone
        .
      }
569   else {
        _b &= ~(1 << bitPos); // forces nth bit of _b to be 0.  all other bits left alone
        .
571   }
      writeTo(regAdress, _b);
573 }

575 bool ADXL345::getRegisterBit(byte regAdress, int bitPos) {
      byte _b;
577   readFrom(regAdress, 1, &_b);
      return ((_b >> bitPos) & 1);
579 }
```

```
// print all register value to the serial ouptut, which requires it to be setup
// this can be used to manually to check the current configuration of the device
void ADXL345::printAllRegister() {
  byte _b;
  Serial.print("0x00: ");
  readFrom(0x00, 1, &_b);
  print_byte(_b);
  Serial.println("");
  int i;
  for (i=29;i<=57;i++){
    Serial.print("0x");
    Serial.print(i, HEX);
    Serial.print(": ");
    readFrom(i, 1, &_b);
    print_byte(_b);
    Serial.println("");
  }
}

void print_byte(byte val){
  int i;
  Serial.print("B");
  for(i=7; i>=0; i--){
    Serial.print(val >> i & 1, BIN);
  }
}
```

../Quadcopter/Quadcopter/libraries/FreeSixIMU/FIMU_ADXL345.cpp

```
/***********************************************************************
 *                                                                     *
 * ADXL345 Driver for Arduino                                          *
 *                                                                     *
 ***********************************************************************
 *                                                                     *
 * This program is free software; you can redistribute it and/or modify*
 * it under the terms of the GNU License.                              *
 * This program is distributed in the hope that it will be useful,     *
 * but WITHOUT ANY WARRANTY; without even the implied warranty of      *
 * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the       *
 * GNU License V2 for more details.                                    *
 *                                                                     *
 ***********************************************************************/
#include "Arduino.h"

#ifndef FIMU_ADXL345_h
#define FIMU_ADXL345_h

/* -- ADXL345 addresses --*/
#define ADXL345_ADDR_ALT_HIGH 0x1D // ADXL345 address when ALT is connected to HIGH
#define ADXL345_ADDR_ALT_LOW  0x53 // ADXL345 address when ALT is connected to LOW

/* ------- Register names ------- */
#define ADXL345_DEVID 0x00
#define ADXL345_RESERVED1 0x01
#define ADXL345_THRESH_TAP 0x1d
#define ADXL345_OFSX 0x1e
#define ADXL345_OFSY 0x1f
#define ADXL345_OFSZ 0x20
#define ADXL345_DUR 0x21
#define ADXL345_LATENT 0x22
#define ADXL345_WINDOW 0x23
#define ADXL345_THRESH_ACT 0x24
#define ADXL345_THRESH_INACT 0x25
#define ADXL345_TIME_INACT 0x26
#define ADXL345_ACT_INACT_CTL 0x27
#define ADXL345_THRESH_FF 0x28
#define ADXL345_TIME_FF 0x29
#define ADXL345_TAP_AXES 0x2a
#define ADXL345_ACT_TAP_STATUS 0x2b
#define ADXL345_BW_RATE 0x2c
#define ADXL345_POWER_CTL 0x2d
#define ADXL345_INT_ENABLE 0x2e
#define ADXL345_INT_MAP 0x2f
#define ADXL345_INT_SOURCE 0x30
#define ADXL345_DATA_FORMAT 0x31
```

```
#define ADXL345_DATAX0 0x32
#define ADXL345_DATAX1 0x33
#define ADXL345_DATAY0 0x34
#define ADXL345_DATAY1 0x35
#define ADXL345_DATAZ0 0x36
#define ADXL345_DATAZ1 0x37
#define ADXL345_FIFO_CTL 0x38
#define ADXL345_FIFO_STATUS 0x39

#define ADXL345_BW_1600 0xF // 1111
#define ADXL345_BW_800  0xE // 1110
#define ADXL345_BW_400  0xD // 1101
#define ADXL345_BW_200  0xC // 1100
#define ADXL345_BW_100  0xB // 1011
#define ADXL345_BW_50   0xA // 1010
#define ADXL345_BW_25   0x9 // 1001
#define ADXL345_BW_12   0x8 // 1000
#define ADXL345_BW_6    0x7 // 0111
#define ADXL345_BW_3    0x6 // 0110


/*
 Interrupt PINs
 INT1: 0
 INT2: 1
 */
#define ADXL345_INT1_PIN 0x00
#define ADXL345_INT2_PIN 0x01

/*
 Interrupt bit position
 */
#define ADXL345_INT_DATA_READY_BIT 0x07
#define ADXL345_INT_SINGLE_TAP_BIT 0x06
#define ADXL345_INT_DOUBLE_TAP_BIT 0x05
#define ADXL345_INT_ACTIVITY_BIT   0x04
#define ADXL345_INT_INACTIVITY_BIT 0x03
#define ADXL345_INT_FREE_FALL_BIT  0x02
#define ADXL345_INT_WATERMARK_BIT  0x01
#define ADXL345_INT_OVERRUNY_BIT   0x00

#define ADXL345_OK    1 // no error
#define ADXL345_ERROR 0 // indicates error is predent

#define ADXL345_NO_ERROR   0 // initial state
#define ADXL345_READ_ERROR 1 // problem reading accel
#define ADXL345_BAD_ARG    2 // bad method argument

class ADXL345
{
public:
  bool status;            // set when error occurs
                          // see error code for details
  byte error_code;        // Initial state
  float gains[3];         // counts to Gs

  ADXL345();
  void init(int address);
  void powerOn();
  void readAccel(int* xyx);
  void readAccel(int* x, int* y, int* z);
  void get_Gxyz(float *xyz);

  void setTapThreshold(int tapThreshold);
  int getTapThreshold();
  void setAxisGains(float *_gains);
  void getAxisGains(float *_gains);
  void setAxisOffset(int x, int y, int z);
  void getAxisOffset(int* x, int* y, int*z);
  void setTapDuration(int tapDuration);
  int getTapDuration();
  void setDoubleTapLatency(int floatTapLatency);
  int getDoubleTapLatency();
  void setDoubleTapWindow(int floatTapWindow);
  int getDoubleTapWindow();
  void setActivityThreshold(int activityThreshold);
```

