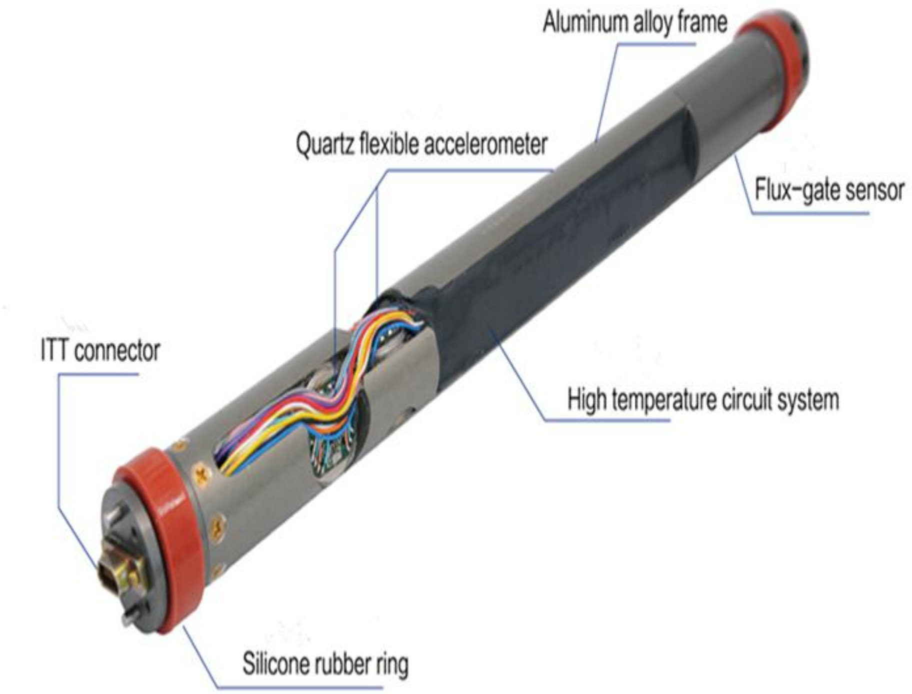
DS750BT

High temperature directional sensor
Operating manual



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1.INTRODUCTION

This manual introduces the DS750BT high temperature directional sensor dimensions, performance parameters, software parameters configuration method and communication protocol.

2.DEVICE DESCRIPTION

The DS750BT high temperature directional sensor consists of a 3-axis fluxgat meter and a 3-axis accelerometer.The inclination angle and the angle of the gravity tool surface were measured by the 3-axis accelerometer. the sensor azimuth angle was measured by the three-axis flux-gate. The measurement accuracy of the inclination angle and angle of the gravity tool surface was ±0.1°, and the measurement accuracy of the azimuth angle was ±0.3°.In addition, the sensor can also measure the total adding speed, the total magnetic field strength, magnetic tool surface angle, geomagnetic inclination angle and temperature.
DS750 uses ASCII description instruction language to communicate through two-way TTL interface.The DS750 software includes an automatic send data mode.

3.PARAMETERS PERFORMANCE

Measurement Accuracy	
Inclination angle	±0.1°
tool face angle	±0.2°@INC=90°
Azimuth angle	±0.3°@ INC=90° ±1° @ INC=10° ±2° @ INC=5°
Electrical Performance	
Input voltage range	+10V~+36V
Input current	＜75mA@+15V；
Digital interface	UART/RS232 optional
Baud rate	1200~115200
Communication protocol	ASCII or Binary
Working Environment	
Working environment range	0~150℃
Storage temperature range	-40~+160℃
Shock	1000g，1ms half sine
Vibration	20g

