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The Design Method and Error Analysis of Machine Electronic Weighing Burden System Controlled by a Computer Automatically

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ABSTRACT

The system is designed for the production and processing of feed,fertilizer,sugar,and grain.It can be used to weigh and transport automatically their pellet,power or nonstickness materials.

In this system,we use discontinuous totalising automatic weighing instruments to weigh materials.It is a closed-cycle control system controlled by industrial controlling computer STD bus.

The system used for processing grain and feed can improve the quality of products,carry out scientific management,increase productivity and decrease the intensity of labour.

Key Word: Mechanism, Configuration, Error

INTRODUCTION

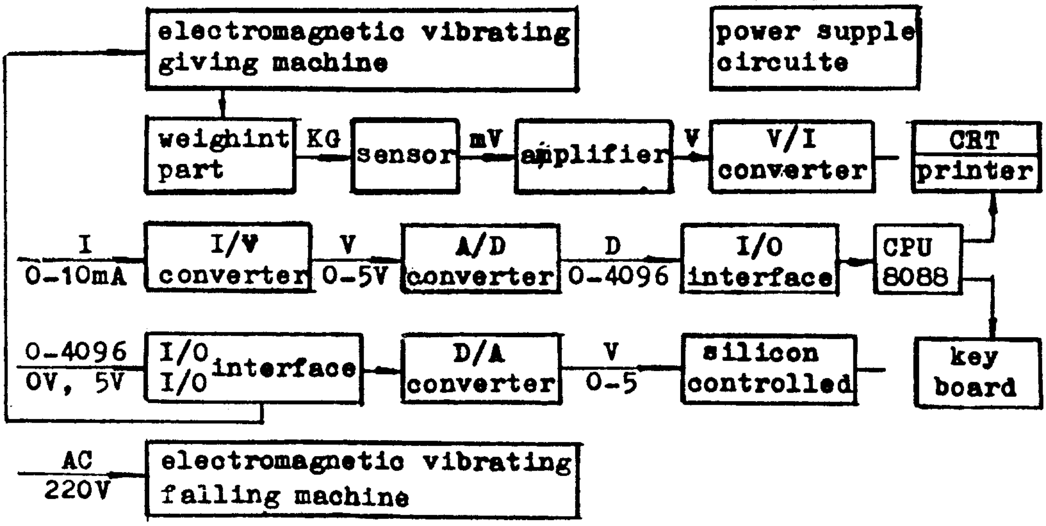
Now the world is in a new information age.Microelectronics,especially computer technology,has become the motivation of the development of science and technology.

The development of microelectronics leads to the breakthrough in the ohmic strain weighing sensor,and brings about the historical advance in mechanical electronic weighing.Nuclear belt weighers,electronic belt weighing,electronic screw-scale,roter scale, impact flowmeter and so on which are quite popular in the world at present time are included in continuous totalising automatic weighing instruments,which is used to measure imcompact materials in the transport procéss.This kind of measurement can work in the dynamic condition so it is quite difficult to improve the precision of the whole system.Discontinuous totalising automatic weighing instrument can measure the weight of pellet,power,and nonstickness materials in the basically static state condition.Its precision is higher than dynamic electronicweighers.So by using this instrument and with the help of STD BUS industrial computer,it can improve product quality,productivity and whole economical benift and decrease labour intensity in these production departments, such as food,fertilizer,cement,metallurgy,medicine,sugar and so on.It can also promote the combination of mechnics and electronics. It is the only way to make production and process automatized and achicve the best control in production process.

The accuracy in measure,real time in control and reliability in practice of mechanical electronic weighing burden system is essential in design and the key points are sensor,amplifier,power supple circuit and mechanical weighing part.So my paper mainly introduces the design and error analysis in these four parts.