```
  int getActivityThreshold();
  void setInactivityThreshold(int inactivityThreshold);
  int getInactivityThreshold();
  void setTimeInactivity(int timeInactivity);
  int getTimeInactivity();
  void setFreeFallThreshold(int freeFallthreshold);
  int getFreeFallThreshold();
  void setFreeFallDuration(int freeFallDuration);
  int getFreeFallDuration();

  bool isActivityXEnabled();
  bool isActivityYEnabled();
  bool isActivityZEnabled();
  bool isInactivityXEnabled();
  bool isInactivityYEnabled();
  bool isInactivityZEnabled();
  bool isActivityAc();
  bool isInactivityAc();
  void setActivityAc(bool state);
  void setInactivityAc(bool state);

  bool getSuppressBit();
  void setSuppressBit(bool state);
  bool isTapDetectionOnX();
  void setTapDetectionOnX(bool state);
  bool isTapDetectionOnY();
  void setTapDetectionOnY(bool state);
  bool isTapDetectionOnZ();
  void setTapDetectionOnZ(bool state);

  void setActivityX(bool state);
  void setActivityY(bool state);
  void setActivityZ(bool state);
  void setInactivityX(bool state);
  void setInactivityY(bool state);
  void setInactivityZ(bool state);

  bool isActivitySourceOnX();
  bool isActivitySourceOnY();
  bool isActivitySourceOnZ();
  bool isTapSourceOnX();
  bool isTapSourceOnY();
  bool isTapSourceOnZ();
  bool isAsleep();

  bool isLowPower();
  void setLowPower(bool state);
  float getRate();
  void setRate(float rate);
  void set_bw(byte bw_code);
  byte get_bw_code();

  byte getInterruptSource();
  bool getInterruptSource(byte interruptBit);
  bool getInterruptMapping(byte interruptBit);
  void setInterruptMapping(byte interruptBit, bool interruptPin);
  bool isInterruptEnabled(byte interruptBit);
  void setInterrupt(byte interruptBit, bool state);

  void getRangeSetting(byte* rangeSetting);
  void setRangeSetting(int val);
  bool getSelfTestBit();
  void setSelfTestBit(bool selfTestBit);
  bool getSpiBit();
  void setSpiBit(bool spiBit);
  bool getInterruptLevelBit();
  void setInterruptLevelBit(bool interruptLevelBit);
  bool getFullResBit();
  void setFullResBit(bool fullResBit);
  bool getJustifyBit();
  void setJustifyBit(bool justifyBit);
  void printAllRegister();
  void writeTo(byte address, byte val);

private:
  void readFrom(byte address, int num, byte buff[]);
```

```
  void setRegisterBit(byte regAdress, int bitPos, bool state);
  bool getRegisterBit(byte regAdress, int bitPos);
  byte _buff[6] ;    //6 bytes buffer for saving data read from the device
  int _dev_address;
};
void print_byte(byte val);
#endif
```

../Quadcopter/Quadcopter/libraries/FreeSixIMU/FIMU_ADXL345.h

```
/*****************************************************************************
* ITG3200.cpp - ITG-3200/I2C library v0.5 for Arduino                        *
* Copyright 2010-2011 Filipe Vieira & various contributors                   *
* http://code.google.com/p/itg-3200driver                                    *
* This file is part of ITG-3200 Arduino library.                             *
*                                                                            *
* This library is free software: you can redistribute it and/or modify       *
* it under the terms of the GNU Lesser General Public License as published   *
* by the Free Software Foundation, either version 3 of the License, or       *
* (at your option) any later version.                                        *
*                                                                            *
* This program is distributed in the hope that it will be useful,            *
* but WITHOUT ANY WARRANTY; without even the implied warranty of             *
* MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the              *
* GNU Lesser General Public License for more details.                        *
*                                                                            *
* You should have received a copy of the GNU Lesser General Public License   *
* along with this program.  If not, see <http://www.gnu.org/licenses/>.      *
*****************************************************************************/
/*****************************************************************************
* Tested on Arduino Mega with ITG-3200 Breakout                              *
* SCL     -> pin 21     (no pull up resistors)                               *
* SDA     -> pin 20     (no pull up resistors)                               *
* CLK & GND -> pin GND                                                       *
* INT       -> not connected  (but can be used)                              *
* VIO & VDD -> pin 3.3V                                                      *
*****************************************************************************/
#include "FIMU_ITG3200.h"


ITG3200::ITG3200() {
  setGains(1.0,1.0,1.0);
  setOffsets(0.0,0.0,0.0);
  setRevPolarity(0,0,0);
  //Wire.begin();        //Normally this code is called from setup() at user code
                         //but some people reported that joining I2C bus earlier
                         //apparently solved problems with master/slave conditions.
                         //Uncomment if needed.
}

void ITG3200::init(unsigned int  address) {
  // Uncomment or change your default ITG3200 initialization

  // fast sample rate - divisor = 0 filter = 0 clocksrc = 0, 1, 2, or 3  (raw values)
  init(address, NOSRDIVIDER, RANGE2000, BW256_SR8, PLL_XGYRO_REF, true, true);

  // slow sample rate - divisor = 0  filter = 1,2,3,4,5, or 6  clocksrc = 0, 1, 2, or
     3  (raw values)
  //init(NOSRDIVIDER, RANGE2000, BW010_SR1, INTERNALOSC, true, true);

  // fast sample rate 32Khz external clock - divisor = 0  filter = 0  clocksrc = 4  (
    raw values)
  //init(NOSRDIVIDER, RANGE2000, BW256_SR8, PLL_EXTERNAL32, true, true);

  // slow sample rate 32Khz external clock - divisor = 0  filter = 1,2,3,4,5, or 6
    clocksrc = 4  (raw values)
  //init(NOSRDIVIDER, RANGE2000, BW010_SR1, PLL_EXTERNAL32, true, true);
}

void ITG3200::init(unsigned int address, byte _SRateDiv, byte _Range, byte _filterBW,
     byte _ClockSrc, bool _ITGReady, bool _INTRawDataReady) {
  _dev_address = address;
  setSampleRateDiv(_SRateDiv);
  setFSRange(_Range);
  setFilterBW(_filterBW);
  setClockSource(_ClockSrc);
```

```
  setITGReady(_ITGReady);
64  setRawDataReady(_INTRawDataReady);
  delay(GYROSTART_UP_DELAY);  // startup
66 }

68 byte ITG3200::getDevAddr() {
  /*readmem(WHO_AM_I, 1, &_buff[0]);
70  return _buff[0];  */
  return _dev_address;
72 }

74 void ITG3200::setDevAddr(unsigned int  _addr) {
  writemem(WHO_AM_I, _addr);
76  _dev_address = _addr;
}
78
byte ITG3200::getSampleRateDiv() {
80  readmem(SMPLRT_DIV, 1, &_buff[0]);
  return _buff[0];
82 }

84 void ITG3200::setSampleRateDiv(byte _SampleRate) {
  writemem(SMPLRT_DIV, _SampleRate);
86 }

