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Cutting of Rebar through Flying Shear

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Abstract— **This Present Study on the Project is comprises on Advancement on Flying Shear which is one of the major part in rolling process in AGHA STEEL MILLS. They already have this machine with DC shearing motor. They want from us to replace this DC motor with AC motor with the Starting and Braking circuitry for the motor. DC motor has the following issues. It wants frequent maintenance which hurdle the running process therefore the production will be affected and its maintenance cost will be high. The function of this motor is to cut the billet in one revolution. Since the ac motor has high starting torque so we will need starting circuit and to stop motor after 1 revolution we need electrical braking system. So we will replace this DC motor with the AC motor at the field and we will made prototype of this shearing machine for the UIT with the ac motor.**

Index Terms— **Rebar, Flying Shear Cutter, Fatek PLC, AVR ATmega8 8-bit microcontroller, Analog to Digital Conversion.**

I. Introduction

A Fly Shear Machine is one of the major parts in rolling mill. The flying Shear is used for cutting metal rebar that come from the rolling mill at full speed in various custom lengths sections. Fly shear cutters, similar to those of today, were patented in 1844 and 1852 by Guillaume Massiquot. They have been around since the late 1830s, when in 1837; Thirault built a model with a fixed blade to a flat surface. Since the middle of 19th century considerable improvements have been made by form and Krause of Germany, Furnivall in England, and Oswego and Seybold in United States.[1, 2]

Functions of Fly shear Machine: [2]

1. Plc is controlling all the logical operations.
2. Rollers are running through DC servo motor.
3. Rollers are pushing wire as a cutting material in forward direction.
4. Shaft Encoder is attach with dc motor which count the length of the wire
5. Movement of cutter is done through ac induction motor.
6. Induction motor is attached vertical with screw spindle and the weight of motor used as a load on the cutter.
7. Limit switches sense the movement of cutter

Flying shears are used for cutting applications, where endless material to be cut to length cannot be stopped during the cutting process and the cut must be effected "on the fly".[2] The mechanical construction provides a saw or shear system mounted on a carriage, that follows the material with synchronous speed while cutting is in progress, and then returns to a home position to wait for the next cut. The flying shear control is based on a PLC. The system has been designed for the special requirements of flying shears under consideration of maximum efficiency and accuracy at minimum stress for all mechanical parts.

A small keypad with LCD provides easy setup, through which we can change the cutting length according to our choice. All essential registers like cutting length are also accessible by parallel interface, providing easy setting by PLC parallel output.

The drive is configured using real engineering units of choice such as meter or feet. This means that the configuration of the system is made very easy, through an operator interface or by entering configuration parameters directly on the drive. The drive will then calculate the profile and perform checks to ensure that the parameters entered are achievable, given the length of motion available, and also the required cut length.

The voltages present in the Drive and external Option Units are capable of inflicting a severe electric shock and may be lethal. The Stop function of the Drive does not remove dangerous voltages from the terminals of the Drive and external Option Unit. Mains supplies should be removed before any servicing work is performed. The Stop and Start inputs of the Drive should not be relied upon to ensure safety of personnel. If a safety hazard could exist from unexpected starting of the Drive, an interlock should be installed to prevent the motor being inadvertently started.

Applications and Designs

The Flying Shear is a common industrial application for cutting a product into smaller lengths, without stopping the line, this means that the main production process is not interrupted, and so machine productivity is maximized.

The cutting tool is typically mounted on a carriage that moves either parallel to the product flow or at an angle across the product flow. The flying shear drive accelerates the carriage to synchronize with the line speed, while synchronized the cut is done and the carriage then decelerates and returns to its original position ready to cut again. There are also many other similar applications where a carriage must be synchronized at line speed and most of these can also be accommodated using the flying shear application software.

