# Application of angle and fluxgate sensor algorithm in design the smart sensor system

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**ABSTRACT**

*Magnetic sensitive angle sensor is a high performance integrated magnetic sensitive element, the inductive magnetic signal characteristics of non-contact, with microprocessor for a new generation of angle sensor intelligent signal processing is made. Fluxgate sensor is the use of soft magnetic materials, some high permeability (such as slope Mo alloy) as the magnetic core, with it's together under AC magnetic saturation characteristics of the times and Faraday electromagnetic induction principle of magnetic measuring device. The paper proposes the application of angle sensor and fluxgate sensor in design the smart sensor system. The simulation experiments show that the method is effective to design smart sensor.*

**Keywords:** Angle sensor, Fluxgate sensor, Smart sensor.
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## INTRODUCTION

The angle sensor is able to feel the angle measured and converted into usable output signal of the sensor. The angle sensor is used to detect the angle. There was a hole in its body, can be matched with the shaft lego. When the connection to the RCX, 1/16 axis rotates each circle, angle sensor will count once. Go in one direction, count increased, change of the rotational direction, the decrease in the number of. Count and the initial is position of the angle sensor. When the initial angle sensor, count it is set to 0, if necessary, you can use the program to reset.

Fluxgate magnetometer and it is also known as the storable magnetometer. It is a kind of electronic magnetometer. It uses high permeability Po Mo alloy as the sensitive element, magnetic saturation can be achieved in a weak magnetic fields [1]. Core sensitive element for the closed magnetic circuit, the two sides around to the same number of turns, winding excitation winding on the contrary, is outside the output winding. The excitation winding with alternating voltage, the sensitive element to achieve close to saturation, if there is no external magnetic field, magnetic flux waveform symmetry on both sides of the reverse, then there will be no signal winding induction voltage output.

Magnetic sensitive angle sensors with high performance integrated magnetic sensitive element, the inductive magnetic signal characteristics of non-contact, with microprocessor for a new generation of angle sensor intelligent signal processing is made.

Stay-supported style displacement sensor using the traditional potentiometer displacement sensors, which components will be through the potentiometer mechanical displacement into linear or any function of the resistance or voltage output and. General linear and circular potentiometer can be used as a linear displacement and angular displacement sensor. However, designed to achieve the purpose of measuring the displacement potentiometer, requirements between the displacement variation and resistance variation has a certain relationship. Potentiometer displacement sensors movable brush and the object to be measured is connected, caused the displacement of objects

resistance potentiometer at mobile terminals. Variation value reflects the magnitude of displacement, the resistance increase or decrease indicates that the displacement direction.

Fluxgate sensor is the use of soft magnetic materials, some high permeability (such as slope Mo alloy) as the magnetic core, with it's together under AC magnetic saturation characteristics of the times and Faraday electromagnetic induction principle of magnetic measuring device. The structure can be viewed as a special transformer, a fluxgate magnetometer method is using the special transformer core, when alternating current flows through the primary winding of a transformer, magnetic core repeatedly by alternating saturation magnetization excitation, when there is an external magnetic field, the excitation is not symmetric, modulated output signal transformer by the external magnetic field. By means of measurement of modulation signal detection output can be achieved on the external magnetic field. The paper proposes the application of angle sensor and fluxgate sensor in design the smart sensor system.

**2. The Working Principle of the Fluxgate Sensor**
A fluxgate magnetometer instrument is the core to change magnetic properties in the alternating magnetic field excitation thereby modulating the measured magnetic field measurement of external magnetic field, by means of detecting the modulated signal. A fluxgate magnetometer method with its wide measurement range, high resolution, and it is wide frequency band and economical and practical characteristics.

Intelligent instrument is the computer technology and testing technology product of the combination, contain a microcomputer or microprocessor measuring instruments. As it has for data storage, calculation, logic and automation functions, with some intelligence role, which is called intelligent instruments. Hardware includes a microprocessor, memory, input channels, output channels, man-machine interface circuits, communications interface circuits and other parts.

The three component fluxgate magnetic field detection device is mainly based on Faraday electromagnetic induction principle to realize the detection of the geomagnetic field. The geomagnetic sensor signals into electric signals, judging the geomagnetic signal detection device size by detecting the electric signal detection, and then judge the sites of. To achieve this judgment relies mainly on the three component fluxgate sensors, each sensor which adopts double core structure, the excitation current of winding in series two iron core excitation coils back through the excitation coil.