88 byte ITG3200::getFSRange() {
  readmem(DLPF_FS, 1, &_buff[0]);
90  return ((_buff[0] & DLPFFS_FS_SEL) >> 3);
}
92
void ITG3200::setFSRange(byte _Range) {
94  readmem(DLPF_FS, 1, &_buff[0]);
  writemem(DLPF_FS, ((_buff[0] & ~DLPFFS_FS_SEL) | (_Range << 3)) );
96 }

98 byte ITG3200::getFilterBW() {
  readmem(DLPF_FS, 1, &_buff[0]);
100  return (_buff[0] & DLPFFS_DLPF_CFG);
}
102
void ITG3200::setFilterBW(byte _BW) {
104  readmem(DLPF_FS, 1, &_buff[0]);
  writemem(DLPF_FS, ((_buff[0] & ~DLPFFS_DLPF_CFG) | _BW));
106 }

108 bool ITG3200::isINTActiveOnLow() {
  readmem(INT_CFG, 1, &_buff[0]);
110  return ((_buff[0] & INTCFG_ACTL) >> 7);
}
112
void ITG3200::setINTLogiclvl(bool _State) {
114  readmem(INT_CFG, 1, &_buff[0]);
  writemem(INT_CFG, ((_buff[0] & ~INTCFG_ACTL) | (_State << 7)));
116 }

118 bool ITG3200::isINTOpenDrain() {
  readmem(INT_CFG, 1, &_buff[0]);
120  return ((_buff[0] & INTCFG_OPEN) >> 6);
}
122
void ITG3200::setINTDriveType(bool _State) {
124  readmem(INT_CFG, 1, &_buff[0]);
  writemem(INT_CFG, ((_buff[0] & ~INTCFG_OPEN) | _State << 6));
126 }

128 bool ITG3200::isLatchUntilCleared() {
  readmem(INT_CFG, 1, &_buff[0]);
130  return ((_buff[0] & INTCFG_LATCH_INT_EN) >> 5);
}
132
void ITG3200::setLatchMode(bool _State) {
134  readmem(INT_CFG, 1, &_buff[0]);
  writemem(INT_CFG, ((_buff[0] & ~INTCFG_LATCH_INT_EN) | _State << 5));
136 }

138 bool ITG3200::isAnyRegClrMode() {
```

```
  readmem(INT_CFG, 1, &_buff[0]);
  return ((_buff[0] & INTCFG_INT_ANYRD_2CLEAR) >> 4);
}

void ITG3200::setLatchClearMode(bool _State) {
  readmem(INT_CFG, 1, &_buff[0]);
  writemem(INT_CFG, ((_buff[0] & ~INTCFG_INT_ANYRD_2CLEAR) | _State << 4));
}

bool ITG3200::isITGReadyOn() {
  readmem(INT_CFG, 1, &_buff[0]);
  return ((_buff[0] & INTCFG_ITG_RDY_EN) >> 2);
}

void ITG3200::setITGReady(bool _State) {
  readmem(INT_CFG, 1, &_buff[0]);
  writemem(INT_CFG, ((_buff[0] & ~INTCFG_ITG_RDY_EN) | _State << 2));
}

bool ITG3200::isRawDataReadyOn() {
  readmem(INT_CFG, 1, &_buff[0]);
  return (_buff[0] & INTCFG_RAW_RDY_EN);
}

void ITG3200::setRawDataReady(bool _State) {
  readmem(INT_CFG, 1, &_buff[0]);
  writemem(INT_CFG, ((_buff[0] & ~INTCFG_RAW_RDY_EN) | _State));
}

bool ITG3200::isITGReady() {
  readmem(INT_STATUS, 1, &_buff[0]);
  return ((_buff[0] & INTSTATUS_ITG_RDY) >> 2);
}

bool ITG3200::isRawDataReady() {
  readmem(INT_STATUS, 1, &_buff[0]);
  return (_buff[0] & INTSTATUS_RAW_DATA_RDY);
}

void ITG3200::readTemp(float *_Temp) {
  readmem(TEMP_OUT,2,_buff);
  *_Temp = 35 + (((_buff[0] << 8) | _buff[1]) + 13200) / 280.0;     // F=C*9/5+32
}

void ITG3200::readGyroRaw(int *_GyroX, int *_GyroY, int *_GyroZ){
  readmem(GYRO_XOUT, 6, _buff);
  *_GyroX = ((_buff[0] << 8) | _buff[1]);
  *_GyroY = ((_buff[2] << 8) | _buff[3]);
  *_GyroZ = ((_buff[4] << 8) | _buff[5]);
}

void ITG3200::readGyroRaw(int *_GyroXYZ){
  readGyroRaw(_GyroXYZ, _GyroXYZ+1, _GyroXYZ+2);
}

void ITG3200::setRevPolarity(bool _Xpol, bool _Ypol, bool _Zpol) {
  polarities[0] = _Xpol ? -1 : 1;
  polarities[1] = _Ypol ? -1 : 1;
  polarities[2] = _Zpol ? -1 : 1;
}

void ITG3200::setGains(float _Xgain, float _Ygain, float _Zgain) {
  gains[0] = _Xgain;
  gains[1] = _Ygain;
  gains[2] = _Zgain;
}

void ITG3200::setOffsets(int _Xoffset, int _Yoffset, int _Zoffset) {
  offsets[0] = _Xoffset;
  offsets[1] = _Yoffset;
  offsets[2] = _Zoffset;
}

void ITG3200::zeroCalibrate(unsigned int totSamples, unsigned int sampleDelayMS) {
  int xyz[3];
  float tmpOffsets[] = {0,0,0};
```

```
216   for (int i = 0;i < totSamples;i++){
        delay(sampleDelayMS);
218     readGyroRaw(xyz);
        tmpOffsets[0] += xyz[0];
220     tmpOffsets[1] += xyz[1];
        tmpOffsets[2] += xyz[2];
222   }
      setOffsets(-tmpOffsets[0] / totSamples, -tmpOffsets[1] / totSamples, -tmpOffsets[2]
        / totSamples);
224 }

226 void ITG3200::readGyroRawCal(int *_GyroX, int *_GyroY, int *_GyroZ) {
      readGyroRaw(_GyroX, _GyroY, _GyroZ);
228   *_GyroX += offsets[0];
      *_GyroY += offsets[1];
230   *_GyroZ += offsets[2];
    }
232
    void ITG3200::readGyroRawCal(int *_GyroXYZ) {
234   readGyroRawCal(_GyroXYZ, _GyroXYZ+1, _GyroXYZ+2);
    }
236
    void ITG3200::readGyro(float *_GyroX, float *_GyroY, float *_GyroZ){
238   int x, y, z;

240   readGyroRawCal(&x, &y, &z); // x,y,z will contain calibrated integer values from
        the sensor
      *_GyroX =  x / 14.375 * polarities[0] * gains[0];
242   *_GyroY =  y / 14.375 * polarities[1] * gains[1];
      *_GyroZ =  z / 14.375 * polarities[2] * gains[2];
244 }

