LEC315
3D Digital
Compass Module

Introduction

LEC315 is a high-precision 3D digital compass, using the patent technology of 3D compensation, making that product can provide an accurate heading data even under the angle of ±40 °.

LEC315 has small volume, low power consumption,and it's more suitable for the volume sensitive measurement system, used widely in many fields, like antenna stabilization, vehicle navigation, attitude reference etc.

LEC315

Features

1. Accuracy: 2°
2. High cost-effective
3. RS232/RS485/TTL Optional; Modbus Optional
4. Size: L33mm*W27mm*H5mm (Customizable)
5. Measuring Range: ±30° degree
6. Hard and soft magnetic compensation
7. Low working current: < 40mA

Applications

1. Survey equipment
2. Robot
3. Laser Measurement
4. Drilling exploration
5. Driving directions
6. Vehicle detection
7. Satellite positioning
8. Underwater robot navigation

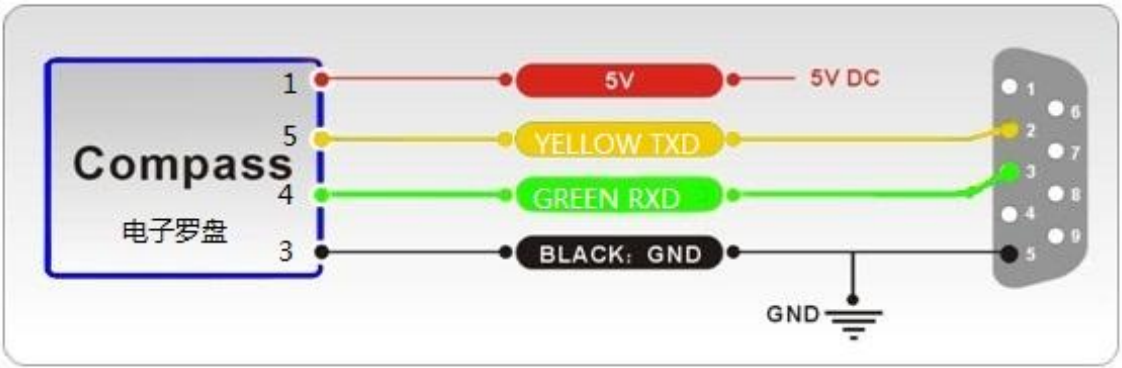
Specifications

Performance Specifications			
Parameters		Typical	Units
Heading accuracy		2°	Deg RMS
Resolution		0.1°	
Tilt Specifications			
Parameters		Typical	Units
Pitch Accuracy		0.2°	Deg RMS
Roll Accuracy		0.2°	Deg RMS
Tilt Range		±30°	Deg
Tilt Resolution		< 0.01°	Deg RMS
Calibration			
Parameters		Typical	Units
Hard Iron Calibration		Yes	
Soft Iron Calibration		Yes	
User Calibration		Yes	
Mechanical Specifications			
Parameters		Typical	Units
Dimensions (L x W x H)		55x37x24	mm
Weight		85	g
Mounting Options		RS232/RS485/TTL Optional; Modbus Optional	
I/O Specifications			
Parameters		Typical	Units
Latency from Power-On		< 50	mSec
Maximum Sample Rate		50	samples/sec
Communication Rate		2400 to 115200	Baud/S
Output Formats		Binary Protocol	
Power Specifications			
Parameters		Typical	Units
Supply Voltage		5V	VDC
Current (Continuous Output)	Max	40	mA
	TYP	30	
Environmental Specifications			
Parameters		Typical	Units
Operating Temperature		− 40 to 85	°C
Storage Temperature		− 40 to 125	°C
Shock		2000	g