Because of the long-term stability of instrument, temperature characteristics and so can not meet improve the stability of the instrument number, temperature of geomagnetic low instrument, reducing complexity, reduce the size of the instrument installation, improve the degree of automation instrument has been the instrument continues development and improvement goals. The main feature of this three component fluxgate magnetic field is discussed in this paper, the measuring device has the small volume, simple installation, high stability, because it can simultaneously measure the magnetic field in the direction of three components, then the vector synthesis, so the measured data with high reliability.

$$\hat{C}_J = (\alpha C_J^1 + \beta C_J^2)/2$$

(1)

The direction of the magnetic field generated in the two core excitation in the opposite, if the two core shape, size and electromagnetic parameters are completely symmetrical, the induced EMF in two core flux generated in the measuring coils in the offset each other, the output is zero; when the external magnetic field is applied along the direction of the long axis of the magnetic core, ahead of a core of another to achieve saturation, resulting in induction electromotive force cannot be measured in a coil output offset each other, asymmetric waveform, the main component is the two harmonic wave excitation signal [2]. The induced electromotive force generated by the magnetic field amplitude is proportional to the external magnetic field size, can be measured by the two harmonic component of measuring the output signal of the magnetic field.

Intelligent sensor independent, although able to detect environmental information quickly and accurately, but with the continuous expansion of the scope of measurement and control, access to a single node, passive information has been unable to meet the requirements of distributed measurement and control, intelligent sensor and communication network technology, the formation of a networked smart sensor. Networked intelligent sensor to sensor by a single function, single detection to multiple functions and multiple point detection development; information processing direction from passive to active detection; from in situ measurements to the development of remote real-time online measurement and control. The sensor can be the nearest access network, sensor and control devices without a point-to-point connection, greatly simplifying the circuit, saving investment, convenient maintenance and expansion

of the system.

The three component fluxgate magnetic field detection device is mainly to measure the magnetic field strength by detection of the geomagnetic field in three mutually perpendicular directions on the components. The three component fluxgate magnetic sensor can detect various components of geomagnetic field is modulated signal, the frequency selection amplifying circuit is proportional to the size and weight of the amplitude of the two harmonic, the signal is 6 times the frequency of sampling with 16 A/D, through the external interrupt the sampling data to the SCM is respectively, SCM enough sampling data of two cycles in reading (a total of three groups, each group of 16 bytes is 9 32 bit data), the MAX232, conversion of data to the computer through the serial port to send the way, with the computer to complete the data processing and analysis of the final.
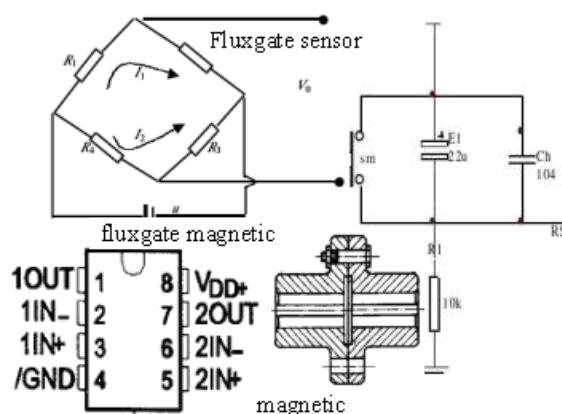


**Fig. 1. Working Principle of the Fluxgate Sensor**

Changes in the scope of the aperture time, namely the aperture time is not constant, but random changes within a certain range. When the switch is off, the CH value is not stable, after TAP, the output is still a wave, after a period of steady time to remain stable. In order to accurately quantify, should be delayed for some time in a keep instructions, and then start the A/D conversion. Aperture error: sample-and-hold output actual retention value and ideal output difference.