1. System formation and working principle:

a. system formation:



b.Working principle process:
Switching on--electromagnetic vibrating giving machine giving materials--measuring the planned data at the same time--stopping the upper electromagnetic vibrating giving machine--putting down the sensor volume--magnifing--V/I converting--I/V converting--A/D converting--calculating gradually and handling--switching on the lower electromagnetic giving machine to move the material away--transfering with belt(in the meanwhile monitoring the amount)--meeting the planned data and modifing them--ending the process of giving and switching off

So a circle finishes.

2. Key points in design and error analysis:

a. mechanical weighing part:

the weighint part(Fig.1)is a the first reference part in measurement.Its design,assembling and debuging can result in the accuracy of the system.So the followings are quite necessary:First is that whole structure must be proper;Second is enough stiff ness and intensity;Third is to ensure its greatrepetition,that is,good recovery power;Forth is that there is no answer to torque and bending moment;Fifth is the small frictions in its active parts;Sixth is the elastic deformation in structure of passing power recovery machines of three sensors must be identical;Seventh is its good stability,reliability and technology propenty in order to process,install,debug and maintain easily and come to standerdization;Eighth is to use sealed structure in the route of flowing materials.

The hopper volume should be 30%—40% larger than its planned volume.The upper opening size should match with the falling opening of electromagentic vibrating giving machine,at the same time pay attention to its height and diameter;The angle of the low cant should be bigger than a common natural piling one.The choosing of wall thickness should calculate its stability and stiffness and meet the design demands.

Fig.1 can show you the force of weighing part;

The points for measurement is three-point suspension structure. Its accuracy is decided by force state of pulling sensor. From the figure; we can see suspending structures are used at the two ends of sensor. So the sensor can be considered as two-force lever; ideal state of sensor receives only gravity; no horizontal force and no turning force; namely Eq.(1) is....

$$F=P \quad ....(1)$$

but when F(pulling force) is not parallel to P(gravity), Eq.(2) is

$$F\cos a=P \quad ....(2)$$

From fig.2, we can see the relative errors at this time Eq.(3) is.

$$\delta=(F-P)/P.100\%$$
$$=(1/\cos -1)100\% \quad ....(3)$$

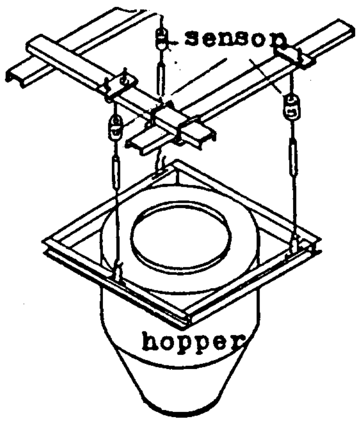


Fig.1. The hopper weigher structure diagram

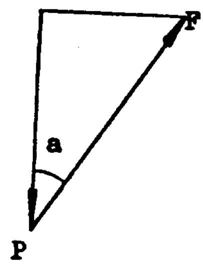


Fig.2. weighed analyse

When a increases, δ increases, too, The causes for a are:

(1) Gravity P is not on the centre of the plane of three sensors. So each of them doesn't receive the same force, which makes the lengthening of each bar different and causes the sensor inclination. This makes a produce horizontal force.

(2) Temperature difference makes the container change its shape and barycenter shifts and sensor a increases. All these cause errors. The calculation of the length of the suspendors connected with sensor is shown as the following (Fig.3) Eq.(4) is....

$$tga=dt/Lmin=R\beta\Delta T/Lmin \quad ....(4)$$
$$Lmin=R\beta\Delta T/tg\,a \quad ....(5)$$

Where dt refers to differente data of thermal expansion during the highest and lowest temperature, R refers to vertical distance from the container center to sensor center, β refers to temperature expansion coefficient, ΔT refers to data of changing intensity, a refers to permitted error cant angle.

From the two points above, the design methods are suspending points should use articulated suspenders. The front one can move forwards and backwards(seeing Fig,4),and the back two can move from left to right.In addition,pay atlention to its intensity and horizontality in order to eliminate α.