Typical applications include various types of cut to length machines, depositors, punches, product inspection, or any other process where synchronization at line speed is required.[2]

A couple of possible applications are:

A machine extrudes plastic pipes that must be supplied to the customer in pre-cut lengths. The extrusion process requires the extruder to run at a continuous speed to maintain the quality of the product. The pipe is uniform along its length

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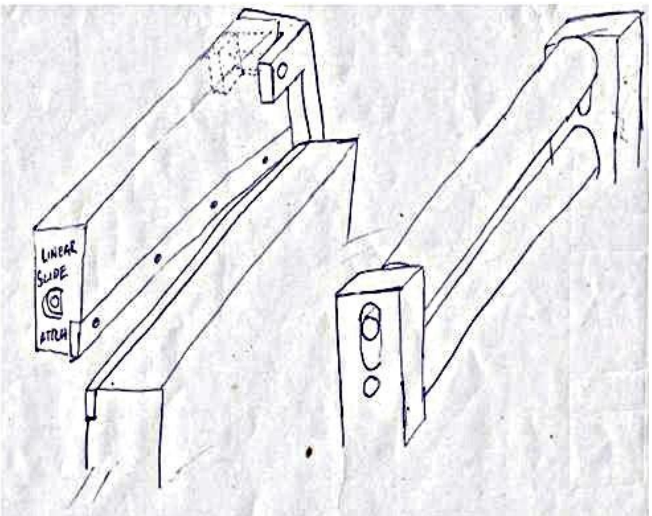
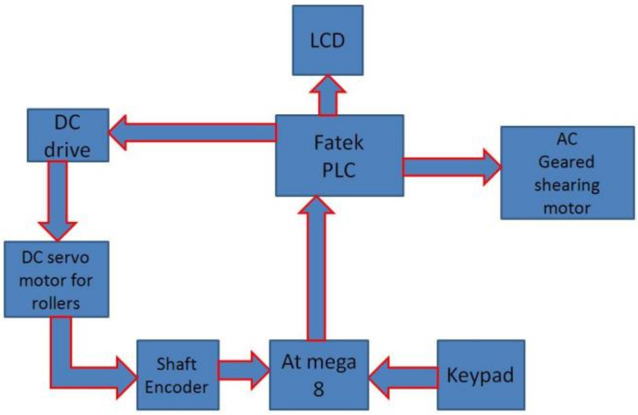
and provided the length is within a set tolerance then the pipe is fit for sale. The flying shear is used to cut the product cyclically.
The actual design of the machine that we observed in the mill was very large in size and it cut the hot billets of diameter 1\2 inch to 1 inch and length will be in several meters and it cost thousands of dollars we cannot made this machine as FYP . So according to situation we had to design the machine of small size to cut something other than hot billet. We chose the design of printer as a model as the design idea was similar to printer and select copper wire as a job .The sketch will be shown
below.





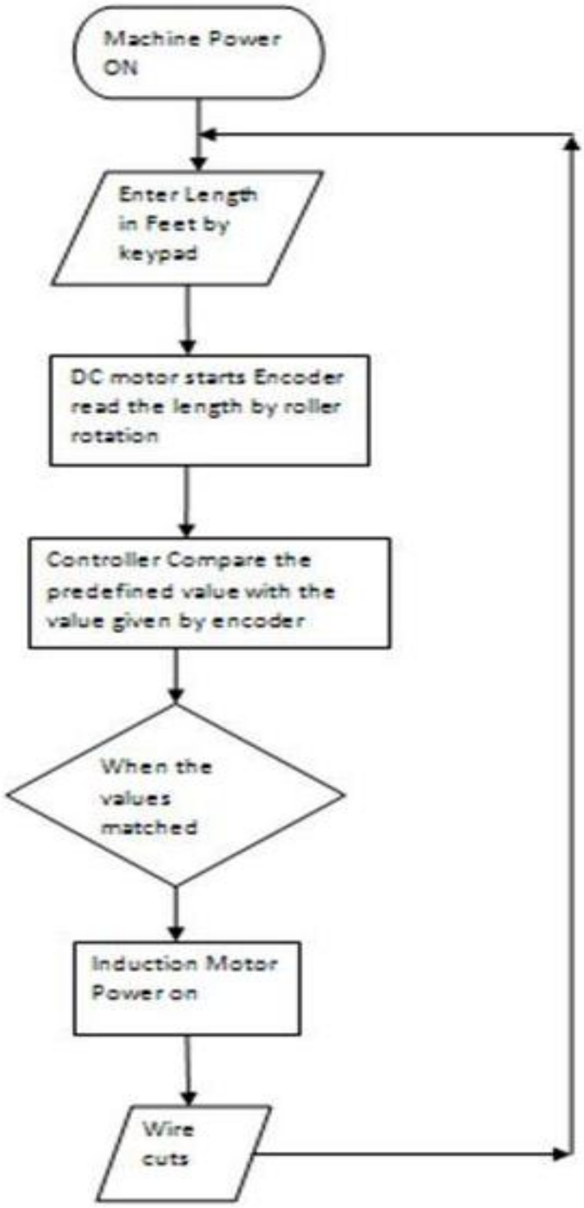
Dimensions Table

Dimension	Value
Width	25 cm
Length	37cm
Height	28cm
Weight	20kg
Iron sheet gauge	18