Fluxgate sensor requires 65 kHz excitation signal, need to have an oscillation circuit to provide frequency source. Quartz crystal oscillator signal frequency generation rate is 65MHz, the need for 4000 times (about $2^{12}=545296$ times) frequency. At the same time, A/D 4 frequency multiplication sampling, 99kHz clock signal, and the duty ratio close to 100% (see AD7656 sequence), so the 85 times the frequency divider output needs to pick up the signal conversion circuit. The frequency divider by 32 binary is counters/divider 74HC4060 and it is circuit principle diagram of figure 2. Figure 98 feet 29 times the frequency of the output, the differential circuit to form 1nF capacitor and 1.6K resistance, and the signal conversion circuit and gate shaping circuit, A/D conversion circuit provides a starting signal.

Smart sensor is a function of having only a traditional sensor signal acquisition, signal conditioning circuitry, and it is a microprocessor bus interface with digital portfolio as a whole constitutes a smart sensor systems. Field bus control system development is to promote the development of such a sensor. Manufacturers can keep the original production process equipment will remain basically unchanged, added a digital bus interface with a microprocessor and equipped with control, data transmission, data processing and other functions of the intelligent software, enabling intelligent sensor function. This is an economical and fast way to build intelligent sensors.

The divider output load capacity is weak, can not be directly used for incentive therefore need to drive circuit power amplifier. The excitation signal ideal should be the frequency of 85 kHz, amplitude of 3V wave, and in the rate of sine wave is very stable, so the actual excitation signal using 95 kHz square wave, the amplitude of 3V. The output amplitude frequency divider is about 6V, the 5.6k buffer resistance reduction; power amplifier circuit output amplitude is about 4V, the need for transformation processing.

Because the sampling frequency must be accurate to four times, so the A/D sampling rate should be variable; because it is the sampling of AC signal, so A/D should be positive and negative sampling; subject to the realization of the three component measurement, there are three road signal input, and also to the three signal sampling, the A/D can achieve three above at the same sampling. According to the above requirements, the final selection of

successive approximation type 16 A/D data acquisition circuit AD7656. The highest sampling frequency of AD7656 can reach 250kHz, which belongs to the successive approximation, the sampling frequency variable, by converting the enable pin input enable signal, control six channels simultaneously data conversion.

$$Var[X] = E[(X - \mu_X)(X - \mu_X)^T] = C_X \tag{2}$$

Multidimensional physical variable detection function is actually a double-edged sword to improve overall performance, but between each element will have a more or less interference, thus affecting the ultimate results, lead to the inaccuracy of measurement, how to eliminate such interference is one of the urgent problems to be solved [3]. 2 data from the storage function far not strong enough sensor with communication protocol as an example, the sensor internal memory space is not enough to store a lot of diagnosis and parameter configuration information, still need to store the industrial control machine PC.

The magnetic measurement instrument according to the type of the magnetic sensor is divided into many. Have been eliminated is mechanical magnetometer using mechanical magnetic sensor; magnetic sensor is widely used at present has the magnetic through proton spin door type magnetic sensor, magnetic sensor, optical pumping magnetic sensor, SQUID (superconducting quantum interference device) magnetic sensor, optical fiber type magnetic sensor, semiconductor magnetic sensor; magnetic measurement instrument in research, testing phase of a solid electron spin resonance magnetometer, atomic magnetometer.

Delay: after the microprocessor sends the starting signal to the A/D converter, A/D converter based on switching time delay, average delay time is slightly larger than the A/D converter switching time, the delay is over, read data. The method is simple; query port not occupied, but occupies CPU time, low efficiency, suitable for processing task is scarce.

The main chip serial communication used is MAX232, its low power consumption shutdown mode suitable for battery-powered systems. The external circuit is simple, so it is suitable for application in the area of the printed circuit board co.. It has dual charge pump voltage of DC-DC converter, RS232 drive, RS232 receiver, and receiver and transmitter enable control input. MAX232 there are two internal charge pump, will be converted to 10V + 5V (no-load), provides working voltage for the RS-232 drive, the first converter using capacitive C1 + 5V input is doubled, get V output on the C3 10V, second converter using the capacitance C2 + 10V is converted to the V output. Integrated smart sensors are sensors inevitable trend of development, but there are still some difficult problems, such as the sensitive components and integrated circuit technology compatibility issues, the chip area is limited, the signal processing circuit test environment impact and other issues. Hybrid implementation is based on the needs and possibilities of each of the integrated areas of the system (eg sensitive unit, a signal processing circuit, the microprocessor unit, a digital bus interface, etc.) in different combinations of two or three integrated on the chip, as is shown by equation3.

$$X' = W(X, P) = \begin{pmatrix} a_1 & a_2 & d_1 \\ a_3 & a_4 & d_2 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix} \tag{3}$$

Channel differences on three component measurement design correction scheme, the difficulties in the design of the three component fluxgate magnetic field detection device is three component measurement, each channel pre-process of each component, the gain may not be completely consistent, this will lead to measurement error, affect the accuracy of the measurement results and reliability.