4.BOUNDARY DIMENSION

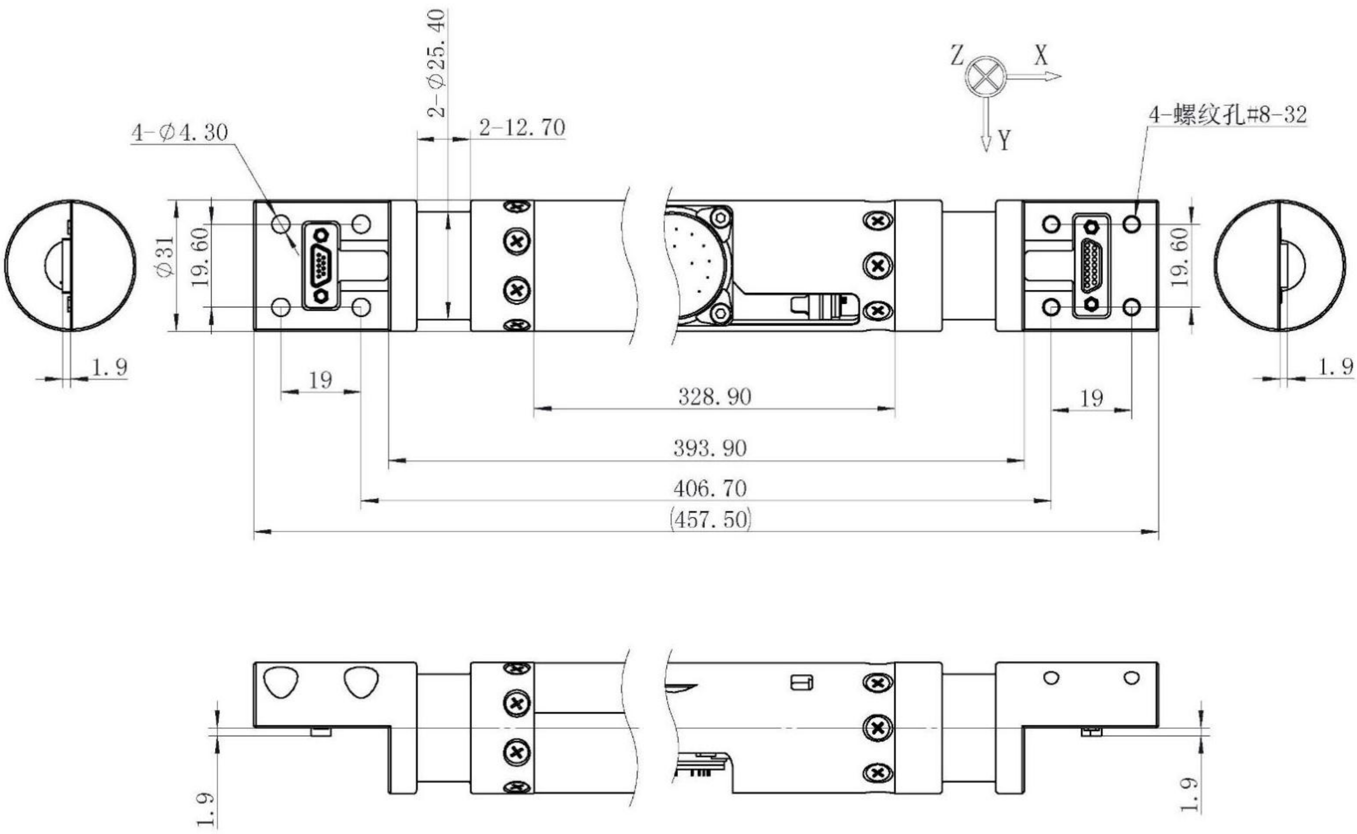

Chart 1 DS750BT outlook boundary dimension

5. ELECTRICAL INTERFACE

The DS750 uses an MDM connector, and the functions of the connector pinouts are shown in **chart 2**.The input voltage range of DS750 is +10V~+36V, which adopts UART or RS232 serial communication interface, in which UART interface is compatible with TTL and CMOS level.The default is 9600 baud rate, with a stop bit and no synchronization bit. The user can change the baud rate by setting the parameters in the sensor EEROM.The DS750 can use two communication protocols:

1) the ASCII

The ASCII protocol is based on sending ASCII characters (instructions) to the DS750 to get data.In response to instructions, data is sent as ASCII data streams including carriage returns and line feeds, easily displayed on a computer display terminal (the UART interface sensor is connected to the computer via a TTL to RS232 converter).

2)Binary

The binary protocol is used for high-speed data transfer between MCUS.In this mode, one byte is sent to request the data, and the DS750 responds with a multi-byte packet containing the required data, data header, checksum, and data tail.

DS750 MDM connector pinouts definition as shown in **chart 2**, which has a connector between the up and down through line, some through wire twisted together by sensors, avoid penetration influence on magnetic flux gate line current, you need to use the twisted together line as the power cord, and through the current should not be too large, up and down the connector of the power input and output power line inside the sensor directly connected.