We used angle iron on columns and base. Welded the sheets of 18mm between those columns we made our project with heavy metal sheets because we have to minimize the vibration. Vibration is a factor due to which the machine would not perform the work efficiently and there will be the difference of cutting length. There is a folding tray on the side which is design to collect the lengths which are cut. We also fixed the sheet on the top of the machine to place the controller and graphical user interface. We weld handle on sides to carry the machine easily during shifting. For rollers we have to design the spring mechanism and also the length of roller is smaller than length of the structure so we have used screw of 2in and specially design the u-shaped adjustable brackets for the rollers. As we had no idea related to mechanical structure so we got help from my friend he was a mechanical engineer he give us the suggestion through which we could easily design the structure. The crucial phase is the designing of structure which we can achieve by the grace of Allah and kind suggestion from my friend. Structure had completed in a month.[1]

Implementation of Design and Technical Specifications

Process Flow Chart



The design of shearing machine has following general technical specification that Small size, fully automated working, and Graphical user interface for better
Operation

Equipment Name	Model Number	Rating
Fatek PLC	fb-14ma	24v DC 8 point

AC Motor	Orient Motors USM 206-402W	6W
DC Servo Motor	Pittman GM9413-5	18W
Rollers	2 no's	------
Ball screw spindle	1 no's	-------
Limit Switches	2 no's	-------
Steel Blade Tempered	1 no's	-------
Keypad	1no's	--------
Lcd	1no's	-------
AVR microcontroller	Atmega8	-------

Major Component Description Used in Project

Fatek PLC fbs-14ma

8 points 24VDC digital input (2 points high speed 100KHz, 2 points medium speed 20KHz, 4 points medium speed total 5KHz); 6 points relay or transistor output (2 point high speed 100KHz, 4 points medium speed 20KHz); 1 RS232 or USB port(expandable up to 3); I/O is not expandable[1, 3]

Specification			FBs-14MAR	FBs-14MATU
Digital Input	24VDC	High speed (100KHZ)	2 points	
		Medium speed (20KHZ)	2 points	
		Medium speed (Total 5KHZ)	4 points	
Digital output	Relay		6 points	–
	Transistor	High speed (100KHZ)	–	2 points
		Medium speed (20KHZ)	–	4 points
		Low speed	–	–
Communication Port	Built-in		1 port (Port0, USB or RS232)	
	Expandable		2 ports (Port1~2, RS485 or RS232 or Ethernet)	
Calendar			optional	
Built-in power supply			SPW14-AC/D12/D24	
Dimension			7.62mm fixed terminal block	

Ports Addressing

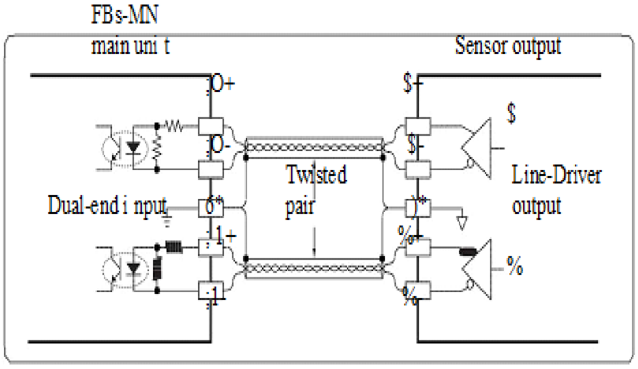
The input and output port connections are shown in the table

Input address	Function	Tag
X1	Count	3
X2	Signal	4
X3	U-Sensor	
X4	L-Sensor	

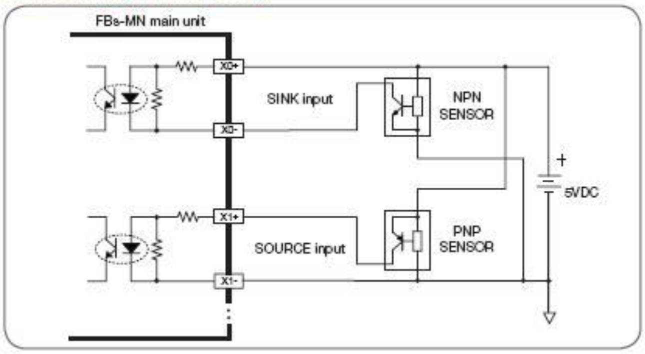
Output Address	Function	Tag
Y0	DC motor	5
Y1	AC motor cw/ccw	6
Y2	AC motor cw on	8
Y3	AC motor ccw on	7