Using the internal reference voltage measurements, input voltage range measurement signal is 0 ~ 500mV, when the input signal full-scale input, analog digital conversion of the MSB output is not 1, but for signal amplification, the maximum magnification of up to 32. When the magnification of input signal is N, the range of the input signal will be reduced to the original 1/N. For example, when choosing a PGA magnification of 2 times, input voltage range measurement signal is 0 ~ 250mV [4].

The fluxgate sensor has the advantages of high resolution, weak magnetic field measurement range, small volume, light weight, low power consumption, the economy is good, can loss directly measuring magnetic field and is suitable for high speed motion system to use and other characteristics, are widely used in various fields. This paper analyzes the working principle of the fluxgate sensor, discusses in detail how to use digital demodulation method for signal processing. This paper also introduces three components of geomagnetic field detection device, the design of

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hardware circuit and MCU program.

**3. Research on Application of Angle Sensor**
Usually on the potentiometer is connected to the power supply voltage, the resistance change is converted to a voltage output. The traditional displacement sensor wiper is moved due to its resistance to turn resistance ladder change; its output characteristic was also stepped. If this displacement sensor used in the servo system position feedback device is too large, then the step voltage can cause system oscillation. Therefore, the production of the potentiometer should be to minimize the resistance of each turn. At the same time, another major drawback of potentiometer sensor is easy to wear, low resolution, low resistance, high frequency characteristics of difference, which leads to a decrease in the measurement accuracy. Its advantages are: simple structure, large output signal, convenient use, low prices.

Stay-supported style displacement sensor magnetic sensitive point of technology in the medium of magnetic field, based on the mechanical displacement, will change as the angle of the magnetic field changes, hand to solve the contact mode of traditional pull displacement sensor, on the other hand, reduce the frequency characteristic of the system is improved, so as to ensure the wear, displacement detection accuracy. The data processing unit, used for magnetic sensitive point of the received signal is through the mathematical model for the displacement signal cable. Communication interface, communication through the communication interface and application system, receiving from the application system of equipment command and the displacement signal is to collect the feedback to the application system[5].

Smart Sensor technology is a booming modern sensor technology, involving micro-mechanical and micro-electronics technology, computer technology, network and communications technology, signal processing technology, circuits and systems, sensor technology, neural network technology, information fusion technology , wavelet transform theory, genetic theory, fuzzy theory and other disciplines integrated technology.

Sensor and magnet sensitive angle is arranged in the same axis, changes to induction magnet angle, using a microprocessor, the processor reads the magnetic susceptibility in terms of information, and through the establishment of mathematical model, the magnetic sensitive angle calculation for cable displacement. Communication interface, a microprocessor through communication interface receives commands from the application system and the displacement information is returned to the application system through the communication interface.
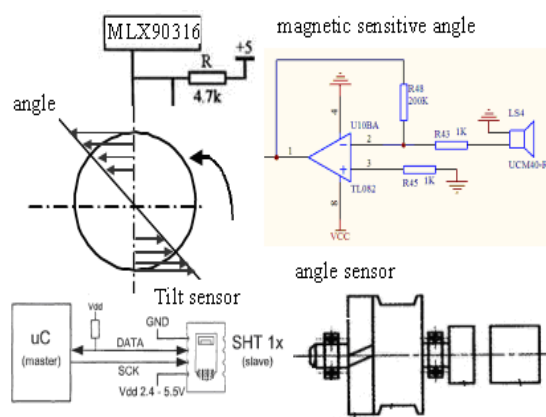


**Fig. 2. Application of Angle Sensor figure**

Through the analysis of Figure 2, magnetic angle sensor using MLX90316, which converts rotating magnet wire displacement caused by the angle for the magnetic sensitive angle. 32 bit embedded ARM microprocessor unit used for treatment on the magnetic susceptibility of the received data, receiving magnetic angle data, the received field transformation perspective, so through the establishment of mathematical model, combined with the diameter of the wheel hub, the magnetic sensitive angle conversion for the guyed displacement. Therefore, in order to establish can receive and model data quickly, here to choose LPC2136 as the data processing unit. Processing of input, output control module is responsible for various external interfaces, such as received from the application system commands through communication interface, return displacement of the collection to the application system.

