北京航空航天大学

实验报告

[redacted]

实验名称: Giant magne to resistance effect and its application 评 分: ______

Miu G. 9. Tian Good!

Abstract

The application of the GMR affect is revolutionary because it increases the capacity of computer hard drives hundreds of times. For a certain thickness, the magnetic moments of the two ferromagnetic layers on both sides change from parallel (under a strong magnetic field) to antiparallel (under a weak magnetic field). When the two magnetic moments are antiparallel, they correspond to the high resistance state, and when they are parallel, they correspod to the low resistance state. The difference between the two resistances is as high as 10%. They call this unprecedented phenomenon of huge changes in resistance a giant magnetoresistance.

The discovery of the giant magnetoresistance effect triggered a new revolution in electronic technology and information technology. The magnetic heads equipped in various digital electronic products have applied the giant magnetoresistance effect. Sensors made of giant magnetoresistance effect have between widely used in various measurement and control fields.

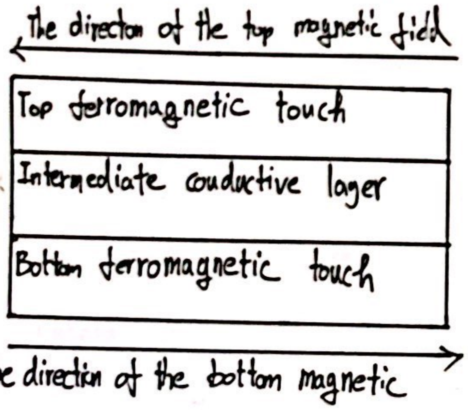
This experiment introduces the principle of multi-layer GMR effect, and through experiments to understand the structure, characteristics and application fields of several GMR sensors.

Introduction

The giant magnetoresistance effects shows that the electron spin has a very strong influence on the current. When electrons conduct electricity, they constantly collide with atoms in the crystal lattice. After each scattering, the electrons will change the direction of movement. The total movement is the superposition of the directional of movement. The total movement is the superposition of the directional acceleration of the electric field on the electrons and this random scattering movement.

Electrons have spin characteristics, and the spin magnetic moment has two possible orientations, parallel or anti-parallel to the external magnetic field. Electrons whose spin magnetic moment is parallel to the direction of the material's magnetic field are much less likely to be scattered than electrons whose spin magnetic moment is antiparallel to the direction of the material's magnetic field.

When there is no external magnetic field, the upper and lower layers of magnetic materials are coupled in antiparaller. After a sufficiently strong external magnetic field is applied, the directions of the two ferromagnetic films are consistent with the direction of the external magnetic field, and the external magnetic field causes the two ferromagnetic films to change from antiparaller coupling to parallel coupling.



The magnetoresistance characteristics of GMR materials gradually decrease with the increase of the external magnetic field, and there is a linear region in between. When the external magnetic field has made the two ferromagnetic films completely coupled in parallel, continue to increase the magnetic field, the resistance will no longer decrease, and enter the magnetic saturation region.

When there is no external magnetic field, the megnetic fields of the upper and lower ferromagnetic films are in opposite directions. Regardless of the initial spin state of the electrons, there will be two processes of small and large scattering probability during the traveling process, similar to the parallel connection of two middle-resistance resistors. Corresponds to the high resistance state. When there is an external magnetic field, the sattering probability of electrons with parallel spins is high. The parallel resistance and a large resistance, which corresponds to the low resistance state.

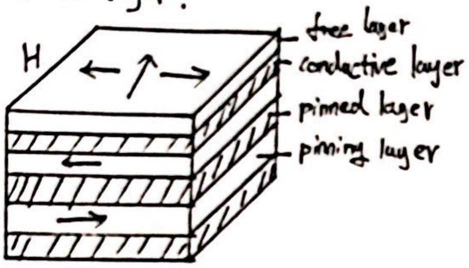
The multi-layer GMR has a simple structure and reliable operation. In the field of digital recording and read-out, in order to further improve the sensitivity,

北京航空航天大学
实验报告

学　号:
班　级:
姓　名:
同组者:
日　期:
评　分:

实验名称:

GMR with a spin value structure has been developed, the spin value structure is composed of a spined layer, a pimed layer, an intermedate conductive layer and a free layer.



Formalation

1. Magnetoelectric conversion characteristic measurement of GMR alnalog sensor

Switch the function to "sensor measurement", connect the 4V valtage source to the "giant magnet" resistance power suply", connect the constant current soure to the "solenoid current input", and connect the "analog signal output" to the voltmeter of the experimental instrument.

Adjust the excitation current, gradually decrease from 100 mA to -100mA, and record the corresponding output voltage every 10 mA. Do the same in reverse.

2. GMR magnetoresistance characteristic measurement

Switch the function to "Giant Magnetoresistance Measurement", connect the 4V voltage source to the ammeter in series, then connect it to the "Giant Magnetoresistance Power Supply", and connect the constant current source to the "solenoid Current Input".

Adjust the excitation current, gradually decrease from 100mA to -100mA, and record the corresponding output voltage every 10 mA. Do the same in reverse.

3. Measurement of magnetoelectric conversion characteristic curve of GMR switch (digital sensor)

Switch the function to "sensor measurement", connect the 4 volt voltage source to the "giant magnet resistance power supply", connect the "circuit power supply" interface to the base "circuit power supply" input jack, and connect the constant current source to the "solenoid current input", "switch signal output" is connected to the voltmeter.