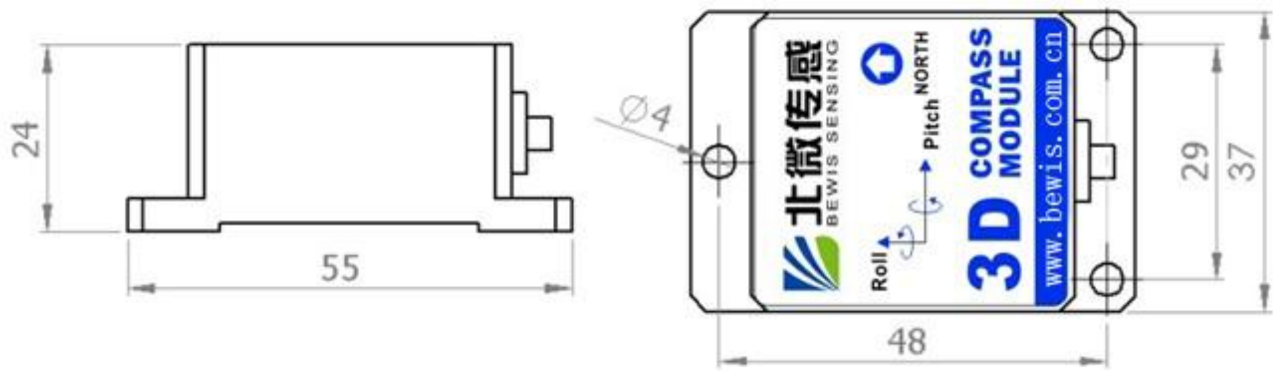
Electrical connection

Line Function	RED	BLUE	BLACK	GREEN	YELLOW

	1	2	3	4	5
	DC 5V	NC	GND	RXD（B、D-）	TXD（A、D+）



Dimensions



Size：L55 x W37 x H24 (mm)

Calibration

The electronic compass has been calibrated in the factory. When used in the place where the magnetic field environment influence is small, there is no need to make environment calibration, can be used directly. The actual use process, suggest make calibration.

Azimuth calibration steps:

Method one -- a planar calibration:

1. The product should access to system, the products should be placed in the level state;
2. Open the serial debugging tools, sending 77 00 04 11 15;
3. Let the product (in the plane of the pitch angle and roll angle within + - 5 °) around the z axis rotate (the z axis means vertical direction), 2-3 turns, with slow rotation process and nearly uniform rotation as much as possible, rotation of a whole ring's time controlled between 10 seconds to 15 seconds;

4. Let the compass x or y axis to rotate, the process can be used in a slow rotation and nearly uniform rotation, around every 2-3 ring rotation for each axis, rotating a whole ring’s time for about 15 seconds;
5. Complete the calibration, sending 77 00 04 12 16 save calibration.

Method two -- polyhedral calibration:
1. To fix electronic compass in the working environment, when calibration don't carry magnetic items like keys, cell phone, etc. as far as possible.
2. Place the compass in the state level (plus or minus 5 degrees).
3. The calibration in hexadecimal format to send the following command: 77 00 04 08 0C, the return value is 77 05 00 00 88 8D.
4. The products placed in the level of state, heads correct (pitch, roll within plus or minus zero to 5 degrees), rotate at a constant speed for one round, once more than 10 seconds;
5. Products placed in the horizontal state, installation up (pitch within plus or minus0 to five degrees, roll is within 180 plus or minus 5 degrees), rotate at a constant speed for one round, once more than about 10 seconds;
6. Products placed in a vertical state, shell smooth side down (pitch within plus or minus 0 to 5 degrees, roll is within 90 plus or minus 5 degrees).
7. Products placed in a vertical state, shell’s another smooth side down (pitch within plus or minus0to five degrees, roll is within 90 plus or minus 5 degrees), rotate at a constant speed for one round, once more than about 10 seconds.
Above step 4.5.6.7 can be exchanged;
8. After the four plane rotation, sending hex command 77 00 04 09 0D, save calibration, return 77 05 00 89 XX YY. (XX on behalf of the calibration error coefficient, the value smaller means better, less than 10 is ideal, FF said calibration failure. YY is the checksum for the command.)
9. The calibration is complete.

(Below are old calibration method, just can have a reference, better to use new calibration above)

All compasses have good performance in a controlled environment, where the ambient magnetic field consists of only the earth’s field. It is unnecessary to make calibration in clear environment. However, in most applications, an electronic compass will be mounted in the host such as a vehicle that can contain large local magnetic sources: ferrous metal chassis, transformer cores, electrical currents, and permanent magnets in motors. By executing the user calibration procedure, SEC385 can learn the major sources of these local magnetic anomalies and subsequently cancel out their effects when measuring the earth’s magnetic field for calculating compass heading.
The purpose of calibration procedure for SEC385 is measuring the static 3D magnetic field vector generated by its host system on which the unit be mounted. This vector is subsequently subtracted from run-time field measurement to obtain the true earth’s field vector. SEC385 is a tri-axial magnetometer/tri-axial inclinometer system and can compensate the magnetic and tilt distortion in all orientations in the whole application tilt range. As mentioned above, compass must measure the local field vector generated by the host system in order to accurately calibrate. When SEC385 be fixed in host system, its local field vector does not change as the host system’s attitude changes, which guarantee that SEC385 can accurately compensate distortions in all pitch and roll.
MEMS provide 5 user calibration procedures for different applications. In most application environments, **AUTO 12 positions calibration method** is recommended. The calibration operator should not carry cell phone, key, and other metal or electronic devices that will distort earth’s field.