(3) The container swing causes centrifugal force F.Suppose the height of swing is H,the length of swing is L,mater is W, then Eq.(5) is....

$$F=H\cdot W/l \qquad ....(6)$$

The force leads to the changing of pulling force F,which causes errors.The design method is to install a device to limit swing (Fig,5.).

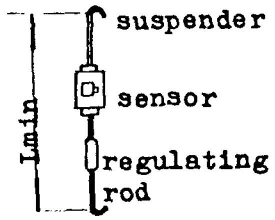


Fig.3. The calculation of the length of suspendres

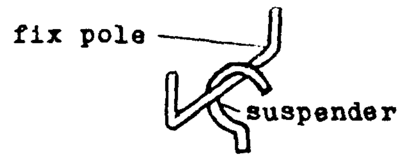


Fig.4. The suspender schematic diagram

(4) The force part of the sensor will changeits shape by turning.The solution is to add a spacing device to stop turning,which is similar to Fig,5.

(5) The friction around the suspenders makes sensor difficult to come back to its vertical state,horizontal forces are needed to make sensor come back to the position =0.So when F=P,the error will appear.The design method is to polish and give heat treatment to the surface of suspending connection so as to decrease friction.

(6) The impact of giving materials makes the weighing part vibrate up and down.That will cause the force on sensor to change periodically.There will be alternating elements in the signals. The solution is to add a low passing filter in the entry part of an amplifier to measure self-oscillating cycle and filter it.

b. Sensor design

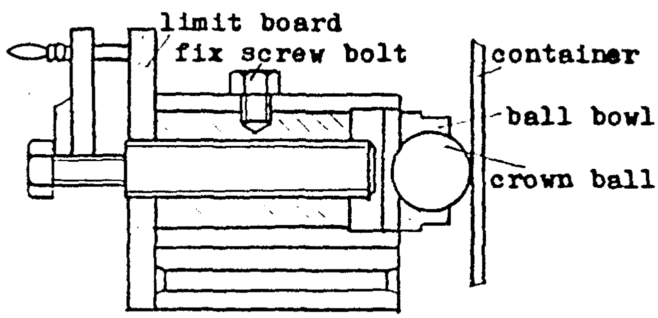


Fig.5. Device to limit swing

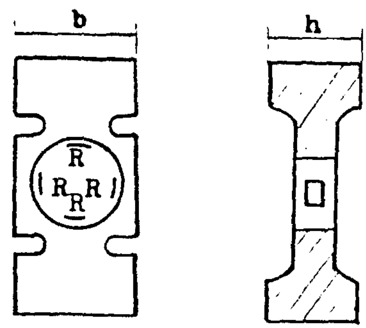


Fig.6.Sensor structure

The demands for sensor design are a good natural linear,entry response as high as possible,high ability against horizontal force,simple structure,processing manufacture and sealing easily and good stability.(Fig,6)
Board-ringlike elastic structure which is popular internationally is chose in design.It shows stability and retlability on force,strong power against impact vibration,well-distributed temperature and simple structure.Because the amplifier is closed to sensor in practice,there is little interference in transmission.So three sensors can be used in series circuit.Its working conditions should meet: $S1V1=S2V2=S3V3$ (S refers to response; V refers to supple bridge volt).The sensor should use reted range: Eq.(7) is....

$$C=K1\cdot K2\cdot K3(Wmax+W)/N \qquad ....(7)$$

Where C is the reted range of one weighing sensor,W is the dead weight of material container,Wmax is the maximum of the net weight of weighed materials,N is the number of weighing sensors, K1 is lash ratio 1-1.2,K2 is the barycenter deviation coefficient of the material container structure,K3 is the wind pressure coefficient decided by assembling position 1-1.3.(K2=1-1.2)

Its output volt Eq.(8) is....

$$VO=3KV/2bh^2\cdot E\cdot Fr \qquad ....(8)$$

where r is the radius of central cycle,V is the supple bridge volt,K is the sensitivity coefficient of strain gauge, b h is the ring's thickness and wideness,E is the elasticity modulus of mental material,F is the amount of force.About VO,we can only get a approximate calculation and need a adjustment after processing zero,temperature and sensitivity contensations are used in the circuit.See Fig,7,where RO is zero compensation ohmic resistance Eq.(9) is....