Reduce the excitation current from 50mA - 0mA, and record the corresponding excitation current when it changes from a high level to a low level. Then increase the current from 0mA - 50mA, and record the negative excitation current when it changes from low level to high level.

Decrease the excitation current from 50mA - 0mA, and record the corresponding excitation current when chaging from a high level to a low level. Then increase the current from 0mA - (-50mA), and record the negative excitation current when it changes from low level to high level.

4. Use GMR analog sensor to measure current

The 4 volt voltage source is connected to the "giant magnet resistance power supply", the constant current source is connected to the "current input to be measured", and the "signal output" is connected to the voltmeter.

Adjust the current to 0, turn the bias magnet away from the GMR sensor, and adjust the distance between the magnet and the sensor so that the output is about 25mV

The current is from 300mA - (-300mA), and the corresponding output voltage is recorded In turn, record the corresponding output voltage.

Adjust the current to be measured to 0. Turn the bias magnet close to the GMR sensor, adjust the distance between the magnet and the sensor, so that the output is about 150mV. Use the same method to measure the relationship between the current to be measured and the output voltage,

5 Characteristics and applications of GMR gradient sensors

The 4V voltage source is connected to the angular displacement measuring component "giant magnetoresistance power supply", and the "signal output" is connected to a voltmeter.

北京航空航天大学
实验报告

学 号:
班 级:
姓 名:
同组者:
日 期:
评 分:

实验名称:

Turn the gear counterclockwise, record the starting angle when the measuring component "giant magnetoresistance power supply", and the "signal output" is connected to a voltmeter.

Turn the gear counterclockwise, record the starting angle when the output voltage is zero, and record the angle and the reading of the voltmeter every 3 degrees. Rotate the 48-degree gear to turn 2 teeth, and the output voltage changs 2 cycles.

6. Magnetic recording and reading

The 4 volt voltage source is connected to the "giant magnet resistance power supply" of the magnetic reading and writing component, the "circuit power supply" is connected to the input of the "circuit power supply", and the magnetic reading and writing component "read data" is connected to to voltmeter. Press the "0/1 conversion" and "write confirmation" buttons at the same time for 2 seconds to initialize.

Enter the binary data that needs to be written and read into the second row of Table 2.

Put the side of the magnetic card with the scale area facing forward, insert the scribe slot along the direction of the arrow mark, and switch to write "0" or "1" as needed. Press and hold the "write confirmation" button, slowly move the magnetic card, according to the scale area line on the magnetic card.

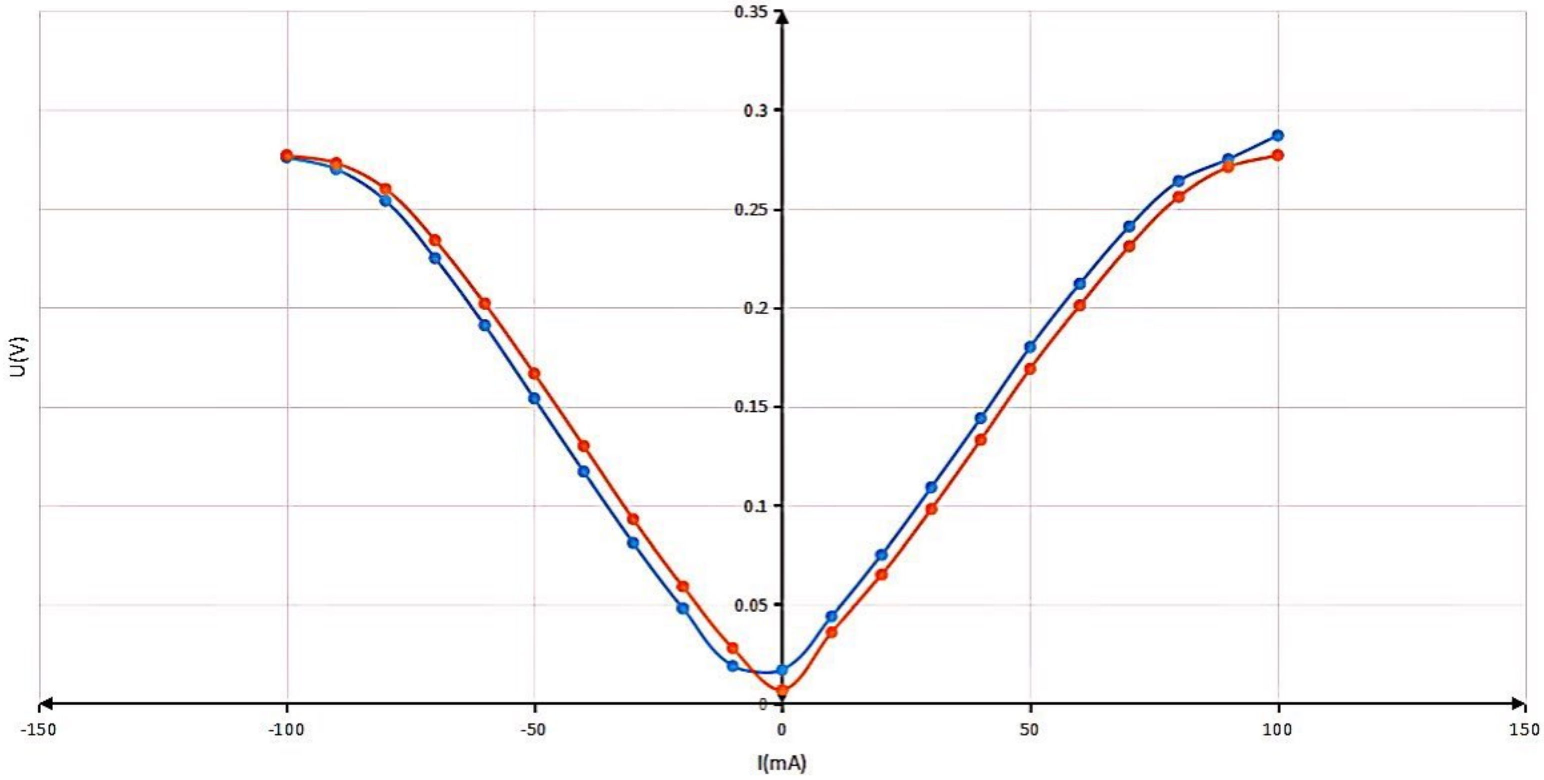
After writing the data, release the "write confirmation" button, move the magnetic card to the reading head, and read the voltage on the voltmeter according to the scale area、 Discussion