246 void ITG3200::readGyro(float *_GyroXYZ){
      readGyro(_GyroXYZ, _GyroXYZ+1, _GyroXYZ+2);
248 }

250 void ITG3200::reset() {
      writemem(PWR_MGM, PWRMGM_HRESET);
252   delay(GYROSTART_UP_DELAY); //gyro startup
    }
254
    bool ITG3200::isLowPower() {
256   readmem(PWR_MGM, 1, &_buff[0]);
      return (_buff[0] & PWRMGM_SLEEP) >> 6;
258 }

260 void ITG3200::setPowerMode(bool _State) {
      readmem(PWR_MGM, 1, &_buff[0]);
262   writemem(PWR_MGM, ((_buff[0] & ~PWRMGM_SLEEP) | _State << 6));
    }
264
    bool ITG3200::isXgyroStandby() {
266   readmem(PWR_MGM, 1, &_buff[0]);
      return (_buff[0] & PWRMGM_STBY_XG) >> 5;
268 }

270 bool ITG3200::isYgyroStandby() {
      readmem(PWR_MGM, 1, &_buff[0]);
272   return (_buff[0] & PWRMGM_STBY_YG) >> 4;
    }
274
    bool ITG3200::isZgyroStandby() {
276   readmem(PWR_MGM, 1, &_buff[0]);
      return (_buff[0] & PWRMGM_STBY_ZG) >> 3;
278 }

280 void ITG3200::setXgyroStandby(bool _Status) {
      readmem(PWR_MGM, 1, &_buff[0]);
282   writemem(PWR_MGM, ((_buff[0] & PWRMGM_STBY_XG) | _Status << 5));
    }
284
    void ITG3200::setYgyroStandby(bool _Status) {
286   readmem(PWR_MGM, 1, &_buff[0]);
      writemem(PWR_MGM, ((_buff[0] & PWRMGM_STBY_YG) | _Status << 4));
288 }
```

```
290 void ITG3200::setZgyroStandby(bool _Status) {
    readmem(PWRMGM, 1, &_buff[0]);
292   writemem(PWRMGM, ((_buff[0] & PWRMGM_STBY_ZG) | _Status << 3));
}
294
byte ITG3200::getClockSource() {
296   readmem(PWRMGM, 1, &_buff[0]);
    return (_buff[0] & PWRMGM_CLK_SEL);
298 }

300 void ITG3200::setClockSource(byte _CLKsource) {
    readmem(PWRMGM, 1, &_buff[0]);
302   writemem(PWRMGM, ((_buff[0] & ~PWRMGM_CLK_SEL) | _CLKsource));
}
304
void ITG3200::writemem(uint8_t _addr, uint8_t _val) {
306   Wire.beginTransmission(_dev_address);   // start transmission to device
    Wire.write(_addr); // send register address
308   Wire.write(_val); // send value to write
    Wire.endTransmission(); // end transmission
310 }

312 void ITG3200::readmem(uint8_t _addr, uint8_t _nbytes, uint8_t __buff[]) {
    Wire.beginTransmission(_dev_address); // start transmission to device
314   Wire.write(_addr); // sends register address to read from
    Wire.endTransmission(); // end transmission
316
    Wire.beginTransmission(_dev_address); // start transmission to device
318   Wire.requestFrom(_dev_address, _nbytes);// send data n-bytes read
    uint8_t i = 0;
320   while (Wire.available()) {
      __buff[i] = Wire.read(); // receive DATA
322     i++;
    }
324   Wire.endTransmission(); // end transmission
}
```

../Quadcopter/Quadcopter/libraries/FreeSixIMU/FIMU_ITG3200.cpp

```
/*****************************************************************************
2 * ITG3200.h - ITG-3200/I2C library v0.5 for Arduino                        *
  * Copyright 2010-2011 Filipe Vieira & various contributors                  *
4 * http://code.google.com/p/itg-3200driver                                  *
  * This file is part of ITG-3200 Arduino library.                            *
6 *                                                                           *
  * This library is free software: you can redistribute it and/or modify      *
8 * it under the terms of the GNU Lesser General Public License as published  *
  * by the Free Software Foundation, either version 3 of the License, or      *
10 * (at your option) any later version.                                      *
  *                                                                           *
12 * This program is distributed in the hope that it will be useful,          *
  * but WITHOUT ANY WARRANTY; without even the implied warranty of            *
14 * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the            *
  * GNU Lesser General Public License for more details.                       *
16 *                                                                           *
  * You should have received a copy of the GNU Lesser General Public License  *
18 * along with this program.  If not, see <http://www.gnu.org/licenses/>.    *
  *****************************************************************************/
20 /*****************************************************************************
  * Tested on Arduino Mega with ITG-3200 Breakout                             *
22 * SCL     -> pin 21     (no pull up resistors)                              *
  * SDA     -> pin 20     (no pull up resistors)                              *
24 * CLK & GND -> pin GND                                                    *
  * INT       -> not connected  (but can be used)                             *
26 * VIO & VDD -> pin 3.3V                                                    *
  *****************************************************************************/
28 #ifndef FIMU_ITG3200_h
  #define FIMU_ITG3200_h
30
  #include "Arduino.h"
32 #include <Wire.h>

34 #define ITG3200_ADDR_AD0_HIGH  0x69   //AD0=1 0x69 I2C address when AD0 is connected
       to HIGH (VCC) - default for sparkfun breakout
```

```
#define ITG3200_ADDR_AD0_LOW   0x68   //AD0=0 0x68 I2C address when AD0 is connected to LOW (GND)
// "The LSB bit of the 7 bit address is determined by the logic level on pin 9.
// This allows two ITG-3200 devices to be connected to the same I2C bus.
// One device should have pin9 (or bit0) LOW and the other should be HIGH." source: ITG3200 datasheet
// Note that pin9 (AD0 - I2C Slave Address LSB) may not be available on some breakout boards so check
// the schematics of your breakout board for the correct address to use.