$$RO=2RVO/V \qquad ....(9)$$

where VO is no-load volt when sensor doesn't bear the weight, V is supple bridge voltage,R is bridge arm ohmic resistance,Rt is temperature compensation ohmic resistance Eq.(10) is....

$$Rt=2R\cdot\Delta VO/\alpha(tH-tL)V \qquad ....(10)$$

where R V are the same as one mentioned above, α is temperature coefficient of temperature compensation ohmic resistance,tH and tL are the highest and lowest temperatures of oil troug when measuring.

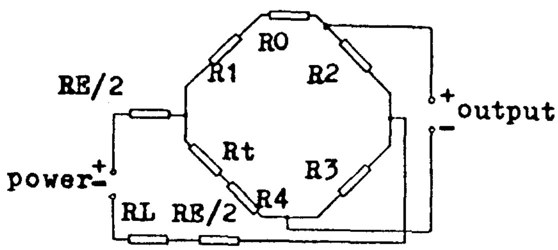


Fig.7.Sensor compensation circuit

Fetch value of sensitivity compensation resistance Eq.(11) is..

$$RE=-R/(\alpha/\alpha E+1) \quad ....(11)$$

where R α are same as the ones mentioned above, αE is elasticity modulus temperature coefficient of compensation ohmic resistance.

The sensor overload should be bigger than 120% and insulation resistance should be bigger than 1000MΩ in order to keep measurement accurate.

b. Electronic appliances:

(1). Amplifier (Fig,8):

Bessel low pass filter is added on the frond part of the amplifier.The folowings are its working processes:

When V1=0,V2=0 and V2 follows in linera and V1=V2. When alternating current signals,caused by instantaneous impact locad stress and vibration noise,are sentout,V1 goes through R1 C1 and is added to inverted input end of amplifier uA741,and R2,R3,C3, C4 constitute the amplifier feedback loop. So the higher the signal frequency is and the degeneration factor is,the bigger amplifier closed-loop gainis.Inverting amplification signals through C2 add to V1,there will be much force to offset V1.So when the higher input signal frequency is, the smaller output amplitude after filtration.Its cut-off frequency fc is decided by R2 R3 C3 C4.In Fig,8,the founction of D1 and D2 is to remove wave creast so as to avoid block.IC2 is used as a low impedance transmission driver to make screened cable potential same as A point potential in order to reject common-made interference signals.The main amplifiers IC3,IC4 and IC5 constitute a instrumentation amplifier. It uses in-phase input and is in the state of voltage series negative feedback.Therefore,its input impedance Eq.(12) is....

$$R1=2Rid\cdot Avd/Kv \quad ....(12)$$

where Rid is sheet amplifier input impedance,Avd is amplifier open loop gain,Kv is amplifier closed loop gain.

Under the circumstances of low frequency,resistor errors have a great effect on amplifier errors.The reckon method is that the magnification of IC3 and IC4 is G1 and the magnification of IC5 is G2 Eq.(13);(14) are...

$$G1=1+(R12+R13)/W1//(R10+R11) \quad ....(13)$$

$$G2=R17/R14 \quad (R14/R17=R15/(R16+W2)) \quad ....(14)$$

Total magnification Eg.(15) is....

$$G=G1\,G2=R17(1+(R12+R13)/W1//(R10+R11)) \quad ....(15)$$

In Fig,8, when ohmic resistance is changed into $R(1\pm\delta)$ Eq(16)is.

$$CMRR=G1(1+G2)/4\delta \quad ....(16)$$

Now suppose high-frequency interference signal is Vp and the error brought in by common mode rejection capacity of measuring amplifier is Δ: Eq.(17) is....

$$\Delta=Vp/(CMRR/Vi)=Vp\,Vi\cdot 4\delta/G1(1+G2) \quad ....(17)$$

From the analysis above,the adjustment of measuring amplifier ohmic resistance should be strict.Bad adjustment will bring serious effect on measuring accuracy.