1. Manga to electric conversion characteristic measurement of GMR analog sensor

exciting current(mA)		100	90	80	70	60	50	40	30	20	10	0	-10
Output vol-	↓	0.278	0.275	0.263	0.241	0.212	0.180	0.144	0.109	0.075	0.044	0.017	0.019
tage (V)	↑	0.277	0.271	0.256	0.231	0.201	0.169	0.133	0.098	0.065	0.036	0.007	0.028

exciting current(mA)		-20	-30	-40	-50	-60	-70	-80	-90	-100			
output vol-	↓	0.048	0.081	0.117	0.154	0.191	0.225	0.254	0.270	0.276			
tage(v)	↑	0.059	0.093	0.130	0.166	0.202	0.234	0.260	0.273	0.277			

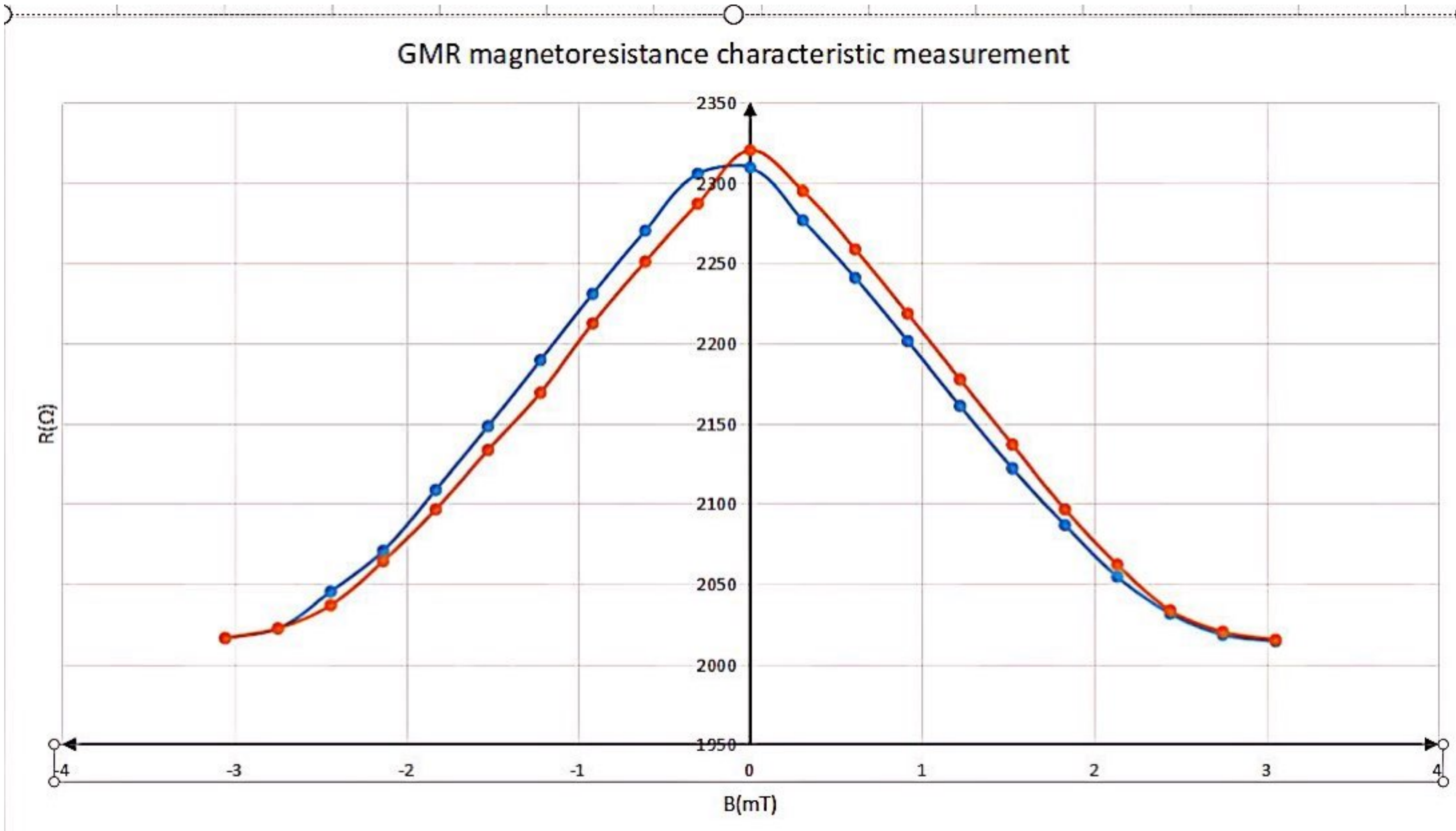
1.Magnetoelectric conversion characteristics measurement of GMR analog sensor