Based on the displacement transducer magnetism sensitive point of technology we design a road RS 485 signal output, RS 485 interface chip MAX3485, used for the displacement data and application system. In order to ensure

the reliability of data communication, communication interface adopts photoelectric isolation chip 6N137. Controllable current output interface, 4 ~ 20 mA output current of a controllable with data processing unit, used to drive on the instrumentation. The PWM2 is connected to the ARM pins of the PWM2, the PWM signal is used for on-off control of optocoupler inverter, mainly used for tuning the waveform, based on the magnetic sensitive angle and displacement relationship, establish mathematical model, calculate the PWM duty cycle, so as to achieve the purpose of regulating the size of current.

When the tilt sensor static is lateral and vertical direction without acceleration, then acting on it is the acceleration of gravity. The angle between the vertical axis and the acceleration sensor sensitive axis between the gravity is inclined angle. With the development of MEMS technology, inertial sensor in the past few years to become the most successful, the most widely used one of the microcomputer electric system devices, and micro accelerometer is the outstanding representative of inertial sensor. As the inertial sensor application the most mature, now MEMS accelerometer with a very high degree of integration, namely sensing system and interface circuit integrated on a chip.

$$\overline{I_k} = \frac{\sum\limits_{x \in \Omega_i} [I_k(X')]}{L \cdot L}, \overline{I_{k-1}} = \frac{\sum\limits_{x \in \Omega_i} [I_{k-1}(X)]}{L \cdot L}$$

(4)

First by using single-chip p0.0~p0.7 given numbers 80H output to 0832, D0~D7. 0832 the digital-analog conversion is the current output into a simulation, and then by the A1 converted into voltage is input to the Vi comparator, if less than Vi P1.0 will be a high level of. Comparison is then input C0H and Vi. If Vi is greater than the input to compare 40H with Vi. The comparison of eight can reach to P0 port input value is converted to digital quantity Vi also achieved a 8 bit successive approximation type ADC converter. Simulation design a no inverting amplifier switch CD4051 trial multiplexer.

Gas by buoyancy in the heated, as solid pendulum and liquid pendulum sensitive quality also has the same, heat flow always tries to keep in vertical direction, so it has the pendulum characteristic. "Gas pendulum" inertial component composed of a sealed cavity, gas and hotline [6]. When the plane where the relative horizontal tilt or cavity by the effect of acceleration, wire resistance to change, and change of resistance is a function of angle hotline Q or acceleration, and thus has the pendulum effect. The change in line resistance is gas exchange with the line energy caused by it.

Tilt sensor MCU, MEMS accelerometer, analog-digital conversion circuit, communication units are all integrated in a very small circuit board. Can be directly output angle of tilt data; make it more convenient to use it. Its characteristics are: silicon micro mechanical sensor (MEMS) by a horizontal plane as a reference plane biaxial angle changes. Output angle to geoids as reference, datum is again calibration. Data output, interface types include RS232, RS485 and custom etc.. Resistance to external is electromagnetic interference ability.

**4. Application of Angle Sensor and Fluxgate Sensor in Design the Smart Sensor System**
Fluxgate sensor with high sensitivity, strong compact, flexible use, reliable work, low power consumption, simple circuit structure and other advantages, is widely used in the field of weak magnetic field measurement [7]. The majority of the magnetic measurement instrument currently using the geomagnetic measurements is imported products; the price is expensive, difficult to repair than. Based on this situation, this paper mainly introduces a new geomagnetic detection device. The detection device has simple circuit, the digital processing of measurement data, convenient operation, low cost, modular design, and easy to repair. And, compared with most of the magnetic measurement instrument detection device, power consumption is very low, with ± 12V external power supply; the measured data can be sent through the serial port to computer for processing and analysis, the convenience of the study.