The protection circuitry of PLC are shown in the following figures below

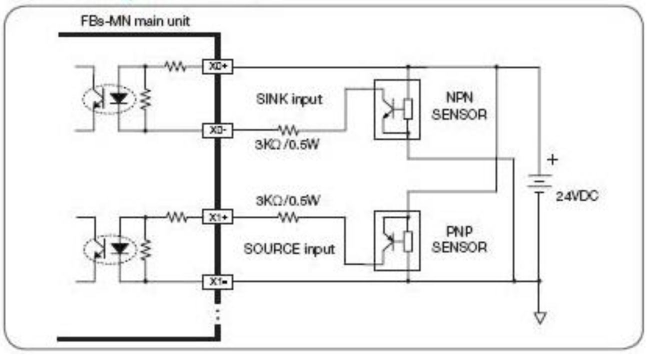
Wi ri ng of 5VDC differe ntial input (with frequency up to 920KHz, for high speed or high noise environ me nts)



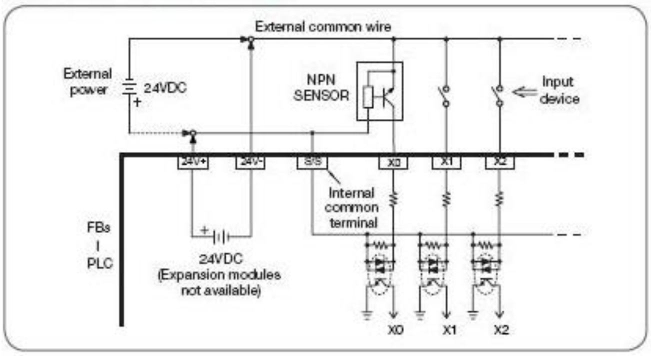
Wiring of 5VDC differential input to 5VDC single-end SINK /SOURCE input (Max. 200KHz)



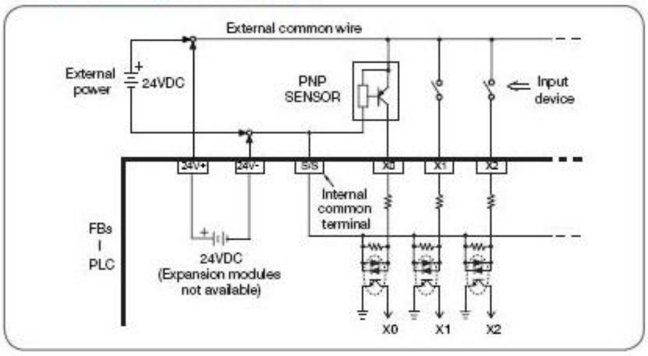
Wiring of 5VDC differential input to 24VDC single-end SINK /SOURCE input (Max. 200KHz)