2. GMR magne to resistance characteristic measurement

I(mA)	100	90	80	70	60	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
B(mT)	3.052	2.747	2.442	2.136	1.831	1.526	1.221	0.916	0.610	0.305	0.000	-0.305	-0.610	-0.916	-1.221	-1.526	-1.831	-2.136	-2.442	-2.747	-3.052
I'(mA) →	1.986	1.982	1.969	1.947	1.917	1.885	1.851	1.817	1.785	1.757	1.732	1.735	1.762	1.793	1.827	1.862	1.897	1.932	1.956	1.978	1.984
R(Ω) →	2014.1	2018.2	2031.5	2054.4	2086.6	2122.0	2160.9	2201.4	2240.9	2276.6	2309.5	2305.5	2270.1	2230.9	2189.4	2148.2	2108.6	2070.4	2045.0	2022.2	2016.1
I'(mA) ←	1.985	1.980	1.967	1.940	1.908	1.872	1.837	1.803	1.771	1.743	1.724	1.749	1.777	1.808	1.844	1.875	1.908	1.938	1.964	1.978	1.984
R(Ω) ←	2015.1	2020.2	2033.6	2061.9	2096.4	2136.8	2177.5	2218.5	2258.6	2294.9	2320.2	2287.0	2251.0	2212.4	2169.2	2133.3	2096.4	2064.0	2036.7	2022.2	2016.1