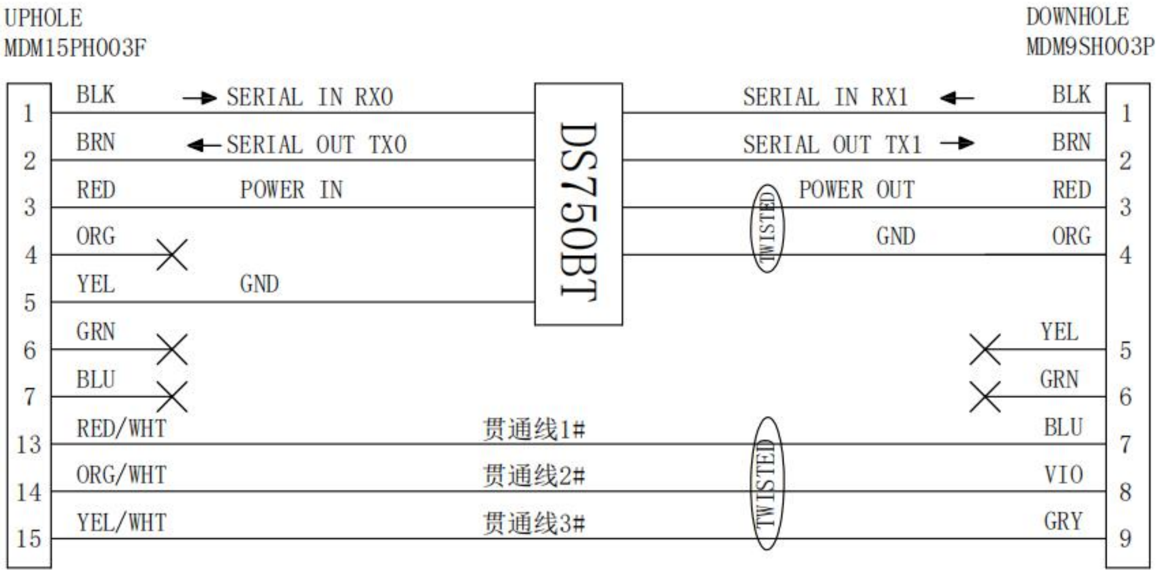

Chart 2 DS750BT Pin out definition

6. Computer interface

The communication interface of DS750 sensor is UART (TTL/CMOS compatible) serial interface.In the standard configuration, data is transmitted to the DS750 via the foot RX terminal and output from the DS750 via the foot TX.The default baud rate value is 9600, with a stop bit and no parity bit.

In order to communicate with an external PC, the TTL interface of the DS750 must be converted to an RS332 interface, suitable for all PC serial interfaces.

6.1 DS750 binary constants and how to set them

The DS750 running mode is controlled by internal binary constants.

Table 1 description of binary constants

Binary constants	Numerical Value	Description
01	5a	Enable automatic send mode
02	02	Sensor component
	04	Output of the angle
08	10	Automatically send ASCII format data after power on
09	Baud rate lock, must be 5a to change the baud rate other than 9600	
10	Setting baud rate .See table 2.	
20	Setting output filter	

In order to change the sensor's binary constants, instructions must first be sent:

0L##

When this instruction is sent to DS750, the following reply will be received:

enabled

Change binary constant 02=04, send instruction:

0WC02b04##

When receiving this instruction, DS750 will reply:

done

Read binary constant 02, send instruction:

0SC02b##

When received, the DS750BT reverts to the value of the binary constant 02.The above instructions are not case sensitive.

6.1.1 Baud rate setting

The default value of DS750BT communication baud rate is 9600, which can be set by the following steps:

1. Set the binary constant 10 according to **table 2**;
2. Set binary constant 09 to 0x5a;
3. Power back on

For example, the following instruction description sets the baud rate to 115200

0 1 # #

0 wc10b07 # #

0 1 # #

0 wc09b5a # #

When the binary constant 09 is set to any value (except 0x5a), the sensor baud rate is 9600.