#define GYROSTART_UP_DELAY  70    // 50ms from gyro startup + 20ms register r/w startup

/* ---- Registers ---- */
#define WHO_AM_I            0x00  // RW   SETUP: I2C address
#define SMPLRT_DIV          0x15  // RW   SETUP: Sample Rate Divider
#define DLPF_FS             0x16  // RW   SETUP: Digital Low Pass Filter/ Full Scale range
#define INT_CFG             0x17  // RW   Interrupt: Configuration
#define INT_STATUS          0x1A  // R Interrupt: Status
#define TEMP_OUT            0x1B  // R SENSOR: Temperature 2bytes
#define GYRO_XOUT           0x1D  // R SENSOR: Gyro X 2bytes
#define GYRO_YOUT           0x1F  // R SENSOR: Gyro Y 2bytes
#define GYRO_ZOUT           0x21  // R SENSOR: Gyro Z 2bytes
#define PWR_MGM             0x3E  // RW  Power Management

/* ---- bit maps ---- */
#define DLPFFS_FS_SEL              0x18  // 00011000
#define DLPFFS_DLPF_CFG            0x07  // 00000111
#define INTCFG_ACTL                0x80  // 10000000
#define INTCFG_OPEN                0x40  // 01000000
#define INTCFG_LATCH_INT_EN        0x20  // 00100000
#define INTCFG_INT_ANYRD_2CLEAR    0x10  // 00010000
#define INTCFG_ITG_RDY_EN          0x04  // 00000100
#define INTCFG_RAW_RDY_EN          0x01  // 00000001
#define INTSTATUS_ITG_RDY          0x04  // 00000100
#define INTSTATUS_RAW_DATA_RDY     0x01  // 00000001
#define PWRMGM_HRESET              0x80  // 10000000
#define PWRMGM_SLEEP               0x40  // 01000000
#define PWRMGM_STBY_XG             0x20  // 00100000
#define PWRMGM_STBY_YG             0x10  // 00010000
#define PWRMGM_STBY_ZG             0x08  // 00001000
#define PWRMGM_CLK_SEL             0x07  // 00000111

/***********************************/
/*     REGISTERS PARAMETERS     */
/***********************************/
// Sample Rate Divider
#define NOSRDIVIDER         0 // default    FsampleHz=SampleRateHz/(divider+1)
// Gyro Full Scale Range
#define RANGE2000           3   // default
// Digital Low Pass Filter BandWidth and SampleRate
#define BW256_SR8           0   // default    256Khz BW and 8Khz SR
#define BW188_SR1           1
#define BW098_SR1           2
#define BW042_SR1           3
#define BW020_SR1           4
#define BW010_SR1           5
#define BW005_SR1           6
// Interrupt Active logic lvl
#define ACTIVE_ONHIGH       0 // default
#define ACTIVE_ONLOW        1
// Interrupt drive type
#define PUSH_PULL           0 // default
#define OPEN_DRAIN          1
// Interrupt Latch mode
#define PULSE_50US          0 // default
#define UNTIL_INT_CLEARED   1
// Interrupt Latch clear method
#define READ_STATUSREG      0 // default
#define READ_ANYREG         1
// Power management
#define NORMAL              0 // default
#define STANDBY             1
// Clock Source - user parameters
```

```
106 #define INTERNALOSC          0   // default
    #define PLL_XGYRO_REF        1
108 #define PLL_YGYRO_REF        2
    #define PLL_ZGYRO_REF        3
110 #define PLL_EXTERNAL32       4   // 32.768 kHz
    #define PLL_EXTERNAL19       5   // 19.2 Mhz
112
    class ITG3200 {
114
    public:
116   float gains[3];
      int offsets[3];
118   float polarities[3];

120   ITG3200();

122   // Gyro initialization
      void init(unsigned int address);
124   void init(unsigned int address, byte _SRateDiv, byte _Range, byte _filterBW, byte
        _ClockSrc, bool _ITGReady, bool _INTRawDataReady);

126   // Who Am I
      byte getDevAddr();
128   void setDevAddr(unsigned int _addr);
      // Sample Rate Divider
130   byte getSampleRateDiv();
      void setSampleRateDiv(byte _SampleRate);
132   // Digital Low Pass Filter BandWidth and SampleRate
      byte getFSRange();
134   void setFSRange(byte _Range); // RANGE2000
      byte getFilterBW();
136   void setFilterBW(byte _BW); // see register parameters above
      // Interrupt Configuration
138   bool isINTActiveOnLow();
      void setINTLogiclvl(bool _State); //ACTIVE_ONHIGH, ACTIVE_ONLOW
140   // Interrupt drive type
      bool isINTOpenDrain();
142   void setINTDriveType(bool _State); //OPEN_DRAIN, PUSH_PULL
      // Interrupt Latch mode
144   bool isLatchUntilCleared();
      void setLatchMode(bool _State); //UNTIL_INT_CLEARED, PULSE_50US
146   // Interrupt Latch clear method
      bool isAnyRegClrMode();
148   void setLatchClearMode(bool _State); //READ_ANYREG, READ_STATUSREG
      // INT pin triggers
150   bool isITGReadyOn();
      void setITGReady(bool _State);
152   bool isRawDataReadyOn();
      void setRawDataReady(bool _State);
154   // Trigger Status
      bool isITGReady();
156   bool isRawDataReady();
      // Gyro Sensors
158   void readTemp(float *_Temp);
      void readGyroRaw(int  *_GyroXYZ);
160   void readGyroRaw(int *_GyroX, int *_GyroY, int *_GyroZ);
      void setRevPolarity(bool _Xpol, bool _Ypol, bool _Zpol);  // true = Reversed  false
        = default
162   void setGains(float _Xgain, float _Ygain, float _Zgain);
      void setOffsets(int _Xoffset, int _Yoffset, int _Zoffset);
164   void zeroCalibrate(unsigned int totSamples, unsigned int sampleDelayMS);  //
        assuming gyroscope is stationary (updates XYZ offsets for zero)
      void readGyroRawCal(int *_GyroX, int *_GyroY, int *_GyroZ);
166   void readGyroRawCal(int *_GyroXYZ);
      void readGyro(float *_GyroXYZ); // includes gain and offset
168   void readGyro(float *_GyroX, float *_GyroY, float *_GyroZ); // includes gain and
        offset
      // Power management
170   void reset(); // after reset all registers have default values
      bool isLowPower();
172   void setPowerMode(bool _State); // NORMAL, STANDBY
      bool isXgyroStandby();
174   bool isYgyroStandby();
      bool isZgyroStandby();
176   void setXgyroStandby(bool _Status); // NORMAL, STANDBY
      void setYgyroStandby(bool _Status);
```

```
178   void setZgyroStandby(bool _Status);
      byte getClockSource();
180   void setClockSource(byte _CLKsource); // see register parameters above

182   void writemem(uint8_t _addr, uint8_t _val);
      void readmem(uint8_t _addr, uint8_t _nbytes, uint8_t __buff[]);
184
    private:
186
      uint8_t _dev_address;
188   uint8_t _buff[6];
    };
190 #endif
```

../Quadcopter/Quadcopter/libraries/FreeSixIMU/FIMU_ITG3200.h