$B = \mu_0 n I$ $\mu_0 = 4\pi \times 10^{-7}$ H/m $R = U/I'$ $U = 4V$

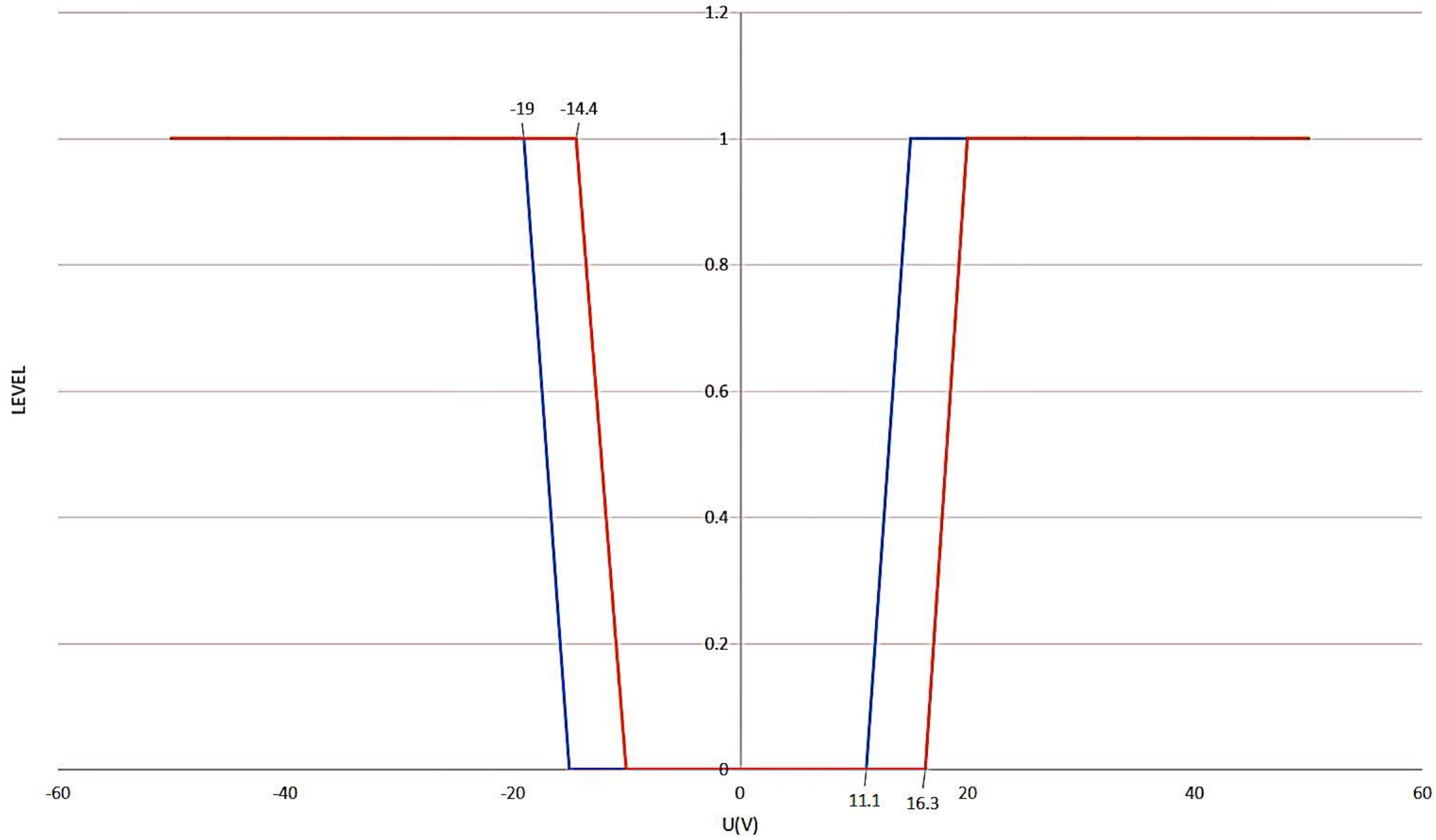

GMR magnetoresistance characteristic measurement
R(Ω)
2350
2300
2250
2200
2150
2100
2050
2000
1950
-4
-3
-2
-1
0
1
2
3
4
B(mT)

3. Measurement of magne to electric conversion characteristic curve of GMR switch sensor

50 mA ⟷ 0 ⟷ -50mA

→	11.1 mA	-19.0 mA
←	16.3 mA	-14.4 mA

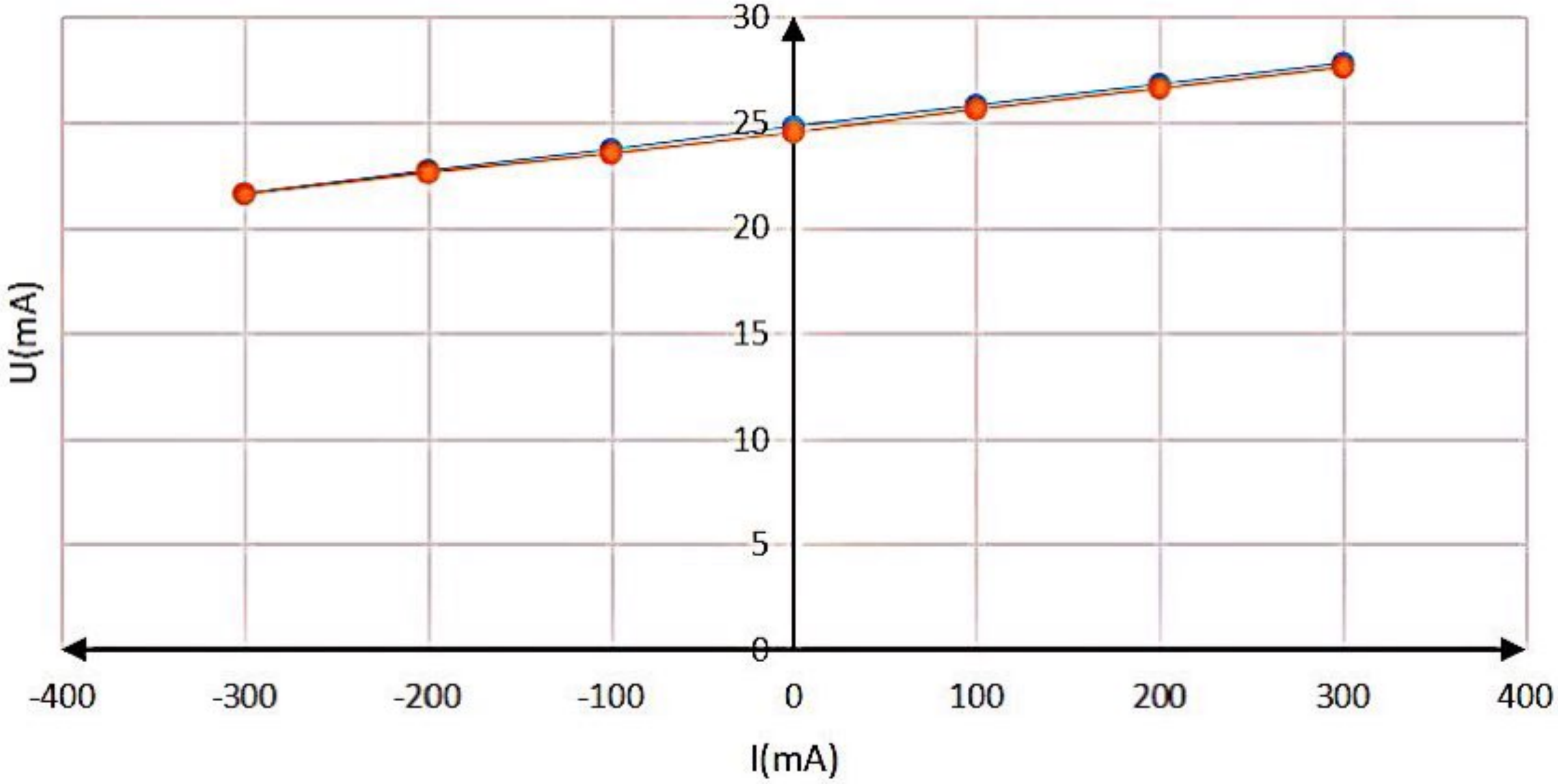
3.Measurement of magnetoelectric conversion charaacteristic curve of GMR switch(digital) sensor