Table 2 baud rate Settings

Baud rate	The value of the binary constant 10
9600	0x30
19200	0x05
38400	0x06
115200	0x07

6.1.2 Filter Settings

In the strong vibration environment, DS750BT makes the output data more stable by digital low-pass filtering.The DS750BT uses digital low-pass filter to filter the output data, and the -3db cut-off frequency can be set by the following instructions:

Reads the current cut-off frequency value:

0SC20b##

Setting cut-off frequency:

0L ##

0WC20bxx##

xx=Integer value 01（0.5Hz）、02（1H）、03（2Hz）、04（4H）、05（5Hz）；

Table 3 illustrates the response time of the sensor from 0g to 1g and 0Gauss to 0.5gauss. When the response speed meets the service requirements, try to select the low cut-off frequency, the default cut-off frequency is 0.5Hz.

Table 3

The value of binary constant 20	f_{-3dB}（Hz）	Time to steady state value ±0.1%(s)
1	0.5	9
2	1	7
3	2	6
4	4	4
5	5	3

6.1.3 TOOL SURFACE ANGLE AND INSTALLATION ERROR CORRECTION

The tool surface angle error and installation coaxiality error can be corrected by the client software.

6.2 SINGLE-PACKET SENDING CONFIGURATION

6.2.1 UPLOAD MODE OF COMPONENT DATA

Upon receipt of 0x80, the DS750 immediately responds by sending binary sensor component packets (double-byte data, high-byte before) :

< 80 > < 0601 > < 02 > < HX > < GX > < HY > < GY > < HZ > < GZ > < T > < V > < CRC > < 0604 >

<80> instruction return (that is, the return value of host sending instruction 0x80);

<0601> component data upload synchronization header, if 0x06 appears in the data or CRC check code, 0x06 will be sent again after 0x06;

<02> component data upload mode;

<HX> is a double byte (x axis magnetic sensor data times 10000);

<GX> is a double byte (x axis acceleration sensor data times 10000);

<HY><GY><HZ><GZ>;same as the component format above;

<T> is a double byte (temperature sensor data multiplied by 100);

<V> is a double byte (input voltage data multiplied by 100);

<CRC> CRC check bit;

<0604> sync tail;

CRC:

The data packages structure as below:

80 06 01 02 dataByte [0] ~ dataByte [15] CrcByte[0] CrcByte [1] 06 04

The sample of the program:

```
unsigned short crc=0; ( unsigned short is 16bits data format )
unsigned short crc16tab[256]={
    0x0000, 0xc0c1, 0xc181, 0x0140, 0xc301, 0x03c0, 0x0280, 0xc241,
    0xc601, 0x06c0, 0x0780, 0xc741, 0x0500, 0xc5c1, 0xc481, 0x0440,
    0xcc01, 0x0cc0, 0x0d80, 0xcd41, 0x0f00, 0xcfc1, 0xce81, 0x0e40,
    0x0a00, 0xcac1, 0xcb81, 0x0b40, 0xc901, 0x09c0, 0x0880, 0xc841,
    0xd801, 0x18c0, 0x1980, 0xd941, 0x1b00, 0xdbc1, 0xda81, 0x1a40,
    0x1e00, 0xdec1, 0xdf81, 0x1f40, 0xdd01, 0x1dc0, 0x1c80, 0xdc41,
    0x1400, 0xd4c1, 0xd581, 0x1540, 0xd701, 0x17c0, 0x1680, 0xd641,
    0xd201, 0x12c0, 0x1380, 0xd341, 0x1100, 0xd1c1, 0xd081, 0x1040,
    0xf001, 0x30c0, 0x3180, 0xf141, 0x3300, 0xf3c1, 0xf281, 0x3240,
    0x3600, 0xf6c1, 0xf781, 0x3740, 0xf501, 0x35c0, 0x3480, 0xf441,
    0x3c00, 0xfcc1, 0xfd81, 0x3d40, 0xff01, 0x3fc0, 0x3e80, 0xfe41,
    0xfa01, 0x3ac0, 0x3b80, 0xfb41, 0x3900, 0xf9c1, 0xf881, 0x3840,
    0x2800, 0xe8c1, 0xe981, 0x2940, 0xeb01, 0x2bc0, 0x2a80, 0xea41,
    0xee01, 0x2ec0, 0x2f80, 0xef41, 0x2d00, 0xedc1, 0xec81, 0x2c40,
    0xe401, 0x24c0, 0x2580, 0xe541, 0x2700, 0xe7c1, 0xe681, 0x2640,
    0x2200, 0xe2c1, 0xe381, 0x2340, 0xe101, 0x21c0, 0x2080, 0xe041,
    0xa001, 0x60c0, 0x6180, 0xa141, 0x6300, 0xa3c1, 0xa281, 0x6240,
    0x6600, 0xa6c1, 0xa781, 0x6740, 0xa501, 0x65c0, 0x6480, 0xa441,
    0x6c00, 0xacc1, 0xad81, 0x6d40, 0xaf01, 0x6fc0, 0x6e80, 0xae41,
    0xaa01, 0x6ac0, 0x6b80, 0xab41, 0x6900, 0xa9c1, 0xa881, 0x6840,
    0x7800, 0xb8c1, 0xb981, 0x7940, 0xbb01, 0x7bc0, 0x7a80, 0xba41,
    0xbe01, 0x7ec0, 0x7f80, 0xbf41, 0x7d00, 0xbdc1, 0xbc81, 0x7c40,
    0xb401, 0x74c0, 0x7580, 0xb541, 0x7700, 0xb7c1, 0xb681, 0x7640,
    0x7200, 0xb2c1, 0xb381, 0x7340, 0xb101, 0x71c0, 0x7080, 0xb041,
    0x5000, 0x90c1, 0x9181, 0x5140, 0x9301, 0x53c0, 0x5280, 0x9241,
    0x9601, 0x56c0, 0x5780, 0x9741, 0x5500, 0x95c1, 0x9481, 0x5440,
    0x9c01, 0x5cc0, 0x5d80, 0x9d41, 0x5f00, 0x9fc1, 0x9e81, 0x5e40,
    0x5a00, 0x9ac1, 0x9b81, 0x5b40, 0x9901, 0x59c0, 0x5880, 0x9841,
    0x8801, 0x48c0, 0x4980, 0x8941, 0x4b00, 0x8bc1, 0x8a81, 0x4a40,
    0x4e00, 0x8ec1, 0x8f81, 0x4f40, 0x8d01, 0x4dc0, 0x4c80, 0x8c41,
    0x4400, 0x84c1, 0x8581, 0x4540, 0x8701, 0x47c0, 0x4680, 0x8641,
    0x8201, 0x42c0, 0x4380, 0x8341, 0x4100, 0x81c1, 0x8081, 0x4040
};
//CRC generate
```

```
    void CalcCRC16(unsigned char   c)
    {
        crc = ((unsigned short)((crc >> 8) ^ crc16tab[ (crc ^ c) & 0xFF ]));
 }

    void   CheckCrc( void )
 {
    crc = 0;
              CalcCRC16(0x01);
              CalcCRC16(0x02);
       for (int i=0;i<16;i++)// all data number
       {
              CalcCRC16(dataByte [i]);
       }
       if (CrcByte [0] ==    (unsigned char)(crc>>8) && CrcByte [1] == (unsigned
char)(crc))
       {
        CrcCheckPass;
       }
       else
       {
        CrcCheckFail;
       }
}
```

6.2.2 UPLOADING MODE OF ANGLE DATA

Upon receipt of 0x83, the DS750BT responds immediately by sending the binary sensor component packet (double byte data, high byte in front).

< 83 > < 0602 > < 3 > < TF > < MS > < INC > < BT > < AZ > < GT > < T > < V > < CRC > < 0604 >

<83> instruction return (that is, the return value of host sending instruction 0x83);

<0602> calculates the data upload synchronization header. If 0x06 appears in the data or CRC check code, it will send 0x06 again after 0x06.

<03> calculation data upload mode;

<TF> is a double byte (gravity tool surface Angle calculation data multiplied by 10);

<MS> is a double byte (magnetic tool surface Angle calculation data multiplied by 10);

<INC> is a double byte (inclination calculation times 10);

<BT> is double byte (calculated data of total magnetic field strength multiplied by 10000);

<AZ> is a double byte (azimuth computed data times 10);

<GT> is a double byte (the total speed calculation is multiplied by 10000);

<Temp> is a double byte (temperature sensor data multiplied by 100);

<Voltage> is a double byte (Voltage input times 100);

<CRC> invalid fill, standby;

<0604> sync tail;

CRC:

Data package structure as below:

83 06 02 03 dataByte [0] ~ dataByte [15] CrcByte[0] CrcByte [1] 06 04

The sample of the program:

```
unsigned short crc=0; ( unsigned short is 16bits data format )
unsigned short crc16tab[256]={
    0x0000, 0xc0c1, 0xc181, 0x0140, 0xc301, 0x03c0, 0x0280, 0xc241,
    0xc601, 0x06c0, 0x0780, 0xc741, 0x0500, 0xc5c1, 0xc481, 0x0440,
    0xcc01, 0x0cc0, 0x0d80, 0xcd41, 0x0f00, 0xcfc1, 0xce81, 0x0e40,
    0x0a00, 0xcac1, 0xcb81, 0x0b40, 0xc901, 0x09c0, 0x0880, 0xc841,
    0xd801, 0x18c0, 0x1980, 0xd941, 0x1b00, 0xdbc1, 0xda81, 0x1a40,
    0x1e00, 0xdec1, 0xdf81, 0x1f40, 0xdd01, 0x1dc0, 0x1c80, 0xdc41,
    0x1400, 0xd4c1, 0xd581, 0x1540, 0xd701, 0x17c0, 0x1680, 0xd641,
    0xd201, 0x12c0, 0x1380, 0xd341, 0x1100, 0xd1c1, 0xd081, 0x1040,
    0xf001, 0x30c0, 0x3180, 0xf141, 0x3300, 0xf3c1, 0xf281, 0x3240,
    0x3600, 0xf6c1, 0xf781, 0x3740, 0xf501, 0x35c0, 0x3480, 0xf441,
    0x3c00, 0xfcc1, 0xfd81, 0x3d40, 0xff01, 0x3fc0, 0x3e80, 0xfe41,
    0xfa01, 0x3ac0, 0x3b80, 0xfb41, 0x3900, 0xf9c1, 0xf881, 0x3840,
    0x2800, 0xe8c1, 0xe981, 0x2940, 0xeb01, 0x2bc0, 0x2a80, 0xea41,
    0xee01, 0x2ec0, 0x2f80, 0xef41, 0x2d00, 0xedc1, 0xec81, 0x2c40,
    0xe401, 0x24c0, 0x2580, 0xe541, 0x2700, 0xe7c1, 0xe681, 0x2640,
    0x2200, 0xe2c1, 0xe381, 0x2340, 0xe101, 0x21c0, 0x2080, 0xe041,
    0xa001, 0x60c0, 0x6180, 0xa141, 0x6300, 0xa3c1, 0xa281, 0x6240,
    0x6600, 0xa6c1, 0xa781, 0x6740, 0xa501, 0x65c0, 0x6480, 0xa441,
    0x6c00, 0xacc1, 0xad81, 0x6d40, 0xaf01, 0x6fc0, 0x6e80, 0xae41,
    0xaa01, 0x6ac0, 0x6b80, 0xab41, 0x6900, 0xa9c1, 0xa881, 0x6840,
    0x7800, 0xb8c1, 0xb981, 0x7940, 0xbb01, 0x7bc0, 0x7a80, 0xba41,
    0xbe01, 0x7ec0, 0x7f80, 0xbf41, 0x7d00, 0xbdc1, 0xbc81, 0x7c40,
    0xb401, 0x74c0, 0x7580, 0xb541, 0x7700, 0xb7c1, 0xb681, 0x7640,
    0x7200, 0xb2c1, 0xb381, 0x7340, 0xb101, 0x71c0, 0x7080, 0xb041,
```

```
        0x5000, 0x90c1, 0x9181, 0x5140, 0x9301, 0x53c0, 0x5280, 0x9241,
        0x9601, 0x56c0, 0x5780, 0x9741, 0x5500, 0x95c1, 0x9481, 0x5440,
        0x9c01, 0x5cc0, 0x5d80, 0x9d41, 0x5f00, 0x9fc1, 0x9e81, 0x5e40,
        0x5a00, 0x9ac1, 0x9b81, 0x5b40, 0x9901, 0x59c0, 0x5880, 0x9841,
        0x8801, 0x48c0, 0x4980, 0x8941, 0x4b00, 0x8bc1, 0x8a81, 0x4a40,
        0x4e00, 0x8ec1, 0x8f81, 0x4f40, 0x8d01, 0x4dc0, 0x4c80, 0x8c41,
        0x4400, 0x84c1, 0x8581, 0x4540, 0x8701, 0x47c0, 0x4680, 0x8641,
        0x8201, 0x42c0, 0x4380, 0x8341, 0x4100, 0x81c1, 0x8081, 0x4040
    };
    //CRC generate
    void CalcCRC16(unsigned char   c)
    {
        crc = ((unsigned short)((crc >> 8) ^ crc16tab[ (crc ^ c) & 0xFF ]));
  }

    void   CheckCrc( void )
  {
    crc = 0;
            CalcCRC16(0x02);
            CalcCRC16(0x03);
       for (int i=0;i<16;i++)// all data number
       {
            CalcCRC16(dataByte [i]);
       }
       if (CrcByte [0] ==    (unsigned char)(crc>>8) && CrcByte [1] == (unsigned
char)(crc))
       {
        CrcCheckPass;
       }
       else
       {
        CrcCheckFail;
       }
}
```