IC6 and VT1 are not only V/I converters,but also constant-source .Its transmit can be used in long distance to decrease the signal decay and interference.Constant-source transmit uses the method of same ground load and the current signal acquisited by feedback resistance R23 is added to the calculating amplifier input end in form of voltage,acquisited polarity is opposite to the input signal polarity.So it is a shunt voltage feedback circuit and sample feedback signal is just output current signal. Therefore,it has the founction of constant current and strong power to drive.The equations are Eq.(18),(19).

$$Vi6/R18 \approx R23 \cdot Iout/R21 \qquad \ldots.(18)$$

$$Iout=Vi6 \cdot R21/R18 \cdot R23 \qquad \ldots.(19)$$

The zero point of V/I change is adjusted by W3,R18 and R19 should be symmetry to R20 and R21,R20 or R21≫R23,which have a direct effect on the liner of V/I converter.We can cascade a potentiometer on R21 to get Iout linear adjustment and when input voltage changes at 0—Vmax,V/I converter makes output current 0—10mA best.

The design of whole circuit board is also a key to keep the quality of amplifier,so we should prevent noise from going into the circuit and make the going current and coming current close when planning lines on the circuit board.The leakance of printed circuit board can cause noise,so pay attention to the protect of sensitive parts of leakance,and the wiring diagram of these sensitive parts should be printed on both side.The temperature difference on the two ends of ohmic resistance can also cause noise,so it should be assembled horizontally to decrease the temperature difference on the two ends.

All the electronic components can be used after decreased more than 40%.

(2). Pair cable is used to transmit signals to prevent noise from going into cable.Abalanced and imbalanced transformer is used in practive assembly which has high impedance to common-mode noise.Signal line should be away from powerful current,to avoid parallel with powerline and big current line and try to enlarge the angle included between vectors.Shielded line should connect with earth on only one end.

(3). Power supply circuit:

In power design,transformer is a key part.So,power transformer uses U-shape ironcore with primary coil and sublevel coil which shield at both sides.The core uses 2 or 3 times real power.Three groups in sublevel are wrapped in sepreate.Power output uses two constant-voltage regulators.When S,the sensor difference,is bigger,supple bridge voltage can be adjusted.

About the method,see Fig,(9). Eq.(20) is....

$$(R1+W+R2)VO/(R1+W) \quad Vdc \quad (R1+W+R2)VO/R1 \qquad \ldots.(20)$$

The other performance parameter should strictly meet the needs of design, such as constant-voltage data,dynamic internal,time drift,temperature drift,noise,ripple voltage and,operation repeatation,which can measure all technical merits by high-precision digital voltmeter.

(4). Direct error between sensor and power:

Transport cable of sensor has an effect on conductor resistance,contact resistance,cable quality,the configuration of alternating current power line and insulation resistance to ground. These factors are essiental to the sensor accuracy.So pay more attention to them.

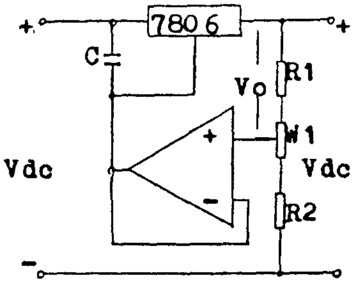


Fig.9.Output voltage adjustment

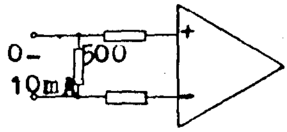


Fig.10.V/Ichanging principle

(5). See Fig,(10),about V/I changing principle.When Iout=0-10 mA,current goes through 500 high-precision resistor and changes into voltage and magnifies.The precision of I/V changing is decided by the precision of resistor.

d. Computer choosing and demands of software design:

In production process,the whole system design for automatic control must ensure reliability,anti-jamming capacity,long constant working time and the ratio between cost and effectiveness. Therefore,STD BUS industrial controlling machine is a better one. The following is the method about choosing interface board:

CUP board:The demands for operating system software are good compatibility.The board with watch dog should meet operating speed and accuracy of the system.