1. Auto 12-positions calibration
Rotate the compass to the region nearby the specified attitudes as the following table (strictly alignment is not necessary), then the compass will record the magnetic field automatically. At most 12 samples will be collected.

Serial NO.	Heading(°)	Pitch(°)	Roll(°)
1	0	-5~+5	30~40
2	90	-5~+5	-30~-40
3	180	-5~+5	30~40
4	270	-5~+5	-30~-40
5	30	>+45	30~40
6	120	>+45	-30~-40
7	210	>+45	30~40
8	300	>+45	-30~-40
9	60	<-45	30~40
10	150	<-45	-30~-40
11	240	<-45	30~40
12	330	<-45	-30~-40

Calibration procedure:

1. Fix the compass in application environment, and then rotate the compass with the host system together when making calibration.
2. Send the following calibration command in hexadecimal format:
77 04 00 63 67
Or open the **MEMS compass assistant**, select auto **12-positionscalibration** in the page of magnetic calibration, and then click **start calibration** button (as shown in following diagram).
3. Rotate the compass to the specified attitudes as above-mentioned.
4. After gotten a sample successfully, the compass will return a command **77 04 00 66 +15 byte magnetic value + 1 byte effective num + 1 byte check sum. Effective num means the number that compasses get for calibration calculation.**
5. If quitting calibration is needed, send a stop calibration command **77 04 00 12 16** in hexadecimal format. Or open the **MEMS compass assistant,** and then click **stop calibration** button in the page of **magnetic calibration**.
6. If calibration is completed, please send **save calibration** command **77 04 00 09 0D** in hexadecimal format. If **save calibration** completed successfully, a hexadecimal command **77 09 00 89FitErrYY** (the detail is described in the following command list) will be returned. **Fit Err** means calibration error. The smaller the value is, the better the calibration effect. If **Fit Err** is more than 10, re-calibration is needed. **YY** is the checksum. If you use the **MEMS compass assistant**, the calibration error will be shown in the indicator (as shown in following diagram).

2. Manual calibration

Manual calibration is most suitable for users who have already known which pitch, roll or azimuth the compass will be used, and then rotate the compass to the known position to collect the calibration sample. For example, you have already known that the compass will be used nearby the roll equal to 0°, pitch equal to 30°.so you collect more calibration samples in this region and less samples in the others. Because you don't know the azimuth, so you collect samples in different azimuth evenly. After rotate the compass to a wanted position, manually send **collect calibration sample** command to collect a sample. You can collect enough samples (at least 12 samples are needed), and then the correction coefficient is calculated to compensate the interference magnetic field by collected samples.

Calibration procedure:

1. Fix the compass in application environment, and then rotate the compass with the host system together when making calibration.
2. Send the following calibration command in hexadecimal format:
77 04 00 65 69
Or open the **MEMS compass assistant**, select manual calibration in the page of magnetic calibration, and then click start calibration button
3. Rotate to the position you want, and then send **collect calibration** command **77 04 00 67 6B to collect a sample, or click collect calibration button in MEMS compass assistant.**
4. The other procedures are the same as above.

3. Auto all-position calibration

The principle of the auto all-position calibration is that the compass is rotated to all possible attitude, the pitch, roll and azimuth combinations will cover all attitudes. The compass will **collect suitable calibration** samples automatically. More samples, the better the performance. At most 96 samples can be collected. This method is the most accuracy theoretically in all attitudes.

Calibration procedure:

1. Fix the compass in application environment, and then rotate the compass with the host system together when making calibration.
2. Send the following calibration command in hexadecimal format:
77 04 00 08 0C
Or open the **MEMS compass assistant**, select **Auto all-position calibration** in the page of **magnetic calibration**, and then click start calibration button.
3. Rotate the compass around Z-axis (Z-axis is vertical to the ground plane) 2-3 circles. Try to change the speed. For example: speed up->speed down->speed up->speed down. It takes 10 to 15 seconds for a circle.
4. Rotate the compass around x-axis (east) and y-axis (north) 1-2 circles and keep the speed stable. it takes about 10 seconds for a circle.
5. Rotate the compass randomly. Keep the speed slow and stable. The rotating axis should not repeated, try to make the compass cover all attitudes.
6. The other procedures are the same as above.