```
    /*
2   FreeSixIMU.cpp - A libre and easy to use orientation sensing library for Arduino
    Copyright (C) 2011 Fabio Varesano <fabio at varesano dot net>
4
    Development of this code has been supported by the Department of Computer Science,
6   Universita' degli Studi di Torino, Italy within the Piemonte Project
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22  */

24  #include <inttypes.h>
    //#define DEBUG
26  #include "FreeSixIMU.h"
    // #include "WireUtils.h"
28  //#include "DebugUtils.h"


30
    FreeSixIMU::FreeSixIMU() {
32    acc = ADXL345();
      gyro = ITG3200();
34    //magn = HMC58X3();

36    // initialize quaternion
      q0 = 1.0f;
38    q1 = 0.0f;
      q2 = 0.0f;
40    q3 = 0.0f;
      exInt = 0.0;
42    eyInt = 0.0;
      ezInt = 0.0;
44    twoKp = twoKpDef;
      twoKi = twoKiDef;
46    integralFBx = 0.0f,  integralFBy = 0.0f, integralFBz = 0.0f;
      lastUpdate = 0;
48    now = 0;
    }
50
    void FreeSixIMU::init() {
52    init(FIMU_ACC_ADDR, FIMU_ITG3200_DEF_ADDR, false);
    }
54
    void FreeSixIMU::init(bool fastmode) {
56    init(FIMU_ACC_ADDR, FIMU_ITG3200_DEF_ADDR, fastmode);
    }
58
    void FreeSixIMU::init(int acc_addr, int gyro_addr, bool fastmode) {
60    delay(5);
```

```
62    // disable internal pullups of the ATMEGA which Wire enable by default
      #if defined(__AVR_ATmega168__) || defined(__AVR_ATmega8__) || defined(
        __AVR_ATmega328P__)
64      // deactivate internal pull-ups for twi
        // as per note from atmega8 manual pg167
66      cbi(PORTC, 4);
        cbi(PORTC, 5);
68    #endif
      #if defined(ARDUINO_ARCH_SAM)
70    #else
        // deactivate internal pull-ups for twi
72      // as per note from atmega128 manual pg204
        cbi(PORTD, 0);
74      cbi(PORTD, 1);
      #endif
76
      if(fastmode) { // switch to 400KHz I2C - eheheh
78    #if not defined(ARDUINO_ARCH_SAM)
        TWBR = ((16000000L / 400000L) - 16) / 2; // see twi_init in Wire/utility/twi.c
80      // TODO: make the above usable also for 8MHz arduinos..
      #endif
82    }

84    // init ADXL345
      acc.init(acc_addr);
86

88    // init ITG3200
      gyro.init(gyro_addr);
90    delay(1000);
      // calibrate the ITG3200
92    gyro.zeroCalibrate(128,5);

94    // init HMC5843
      //magn.init(false); // Don't set mode yet, we'll do that later on.
96    // Calibrate HMC using self test, not recommended to change the gain after
        calibration.
      //magn.calibrate(1); // Use gain 1=default, valid 0-7, 7 not recommended.
98    // Single mode conversion was used in calibration, now set continuous mode
      //magn.setMode(0);
100   //delay(10);
      //magn.setDOR(B110);
102
  }
104

106 void FreeSixIMU::getRawValues(int * raw_values) {
      acc.readAccel(&raw_values[0], &raw_values[1], &raw_values[2]);
108   gyro.readGyroRaw(&raw_values[3], &raw_values[4], &raw_values[5]);
      //magn.getValues(&raw_values[6], &raw_values[7], &raw_values[8]);
110
  }
112

114 void FreeSixIMU::getValues(float * values) {
      int accval[3];
116   acc.readAccel(&accval[0], &accval[1], &accval[2]);
      values[0] = ((float) accval[0]);
118   values[1] = ((float) accval[1]);
      values[2] = ((float) accval[2]);
120
      gyro.readGyro(&values[3]);
122
      //magn.getValues(&values[6]);
124 }

126
  // Quaternion implementation of the 'DCM filter' [Mayhony et al]. Incorporates the
      magnetic distortion
128 // compensation algorithms from Sebastian Madgwick filter which eliminates the need
      for a reference
  // direction of flux (bx bz) to be predefined and limits the effect of magnetic
      distortions to yaw
130 // axis only.
  //
```

```
// See: http://www.x-io.co.uk/node/8#open_source_ahrs_and_imu_algorithms
//
//=============================================================================

void FreeSixIMU::AHRSupdate(float gx, float gy, float gz, float ax, float ay, float
    az, float mx, float my, float mz) {
  float recipNorm;
  float q0q0, q0q1, q0q2, q0q3, q1q1, q1q2, q1q3, q2q2, q2q3, q3q3;
  float halfex = 0.0f, halfey = 0.0f, halfez = 0.0f;
  float qa, qb, qc;

  // Auxiliary variables to avoid repeated arithmetic
  q0q0 = q0 * q0;
  q0q1 = q0 * q1;
  q0q2 = q0 * q2;
  q0q3 = q0 * q3;
  q1q1 = q1 * q1;
  q1q2 = q1 * q2;
  q1q3 = q1 * q3;
  q2q2 = q2 * q2;
  q2q3 = q2 * q3;
  q3q3 = q3 * q3;


  /*
  // Use magnetometer measurement only when valid (avoids NaN in magnetometer
    normalisation)
  if((mx != 0.0f) && (my != 0.0f) && (mz != 0.0f)) {
    float hx, hy, bx, bz;
    float halfwx, halfwy, halfwz;

    // Normalise magnetometer measurement
    recipNorm = invSqrt(mx * mx + my * my + mz * mz);
    mx *= recipNorm;
    my *= recipNorm;
    mz *= recipNorm;

    // Reference direction of Earth's magnetic field
    hx = 2.0f * (mx * (0.5f - q2q2 - q3q3) + my * (q1q2 - q0q3) + mz * (q1q3 + q0q2))
    ;
    hy = 2.0f * (mx * (q1q2 + q0q3) + my * (0.5f - q1q1 - q3q3) + mz * (q2q3 - q0q1))
    ;
    bx = sqrt(hx * hx + hy * hy);
    bz = 2.0f * (mx * (q1q3 - q0q2) + my * (q2q3 + q0q1) + mz * (0.5f - q1q1 - q2q2))
    ;

    // Estimated direction of magnetic field
    halfwx = bx * (0.5f - q2q2 - q3q3) + bz * (q1q3 - q0q2);
    halfwy = bx * (q1q2 - q0q3) + bz * (q0q1 + q2q3);
    halfwz = bx * (q0q2 + q1q3) + bz * (0.5f - q1q1 - q2q2);

    // Error is sum of cross product between estimated direction and measured
    direction of field vectors
    halfex = (my * halfwz - mz * halfwy);
    halfey = (mz * halfwx - mx * halfwz);
    halfez = (mx * halfwy - my * halfwx);
  }
  */