7. DEFINITION OF SENSOR COORDINATE SYSTEM AND ANGLE

The X,Y and Z directions of the DS750BT sensor are shown in chart 1.If the X-axis arrow points to the north of the northern hemisphere, the output voltage of the X-axis fluxgate is positive.If the X-axis arrow points down, the X-axis accelerometer output is positive.

The following is the formula equation for calculating the angle of DS750BT, where

Gx accelerometer X axis output;

Gy accelerometer Y axis output;

Gz accelerometer Y axis output;

Hx fluxgate X-axis output;

Hy fluxgate Y axis output;

Hz fluxgate Z axis output.

7.1 CALCULATION OF SURFACE ANGLE OF GRAVITY TOOL AND MAGNETIC TOOL

The angle of the surface of the gravity tool is the angle from which the output of the Y-axis accelerometer is 0 and the output of the Z-axis accelerometer is clockwise to the current position (seen from the opposite direction of the X-axis).The Angle theta of the gravity tool is calculated according to the following formula ($0 \leq \theta < 2$)

$$\sin\theta = \frac{Gy}{\sqrt{Gy^2 + Gz^2}}$$

$$\cos\theta = \frac{Gz}{\sqrt{Gy^2 + Gz^2}}$$

$$\tan\theta = \frac{Gy}{Gz}$$

When Gy =0 and Gz> 0,θ =0;When Gy = 0 and Gz< 0,θ=π .When the X-axis is close to the vertical (inclination Angle < 5°), the components Gy and Gz become smaller, resulting in the difference in accuracy.In this case, magnetic tool Angle m is often used to determine the DS750 azimuth.The surface Angle of the magnetic tool is 0 from the Y-axis fluxgate output, and the z-axis fluxgate output is clockwise from the current position to the Angle of rotation (seen from the opposite direction of the X-axis).

The surface Angle m of the magnetic tool is calculated according to the following formula ($0 \leq \theta < 2$)

$$\sin\theta m = \frac{Hy}{\sqrt{Hy^2 + Hz^2}}$$

$$\cos\theta m = \frac{Hz}{\sqrt{Hy^2 + Hz^2}}$$

$$\tan\theta = \frac{Hy}{Hz}$$

7.2 CALCULATION OF INCLINATION ANGLE

The inclination angle is the angle between the X-axis and the vertical direction. When the X-axis goes straight down, the inclination angle is equal to 0; when the X-axis goes straight down, the dip Angle is π /2; when the X-axis goes straight up, the inclination angle is equal to π.

The inclination Angle is calculated according to the following formula (0≤ ε≤)

$$\sin\varepsilon = \frac{\sqrt{Gy^2 + Gz^2}}{g}$$

$$\cos\varepsilon = \frac{Gx}{g}$$

$$\tan\varepsilon = \frac{\sqrt{Gy^2 + Gz^2}}{Gx}$$

$$g=\sqrt{Gx^2 + Gy^2 + Gz^2}$$

7.3 AZIMUTH CALCULATION

The azimuth Angle is the rotation Angle from the magnetic north direction (clockwise from above) to the projection of the sensor X-axis on the horizontal surface. When the X-axis of DS750BT points to the magnetic north, the azimuth Angle is 0; when it points to the east, the azimuth Angle is PI /2. The azimuth Angle is calculated according to the following formula (0≤ ε≤2).

$$\tan\varphi = \frac{(HzGy - HyGz)g}{Hx(Gy^2 + Gz^2) - HyGxGy - HzGxGz}$$

$$g=\sqrt{Gx^2 + Gy^2 + Gz^2}$$