4. Auto 12-postion small tilt calibration

This calibration is most suitable for the application when roll is small (<5°). Rotate the compass to the specified attitude. Then the compass will collect calibration samples automatically. At most 12 samples are collected.

Serial NO.	Heading(°)	Pitch(°)	Roll(°)
1	0	-5~+5	-5~+5
2	90	-5~+5	-5~+5
3	180	-5~+5	-5~+5
4	270	-5~+5	-5~+5
5	30	>+45	-5~+5
6	120	>+45	-5~+5
7	210	>+45	-5~+5
8	300	>+45	-5~+5
9	60	<-45	-5~+5
10	150	<-45	-5~+5
11	240	<-45	-5~+5
12	330	<-45	-5~+5

Calibration procedure:

1. Fix the compass in application environment, and then rotate the compass with the host system together when making calibration.
2. Send the following calibration command in hexadecimal format:
77 04 00 64 68
Or open the **MEMS compass assistant**, select **auto 12-positions small tilt calibration** in the page of **magnetic calibration**, and then click start calibration button (as shown in following diagram).
3. Rotate the compass to the specified attitudes as above-mentioned.
4. The other procedures are the same as above.

5. 2-D calibration

This method is only suitable for the horizontalplane application. Rotate the compass a circle at a constant speed in the horizontal plane. The compass will collect the suitable calibration samples. At most 12 samples will be collected.

Calibration procedure:

1. Fix the compass in the application environment horizontally, and then rotate the compass with the host system together when making calibration.
2. Send the following calibration command in hexadecimal format:

77 04 00 60 64

Or open the **MEMS compass assistant,** select 2D 12-positionscalibration in the page of **magnetic calibration**, and then click **start calibration** button (as shown in following diagram).

3. Rotate the compass a circle slowly in the horizontal plane.

4. The other procedures are the same as above.

MEMS® provides 5 calibration methods. Their characteristics are listed as follows. You can choose the most suitable one according to your actual using condition.

Calibration method	Most suitable application environment	Calibration effect	Limitation
Manual Calibration	Pitch and roll using range is already known, pick frequently-used attitude angle to make calibration	Good performance in the frequently-used attitude angle range	Unsuitable calibration attitude angle will make the final result severely worse
Auto all-positions calibration	Compass and host system is permitted to rotate in all attitude, this method can be used in complex magnetic environment	Good performance in all attitude and complex magnetic environment	Compass and host system is needed to rotate in all attitude
Auto 12-positions calibration	Compass and host system is permitted to rotate in specified attitude	Good performance in all attitudes. but worse than Auto all-positions calibration in complex magnetic environment	Pitch is needed to rotate bigger than 45°, roll is needed to rotate bigger than 30°
Auto 12-positions small tilt calibration	Roll is limited in 5°. But pitch can change in a big angle range	Good performance when roll is limited in 5°	Roll is limited in 5°, pitch is needed to rotate bigger than 45°
2D 12-positions calibration	Compass is permitted to rotate only in the horizontalplane . Roll and pitch are limited in 2°	Good performance when pitch and roll are limited in 5°	Roll and pitch are limited in 2°in application

Hard and Soft Iron Effects

Hard iron distortion is caused by permanent magnets and magnetized steel or iron objects close to the sensors. This type of distortion will remain constant and in a fixed location relative to the sensors for all heading orientations. Hard-iron distortion will add a constant magnitude field component along each axis of sensor output and can be easily compensated.

Soft iron distortion is the result of interactions between the Earth's magnetic field and any magnetic "soft" material close to the sensors. Soft materials have a high permeability. Soft material is easy to be magnetized and demagnetized, so a changing magnetic field exists. The SEC385 3-axis digital compass features soft-iron and hard-iron correction.