  // Compute feedback only if accelerometer measurement valid (avoids NaN in
    accelerometer normalisation)
  if((ax != 0.0f) && (ay != 0.0f) && (az != 0.0f)) {
    float halfvx, halfvy, halfvz;

    // Normalise accelerometer measurement
    recipNorm = invSqrt(ax * ax + ay * ay + az * az);
    ax *= recipNorm;
    ay *= recipNorm;
    az *= recipNorm;

    // Estimated direction of gravity
    halfvx = q1q3 - q0q2;
    halfvy = q0q1 + q2q3;
    halfvz = q0q0 - 0.5f + q3q3;

```

```
    // Error is sum of cross product between estimated direction and measured
    direction of field vectors
    halfex += (ay * halfvz - az * halfvy);
    halfey += (az * halfvx - ax * halfvz);
    halfez += (ax * halfvy - ay * halfvx);
  }

  // Apply feedback only when valid data has been gathered from the accelerometer or
    magnetometer
  if(halfex != 0.0f && halfey != 0.0f && halfez != 0.0f) {
    // Compute and apply integral feedback if enabled
    if(twoKi > 0.0f) {
      integralFBx += twoKi * halfex * (1.0f / sampleFreq);  // integral error scaled
    by Ki
      integralFBy += twoKi * halfey * (1.0f / sampleFreq);
      integralFBz += twoKi * halfez * (1.0f / sampleFreq);
      gx += integralFBx;  // apply integral feedback
      gy += integralFBy;
      gz += integralFBz;
    }
    else {
      integralFBx = 0.0f; // prevent integral windup
      integralFBy = 0.0f;
      integralFBz = 0.0f;
    }

    // Apply proportional feedback
    gx += twoKp * halfex;
    gy += twoKp * halfey;
    gz += twoKp * halfez;
  }

  // Integrate rate of change of quaternion
  gx *= (0.5f * (1.0f / sampleFreq));   // pre-multiply common factors
  gy *= (0.5f * (1.0f / sampleFreq));
  gz *= (0.5f * (1.0f / sampleFreq));
  qa = q0;
  qb = q1;
  qc = q2;
  q0 += (-qb * gx - qc * gy - q3 * gz);
  q1 += (qa * gx + qc * gz - q3 * gy);
  q2 += (qa * gy - qb * gz + q3 * gx);
  q3 += (qa * gz + qb * gy - qc * gx);

  // Normalise quaternion
  recipNorm = invSqrt(q0 * q0 + q1 * q1 + q2 * q2 + q3 * q3);
  q0 *= recipNorm;
  q1 *= recipNorm;
  q2 *= recipNorm;
  q3 *= recipNorm;
}


void FreeSixIMU::getQ(float * q) {
  float val[9];
  getValues(val);

  /*
  DEBUG_PRINT(val[3] * M_PI/180);
  DEBUG_PRINT(val[4] * M_PI/180);
  DEBUG_PRINT(val[5] * M_PI/180);
  DEBUG_PRINT(val[0]);
  DEBUG_PRINT(val[1]);
  DEBUG_PRINT(val[2]);
  DEBUG_PRINT(val[6]);
  DEBUG_PRINT(val[7]);
  DEBUG_PRINT(val[8]);
  */


  now = micros();
  sampleFreq = 1.0 / ((now - lastUpdate) / 1000000.0);
  lastUpdate = now;
  // gyro values are expressed in deg/sec, the * M_PI/180 will convert it to radians/
    sec
```

```
270   //AHRSupdate(val[3] * M_PI/180, val[4] * M_PI/180, val[5] * M_PI/180, val[0], val
        [1], val[2], val[6], val[7], val[8]);
      // use the call below when using a 6DOF IMU
272   AHRSupdate(val[3] * M_PI/180, val[4] * M_PI/180, val[5] * M_PI/180, val[0], val[1],
        val[2], 0, 0, 0);
      q[0] = q0;
274   q[1] = q1;
      q[2] = q2;
276   q[3] = q3;
}
278
// Returns the Euler angles in radians defined with the Aerospace sequence.
280 // See Sebastian O.H. Madwick report
// "An efficient orientation filter for inertial and intertial/magnetic sensor arrays
    " Chapter 2 Quaternion representation
282 void FreeSixIMU::getEuler(float * angles) {
float q[4]; // quaternion
284   getQ(q);
      angles[0] = atan2(2 * q[1] * q[2] - 2 * q[0] * q[3], 2 * q[0]*q[0] + 2 * q[1] * q
        [1] - 1) * 180/M_PI; // psi
286   angles[1] = -asin(2 * q[1] * q[3] + 2 * q[0] * q[2]) * 180/M_PI; // theta
      angles[2] = atan2(2 * q[2] * q[3] - 2 * q[0] * q[1], 2 * q[0] * q[0] + 2 * q[3] * q
        [3] - 1) * 180/M_PI; // phi
288 }


290
void FreeSixIMU::getAngles(float * angles) {
292   float a[3]; //Euler
      getEuler(a);
294
      angles[0] = a[0];
296   angles[1] = a[1];
      angles[2] = a[2];
298
      if(angles[0] < 0)angles[0] += 360;
300   if(angles[1] < 0)angles[1] += 360;
      if(angles[2] < 0)angles[2] += 360;
302
}
304




308
void FreeSixIMU::getYawPitchRoll(float * ypr) {
310   float q[4]; // quaternion
      float gx, gy, gz; // estimated gravity direction
312   getQ(q);

314   gx = 2 * (q[1]*q[3] - q[0]*q[2]);
      gy = 2 * (q[0]*q[1] + q[2]*q[3]);
316   gz = q[0]*q[0] - q[1]*q[1] - q[2]*q[2] + q[3]*q[3];

318   ypr[0] = atan2(2 * q[1] * q[2] - 2 * q[0] * q[3], 2 * q[0]*q[0] + 2 * q[1] * q[1] -
        1) * 180/M_PI;
      ypr[1] = atan(gx / sqrt(gy*gy + gz*gz))  * 180/M_PI;
320   ypr[2] = atan(gy / sqrt(gx*gx + gz*gz))  * 180/M_PI;
}
322


324 float invSqrt(float number) {
      volatile long i;
326   volatile float x, y;
      volatile const float f = 1.5F;
328
      x = number * 0.5F;
330   y = number;
      i = * ( long * ) &y;
332   i = 0x5f375a86 - ( i >> 1 );
      y = * ( float * ) &i;
334   y = y * ( f - ( x * y * y ) );
      return y;
336 }
```

../Quadcopter/Quadcopter/libraries/FreeSixIMU/FreeSixIMU.cpp