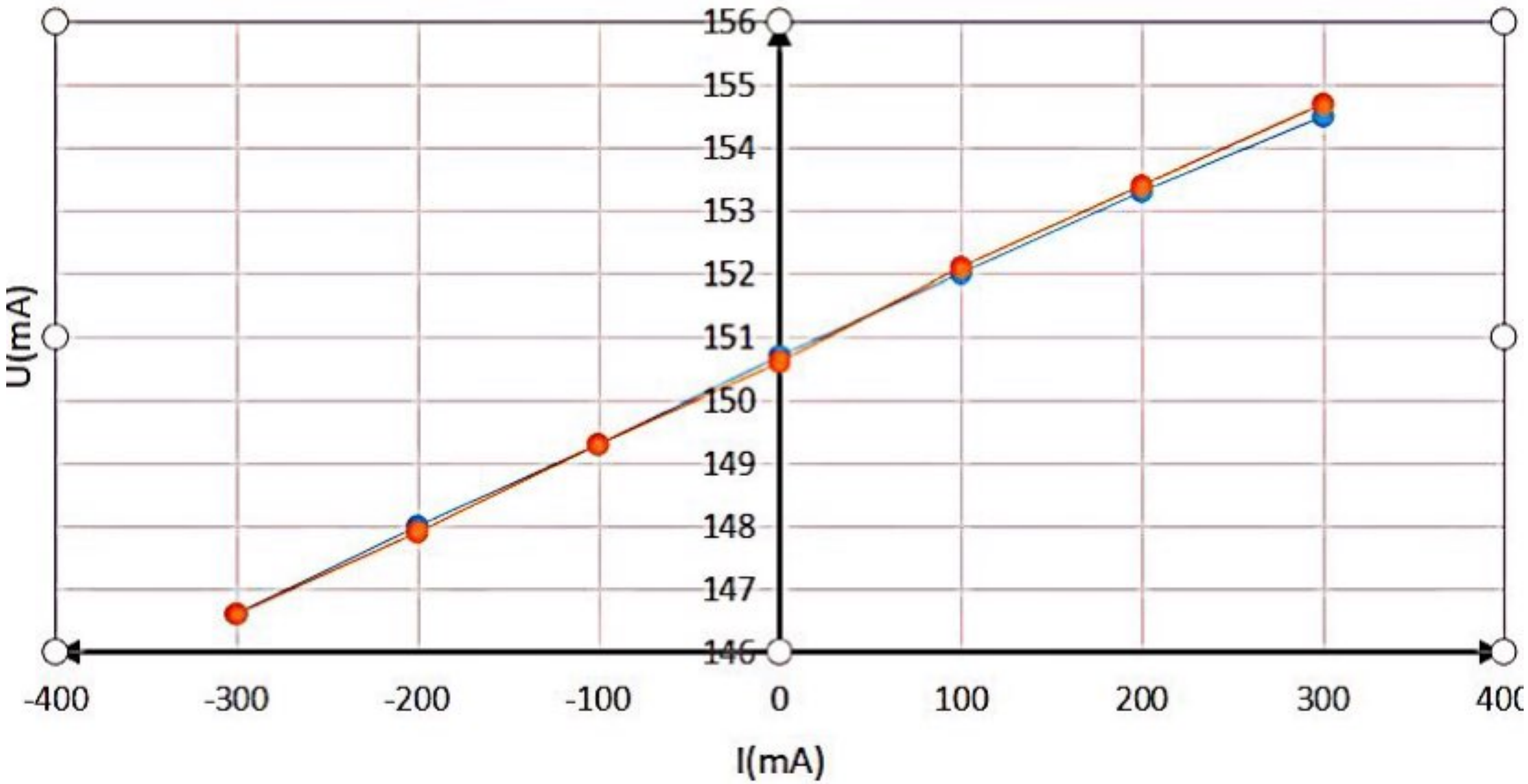
4. Use GMR analog sensor to measure current

I (mA)	300	200	100	0	-100	-200	-300
U(mV) 25mV↑	27.8	26.8	25.8	24.8	23.7	22.7	21.6
U(mV) 25mV↓	27.6	26.6	25.6	24.5	23.5	22.6	21.6
U(mV) 150mV↑	154.5	153.3	152.0	150.7	149.3	148.0	146.6
U(mV) 150mV↓	154.7	153.4	152.1	150.6	149.3	147.9	146.6