Communication Protocol

1. Data Frame Format：（8 data bits，1 stop bit，No parity check，default baud rate 9600）

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
77					

Data Format: Hexadecimal

Identifier：Fixed to 77

Data length：From data length to check sum（including check sum）length

Address code：Accumulating module address，Default :00

Date domain will be changed according to the content and length of command word

Check sum：Data length、Address code、Command word and data domain sum, No carry

2 Command Format

2.1 Read the value of pitch angle

Send the command：77 04 00 01 05

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain （0byte）	Check sum (1byte)
77h	04		01		

Command response：

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain （3byte）	Check sum (1byte)
77h	07		81	SXXX.YY	

Notes：Data domain is 3 bytes return to angle value, is compression BCD code,

S: sign-bit (0=Positive 1=Negative) XXX =3 bit integer value YY=decimal value

Others axis data are the same. For example: 102680 Means:-26.8°

2.2 Read the value of roll angle

Send the command：77 04 00 02 06

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain （0byte）	Check sum (1byte)
77h	04		02		

Command response：

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain （3byte）	Check sum (1byte)
77h			82	SXXX.YY	

2.3 Read the value of heading angle

Send the command：77 04 00 03 07

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain （0byte）	Check sum (1byte)
77h	04		03		

Command response：

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain （3byte）	Check sum (1byte)
77h	07		83	SXXX.YY	

2.4 Read the value of pitch, roll and heading angle

Send the command：77 04 00 04 08

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain （0byte）	Check sum (1byte)
77h	04		04		

Command response：

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (9byte) *	Check sum (1byte)
77h	0D		84	SXXX.YY	

* Data domain includes 9 bytes and represents Pitch, Roll and heading respectively. It is compression BCD code. Every 3 bytes is a group. For example, the command response is 77 0D 00 84 10 26 80 00 33 65 03 13 71 66, then pitch is 10 26 80, Roll is 00 33 65, Heading is 03 13 71. The format is SX XX YY, S: sign-bit (0=Positive 1=Negative) XXX =3 bit integer value YY=decimal value. So the return pitch, roll and heading is：-26.8°, 33.65° and 313.71°respectively.

2.5 Setting the value of magnetic declination angle

Send the command：77 06 00 06 02 08 16

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (2byte)	Check sum (1byte)
77h	06		06	SXXY*	

S: sign-bit (0=Positive 1=Negative) XX =2 bit integer value Y=decimal value

For example: 02 08 means +20.8°. The check sum of this command is 16 (hexadecimal). 16 = 06+00+06+02+08.If the magnetic declination angle is -3.2°,the command will be77 06 00 06 10 32 4E.4E = 06+00+06+10+32.

Command response：

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h	05		86	00 success FF failure	

2.6 Read the value of magnetic declination angle

Send the command：77 04 00 07 0B

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (0byte)	Check sum (1byte)
77h	04		07		

Command response：

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (2byte)	Check sum (1byte)
77h	06		87	SXXY	

2.7 Setting the baud rate

Send the command：77 05 00 0B 02 12

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h			0B		

Command response：

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h			8B	00 success FF Failure	

Baud rate: 00=2400 01=4800 02=9600 03=19200 04=115200

If you want to set the baud rate 19200, the command will be 77 05 00 0B 03 13, 13 = 05+ 00+ 0B+ 03.

Note: When finishing setting baud rate, the unit will give the response in the ordinal baud rate. Then the setting takes effect. Only when upper computer change to the corresponding baud rate, then the communication can be re-established.

2.8 Setting module address

Send the command：77 05 00 0F 01 15

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h	05	XX	0F	YY (module address)	

Command response：

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h	05	YY	8F	00 success FF failure	

2.9 Query module address

Send the command：77 04 00 1F 23

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h	04	00	1F		23

Command response：

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h	05	XX	1F	XX	

When sending the query command, the address in command is 0X00
The response is the hexadecimal module address.

2.10 Setting output mode

Send the command：77 05 00 0C 00 11

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (0byte)	Check sum (1byte)
77h	05		0C	0x00: questionandanswermode 0x01: 5Hz Data Rate 0x02: 10Hz Data Rate 0x03: 15Hz Data Rate 0x04: 25Hz Data Rate 0x05: 50Hz Data Rate	

Notes: The factory default mode is 00

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h	05		8C	00 success FF Failure	

2.11 Query acceleration of gravity G values

Send the command：77 04 00 54 58

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h	04		54		

Command response：

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h	0D		54	SXYYYY	

2.12 Read the value of magnetic field

Send the command：77 04 00 55 59

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h	04		55		

Command response：

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h	0D		55	SYYYYY	

2.13 Save setting

Send the command：77 04 00 0A 0E

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h	04		0A		

Command response：

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h	05		8A	00 success FF failure	

If “save setting” command is not sent, the changed setting will not take effect when power off.

2.14 Calibration clear

Send the command：77 04 00 10 14

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h	04		10		

Command response：

Identifier (1byte)	Date Length (1byte)	Address code (1byte)	Command word (1byte)	Date domain (1byte)	Check sum (1byte)
77h	05		90	00 success FF failure	