Based on the displacement transducer magnetism sensitive angle technology with magnetic vector for the transmission, the displacement transformation into magnetic field angle displacement, at the same time, the displacement signal is returned to the application system through the communication interface [8]. The overall design scheme, the displacement transducer magnetism sensitive angle technology based on the function of the mechanical displacement of cable is changed into electrical signals that can measuring, recording or transmission, mainly by the automatic return spring, wheel hub, a magnet and a data processing unit and other parts.

This paper will have the induction voltage pulse output. The amplitude and the external magnetic field is proportional to the size, it can determine the size of external magnetic field. From the above can be seen from the fluxgate magnetometer instrument has its own advantages, is the other magnetic measurement instrument can not be

replaced. Flux gate is the first electronic magnetometer in practical application. Fluxgate magnetic measurement instrument is now very small, easy to carry, the instrument is simple to use, cost comparison is low, so in the general survey of more.

Design of the detection device can detect the magnetic signal to the three components of the magnetic field, the signal after the preamplifier circuit filter and amplifier to obtain two harmonic measurement needs, AD7656 four frequency multiplication sampling of the two harmonic, each sampled 16 data in interrupt mode 16 bit parallel transmission to the monolithic machine, when the SCM receives up to two cycles of data, close the interrupt, single-chip microcomputer to read in the query data to the computer through the serial port circuit to send. The design used in the high precision analog-to-digital conversion technology and MCU interrupt service and the serial communication.

Software includes 3 modules: SPI communication module PWM control current output module, communication module, RS 485 MLX90316, the programming process is shown in figure3. PWM control current output module mainly through the duty cycle to adjust the current change of PWM size. The RS 854 communication module is used to receive the system instruction and in accordance with the instructions of the data back. SPI communication module of MLX90316 is mainly used for reading magnetic sensitive angle, SPI the communication process: the main control end to output of 854xAA and 955xFF as the communication initiation signal, and then the output of 99 0xFF, and from the end while the output of 55 0xFF, 4 bytes of angle signal and a4 0xFF, in order to complete a data communication.
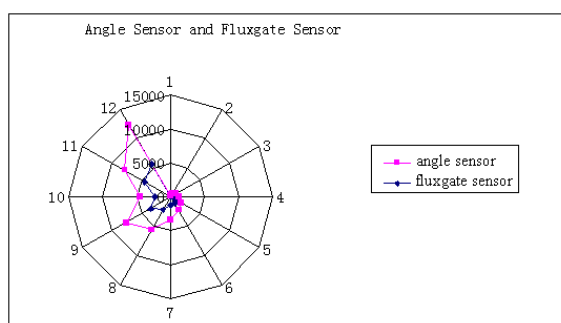


**Fig. 3. Comparison design of angle sensor and fluxgate sensor in design the smart sensor system**

Sensor is composed of magnetic blocks and the sensor is composed of two parts, the sensor itself without a rotating shaft and bearing, so that the greatest degree of convenient client installation and maintenance. Between the magnetic block and the sensor allows non magnetic media, magnetic field can be measured through the medium of space. The signal output is by a shielded cable / seal on the sensor inner conductor tinning. The output of fluxgate probe is mainly two harmonic excitation signal; need to be treated with measured data. According to the geometry of the magnetic fluxgate sensor is divided into closed and not closed.

The detecting device is mainly composed of three component fluxgate sensor, MCU minimum system, A/D data acquisition circuit and the serial port circuit. The size of the volume of vector three component fluxgate sensors detects the magnetic field, the output signal through the active filter and amplifier was obtained after processing the sine signal three amplitude and magnetic components are proportional to the size.

**CONCLUSION**

At present, many important measuring instruments, such as gyro platform, the inertial navigation platform, theologize, star tracker, radar, missile launchers, space telescope, high-precision CNC machine tools, robots and other systems generally require the angle sensor, for measuring the absolute angle relative to a benchmark object or relative to its relative angle at different times. With the development of measurement and control technology, the system control precision requirements of more and more high. The paper proposes the application of angle sensor and fluxgate sensor in design the smart sensor system. The development direction of angle sensor is to the development of high precision; to the development of miniaturized; to intelligent digital development; to the micro power consumption and passive development.

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