4.Use GMR analog sensor to measure current 30mV

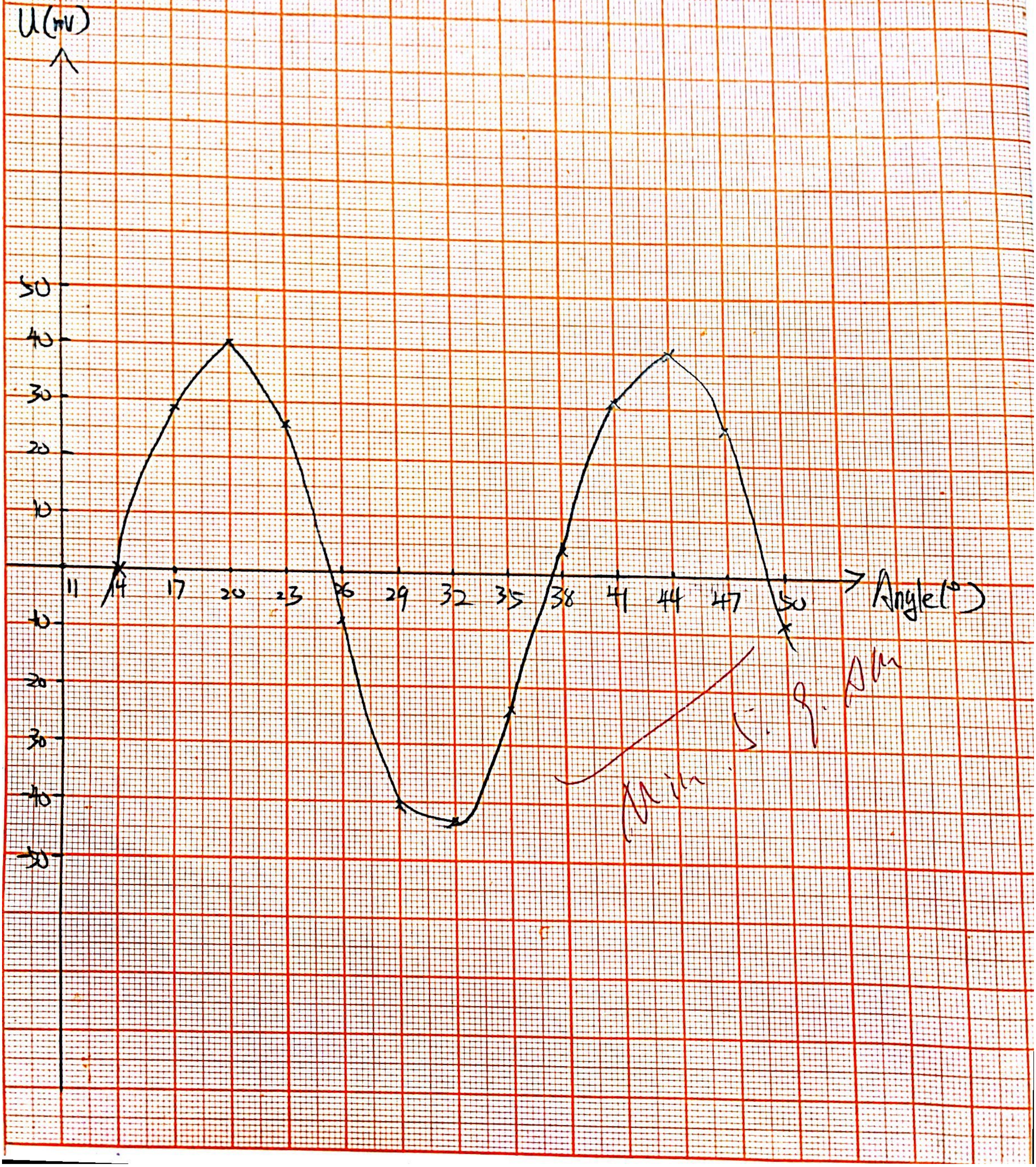


4.Use GMR analog sensor to measure current 150mV

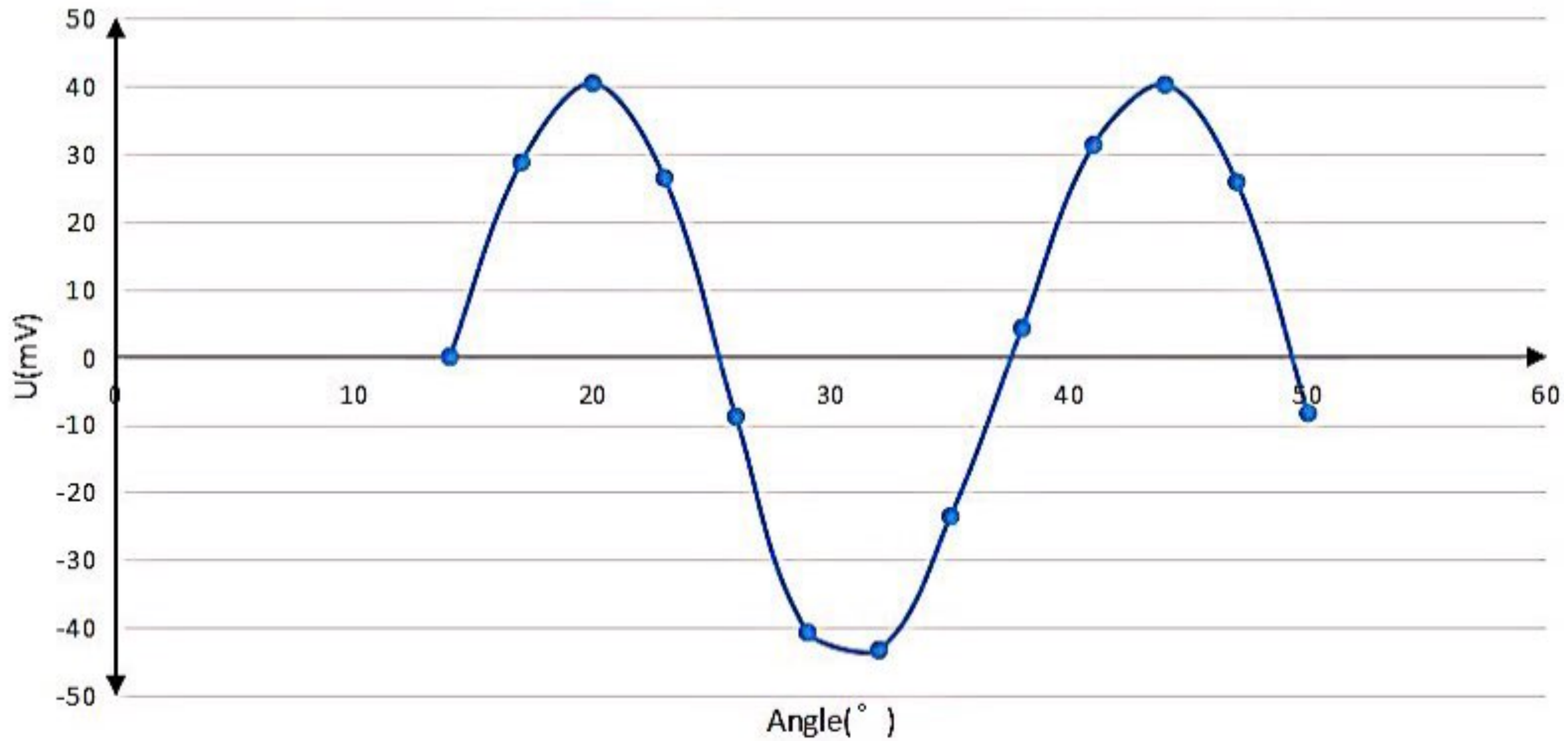


5. characteristics and applications of GMR gradient sensors

Angle(0)	14	17	20	23	26	29	32	35	38	41	44	47	50
U (mV)	0	28.7	40.4	26.4	-8.8	40.7	-43.3	-23.6	4.2	31.3	40.2	25.8	-8.3


U(mV)
50
40
30
20
10
-10
-20
-30
-40
-50
11
14
17
20
23
26
29
32
35
38
41
44
47
50
Angle(°)

5.Characteristics and applications of GMR gradient sensors



北京航空航天大学
实验报告

学 号:
班 级:
姓 名:
同组者:
日 期:
评 分:

实验名称:

Conclusion

Traditional electronics is based on the charge movement of electrons, and the spin of electrons is often ignored. The giant magnetoresistance effect shows that the electron spin has a very strong influence on the current.

According to the microscopic mechanism of conduction, electrons do not travel in a straight line along the electric field when conducting electricity, but constantly collide with atoms in the crystal lattice. Each time the electric are scattered, they will change the direction of movement. The total movement is the directional scattered. they will and acceleration of the electrons by the electric field. The superposition of this random scattering motion.

Generally, the geometric scale of the material is much larger than the mean free path of electrons, and the boundary effect can be ignored. When the geometric size of electron is as small as nanometers and only a few atoms thick, the probability of electron scattering on the boundary increases greatly, and it can be clearly observed that the thickness decreases and the resistivity increases.

The giant magnetoresistance effect has triggered a new revolution in electronic technology and information technology, and is widely used in various measurement and control fields.