ROM board:decided by the size of program.

RAM board:decided by the size of arithmatic logic unit and data logic unit.It should have turn-off protect.

I/O board: decided by the numbers of switch quantity,analog quantity,photoelectric isolation,response time and accuracy demands.

OTHER EQUIPMENTS:CRT's color;density.Width of printer.Popularity of keyboard.Power extension demands.

SOFTWARE demands:Whole program block diagram.See Fig,(11).

CONTROLLING software:Try to be modularity and hierarchical structure.

APPLICATION software:Real time,flexibility,popularity,reliability and maintainability.

As for this system,it has digital filtering and uses modulation signal input method to improve A/D resolution and uses average signal method of dealing with random noise to improve accuracy. We can use error model to correct system errors and PID adjustment.It can print at the same time and have a conversation between people and machine.CRT displays process flow chart.Software mixes C language with assembler language and uses redundancy techniques to keep quality and reliability.

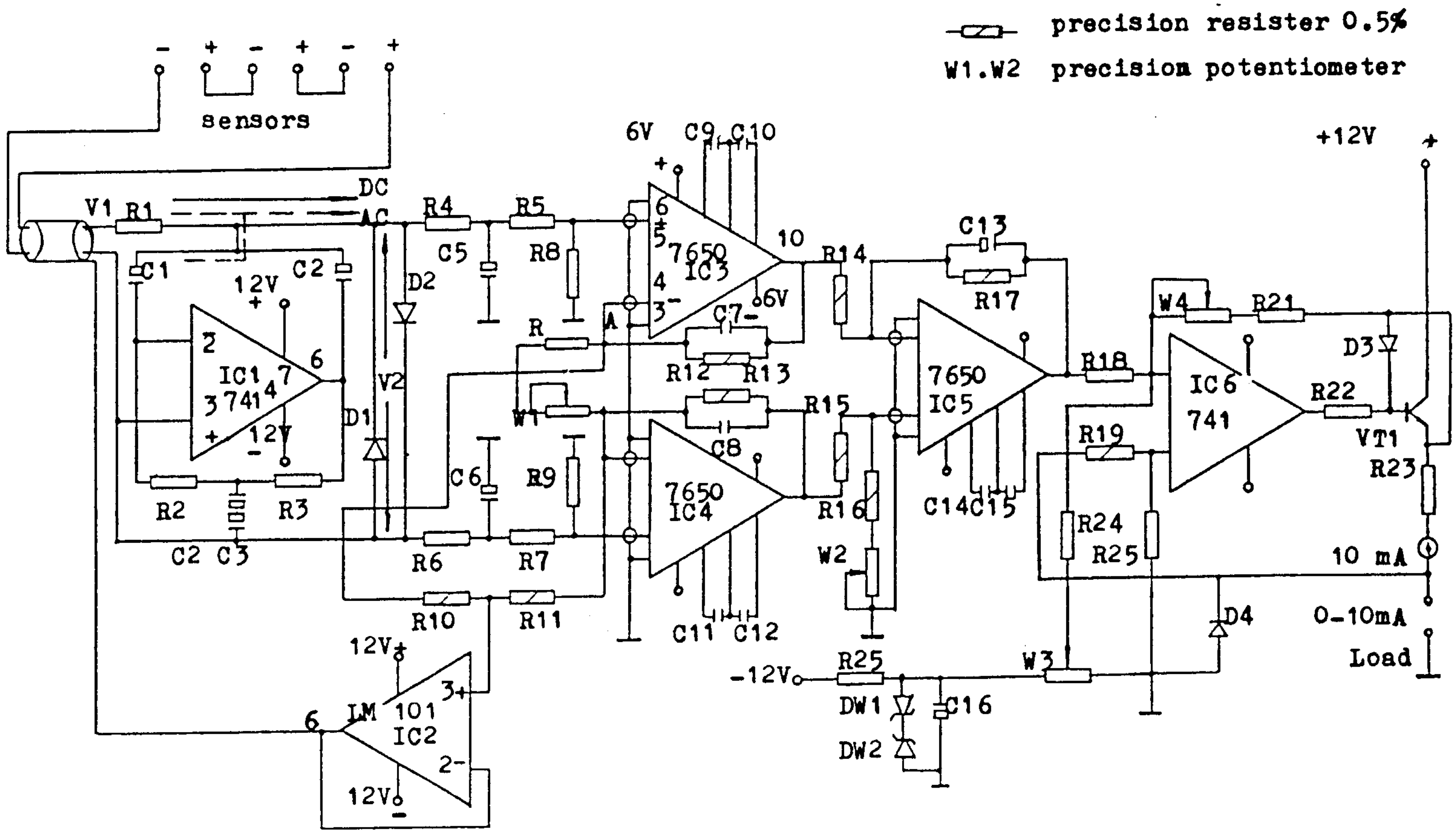


Fig.8. Instrumentation amplifier circuit

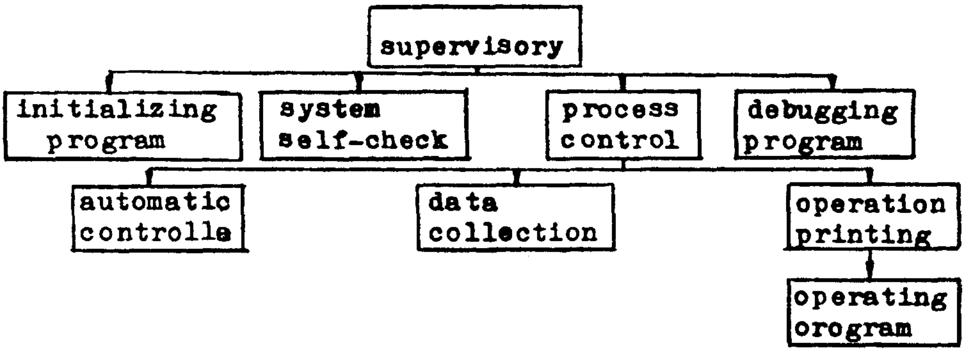


Fig.11. Whole program block diagram

e: Controlling part

Since electromagnetic vibrating machine is given more powerful current,these factors--overheat,overload and interference--should be controlled.Main circuit uses zero cross trigger circuit to control thyristor output.It can decrease radio frequency interference to power net and transient surge current and improve the working life of thyristor.

3. Concluding remarks:

In the whole system,mechanical part must be designed strictly according to the demands of production process.Strain analysis and errors of size chain are distributed reasonably.Structure of sensor should be reasonable.It is on the good strain condition, and has high elasticity,high output accuracy,low impedance,accurate revisions.

In parts of amplification;transmission and power supply;because of adverse circumstances and bad working conditions in the worksite.Interference facilities should be perfect.Weak signal should be seperated with strong power and be far away from each other.Paired cable transmission is used in transmission part.

Since the system is controlled by STD BUS computer,the difficulties which are not avoided or unable to be solved in hardware circuit in mechanical,sensor,amplification,transmission and power supple parts and they can be decreased or revised in software design.On the whole design,the relationship among each part should be fully considered.We should make full use of mechanicalness, microelectronics,software and hardware technology and give full play to the goodness of each part.

I make only one weighing system analysis in my paper.This weighing system can give many kinds of control and it is suitable to produce and process different kinds of materials.When materials need to be given continously,we can put the materials into two or three hoppers to meet the continous demands.

REFERENCES

1. Tian Yun. 1987. STD BUS industrial computer principle and application.
2. Shi Hanqian and Shong Wenmin. 1991.Electronic weighing technology.
3. Zhang Yuyou. 1991. Sonser cricuit design handbook.