```
/*
FreeSixIMU.h - A libre and easy to use orientation sensing library for Arduino
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Development of this code has been supported by the Department of Computer Science,
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*/

#include <Wire.h>
#include "Arduino.h"

#include <FIMU_ADXL345.h>
#define FIMU_ACC_ADDR ADXL345_ADDR_ALT_LOW // SDO connected to GND
#include <FIMU_ITG3200.h>


#ifndef FreeSixIMU_h
#define FreeSixIMU_h


#define FIMU_BMA180_DEF_ADDR BMA180_ADDRESS_SDO_LOW
#define FIMU_ITG3200_DEF_ADDR ITG3200_ADDR_AD0_LOW // AD0 connected to GND
// HMC5843 address is fixed so don't bother to define it


#define twoKpDef  (2.0f * 0.5f) // 2 * proportional gain
#define twoKiDef  (2.0f * 0.1f) // 2 * integral gain

#ifndef cbi
#define cbi(sfr, bit) (_SFR_BYTE(sfr) &= ~_BV(bit))
#endif

class FreeSixIMU
{
  public:
    FreeSixIMU();
    void init();
    void init(bool fastmode);
    void init(int acc_addr, int gyro_addr, bool fastmode);
    void getRawValues(int * raw_values);
    void getValues(float * values);
    void getQ(float * q);
    void getEuler(float * angles);
    void getYawPitchRoll(float * ypr);
    void getAngles(float * angles);


  ADXL345 acc;
    ITG3200 gyro;

    int* raw_acc, raw_gyro, raw_magn;

  private:
    void AHRSupdate(float gx, float gy, float gz, float ax, float ay, float az, float
     mx, float my, float mz);
    //float q0, q1, q2, q3; // quaternion elements representing the estimated
    orientation
    float iq0, iq1, iq2, iq3;
    float exInt, eyInt, ezInt;  // scaled integral error
    volatile float twoKp;      // 2 * proportional gain (Kp)
    volatile float twoKi;      // 2 * integral gain (Ki)
```

```
    volatile float q0, q1, q2, q3; // quaternion of sensor frame relative to
    auxiliary frame
    volatile float integralFBx,  integralFBy, integralFBz;
    unsigned long lastUpdate, now; // sample period expressed in milliseconds
    float sampleFreq; // half the sample period expressed in seconds
    int startLoopTime;
};

float invSqrt(float number);

#endif // FreeSixIMU_h
```

../Quadcopter/Quadcopter/libraries/FreeSixIMU/FreeSixIMU.h

```
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    c) You must license the entire work, as a whole, under this
    License to anyone who comes into possession of a copy.  This
    License will therefore apply, along with any applicable section 7
    additional terms, to the whole of the work, and all its parts,
    regardless of how they are packaged.  This License gives no
    permission to license the work in any other way, but it does not
    invalidate such permission if you have separately received it.

    d) If the work has interactive user interfaces, each must display
    Appropriate Legal Notices; however, if the Program has interactive
    interfaces that do not display Appropriate Legal Notices, your
    work need not make them do so.

  A compilation of a covered work with other separate and independent
works, which are not by their nature extensions of the covered work,
and which are not combined with it such as to form a larger program,
in or on a volume of a storage or distribution medium, is called an
"aggregate" if the compilation and its resulting copyright are not
used to limit the access or legal rights of the compilation's users
beyond what the individual works permit.  Inclusion of a covered work
in an aggregate does not cause this License to apply to the other
parts of the aggregate.

  6. Conveying Non-Source Forms.

  You may convey a covered work in object code form under the terms
of sections 4 and 5, provided that you also convey the
machine-readable Corresponding Source under the terms of this License,
in one of these ways:

    a) Convey the object code in, or embodied in, a physical product
    (including a physical distribution medium), accompanied by the
    Corresponding Source fixed on a durable physical medium
    customarily used for software interchange.

    b) Convey the object code in, or embodied in, a physical product
    (including a physical distribution medium), accompanied by a
    written offer, valid for at least three years and valid for as
    long as you offer spare parts or customer support for that product
    model, to give anyone who possesses the object code either (1) a
    copy of the Corresponding Source for all the software in the
    product that is covered by this License, on a durable physical
    medium customarily used for software interchange, for a price no
    more than your reasonable cost of physically performing this
    conveying of source, or (2) access to copy the
    Corresponding Source from a network server at no charge.

    c) Convey individual copies of the object code with a copy of the
    written offer to provide the Corresponding Source.  This
    alternative is allowed only occasionally and noncommercially, and
    only if you received the object code with such an offer, in accord
    with subsection 6b.

    d) Convey the object code by offering access from a designated
    place (gratis or for a charge), and offer equivalent access to the
    Corresponding Source in the same way through the same place at no
    further charge.  You need not require recipients to copy the
    Corresponding Source along with the object code.  If the place to
    copy the object code is a network server, the Corresponding Source
    may be on a different server (operated by you or a third party)
    that supports equivalent copying facilities, provided you maintain
    clear directions next to the object code saying where to find the
    Corresponding Source.  Regardless of what server hosts the
    Corresponding Source, you remain obligated to ensure that it is
    available for as long as needed to satisfy these requirements.

    e) Convey the object code using peer-to-peer transmission, provided
    you inform other peers where the object code and Corresponding
    Source of the work are being offered to the general public at no
```

charge under subsection 6d.

A separable portion of the object code, whose source code is excluded from the Corresponding Source as a System Library, need not be included in conveying the object code work.

A "User Product" is either (1) a "consumer product", which means any tangible personal property which is normally used for personal, family, or household purposes, or (2) anything designed or sold for incorporation into a dwelling. In determining whether a product is a consumer product, doubtful cases shall be resolved in favor of coverage. For a particular product received by a particular user, "normally used" refers to a typical or common use of that class of product, regardless of the status of the particular user or of the way in which the particular user actually uses, or expects or is expected to use, the product. A product is a consumer product regardless of whether the product has substantial commercial, industrial or non-consumer uses, unless such uses represent the only significant mode of use of the product.

"Installation Information" for a User Product means any methods, procedures, authorization keys, or other information required to install and execute modified versions of a covered work in that User Product from a modified version of its Corresponding Source. The information must suffice to ensure that the continued functioning of the modified object code is in no case prevented or interfered with solely because modification has been made.

If you convey an object code work under this section in, or with, or specifically for use in, a User Product, and the conveying occurs as part of a transaction in which the right of possession and use of the User Product is transferred to the recipient in perpetuity or for a fixed term (regardless of how the transaction is characterized), the Corresponding Source conveyed under this section must be accompanied by the Installation Information. But this requirement does not apply if neither you nor any third party retains the ability to install modified object code on the User Product (for example, the work has been installed in ROM).

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