北京航空航天大学
实验报告

[redacted]

实验名称:

①

1\. exciting current (mA) →

exciting current (mA)	100	90	80	70	60	50	40	30	20	10	0
output voltage (V).	0.278	0.275	0.263	0.241	0.212	0.180	0.144	0.109	0.075	0.044	0.017

exciting current (mA)	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
output voltage (V).	0.019	0.048	0.081	0.117	0.154	0.191	0.225	0.254	0.270	0.276

②.

exciting current (mA) ←

exciting current (mA)	100	90	80	70	60	50	40	30	20	10	0
output voltage (V)	0.277	0.271	0.256	0.231	0.201	0.169	0.133	0.098	0.065	0.036	0.007

exciting current (mA)	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
output voltage (V)	0.028	0.059	0.093	0.130	0.166	0.202	0.234	0.260	0.273	0.277

Mon. 5.8 [illegible]

2.①. →

I (mA)	100	90	80	70	60	50	40	30	20	10	0
I′ (mA)	1.986	1.982	1.969	1.947	1.917	1.885	1.851	1.817	1.785	1.757	1.73[illegible]

I (mA)	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
I′ (mA)	1.735	1.762	1.793	1.827	1.862	1.897	1.932	1.956	1.978	1.984

②.

I(mA)	100	90	80	70	60	50	40	30	20	10	0
I'(mA)	1.984	1.978	1.964	1.938	1.908	1.875	1.841	1.808	1.777	1.749	1.724

	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
	1.743	1.771	1.803	1.837	1.872	1.908	1.946	1.967	1.980	1.985

3. ①$\rightarrow$ 50mA → 0 → -50mA

111mA -190mA

②$\leftarrow$ -50mA → 0 → +50mA

-163mA 144mA

4.

I(mA)		300	200	100	0	-100	-200	-300
U(mV) (25mV)	big	27.8	26.8	25.8	24.8	23.7	22.7	21.6
	small	27.6	26.6	25.6	24.5	23.5	22.6	21.6
(150mV)	big	154.5	153.3	152.0	150.7	149.3	148.0	146.6
	~~Small~~ Small	154.7	153.4	152.1	150.6	149.3	147.9	146.6

5.

Angle (°)	14	17	20	23	26	29	32
U(mV)	0	28.7	40.4	26.4	-8.8	-40.7	-43.3

	35	38	41	~~44~~	47	50
	-23.6	4.2	31.3	40.2	25.8	-8.3

Min 5.9. AM