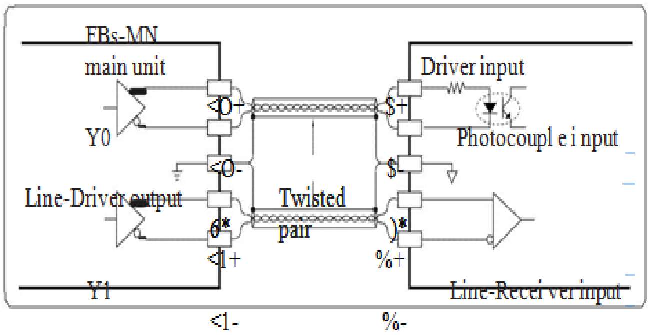
Wiring of 24VDC single-end SINK input



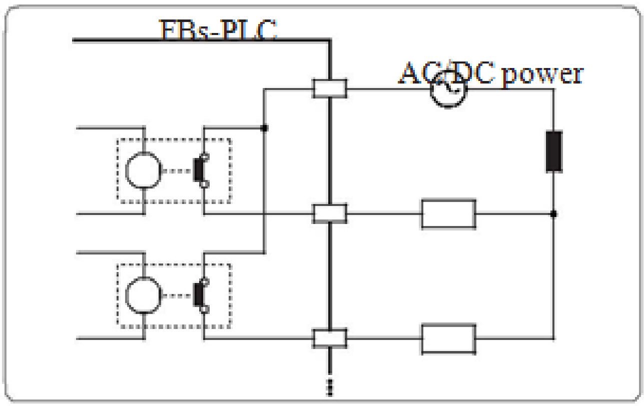
Wiring of 24VDC single-end SOURCE input



Wi ri ng of 5VDC differential output (with frequency up to 920KHz, for high speed or high noise environme nts)



Wiring of relay single-end output

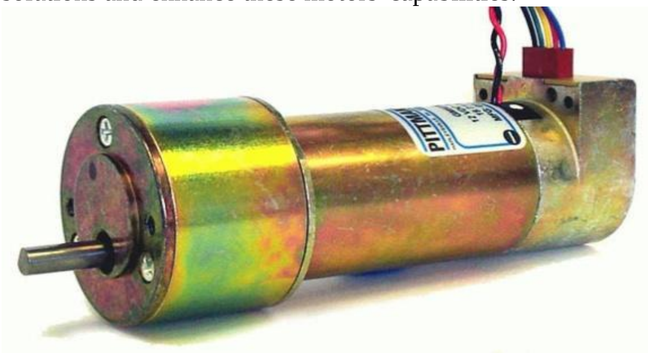


AC Induction Geared Motor

Reversible AC motors have a 30 minute rating to permit instantaneous switching of the rotational direction. A friction brake is equipped at the back of the motor, which makes reversible motors an ideal choice for applications where the rotational direction changes. All you need isto connect a capacitor and plug the motor into an AC power supply and the motor can be easily operated.[3, 4, 5]

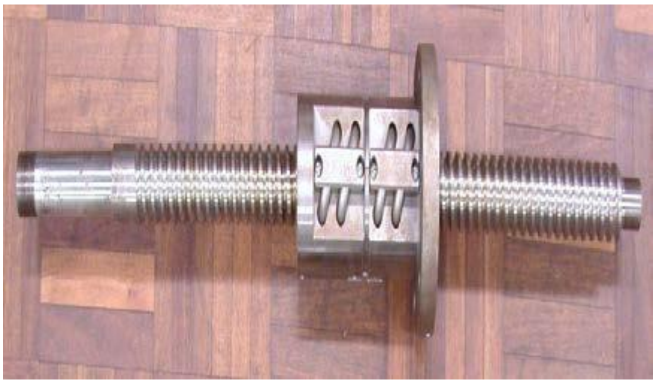
DC Servo Motor

Pittman instrument grade brushless DC servo motors are IP42 rated construction or greater and include a wide range of rated torques and speeds in a compact design. The brushless construction for extended life, low cogging, and smooth low speed performance make these motors ideal for a multitude of applications. High acceleration and power density, integral Hall Effect feedback sensors commutation and optional winding configuration, feedback devices, gearboxes, brakes, connectors, and mating cables allow tailored systems solutions and enhance these motors' capabilities.[3,6, 7, 8]



Ball Screw

A ball screw is a mechanical linear actuator that translates rotational motion to linear motion with little friction. A threaded shaft provides a helical raceway for ball bearings which act as a precision screw. As well as being able to apply or withstand high thrust loads, they can do so with minimum internal friction. They are made to close tolerances and are therefore suitable for use in situations in which high precision is necessary. The ball assembly acts as the nut while the threaded shaft is the screw. In contrast to conventional lead screws, ball screws tend to be rather bulky, due to the need to have a mechanism to re-circulate the balls.[3, 9, 10]



Steel Tempered Blade

Tempering, or heat treating, is done by heating the blade again. The difference is that it is not heated to the point that austenization occurs. Tempering uses a much lower temperature, again based on the steel used. The blade is kept at this temperature for a while, and then it is quenched again. Most blade smiths temper a blade several times to get the exact level of hardness. The idea is that the metal is hard enough to maintain an edge but not so hard that it is brittle, which can cause it to chip or crack. Therefore to easily shear the job we use tempered blade. We also try this with iron blade it cannot shearing the job easily.[3, 11, 12]

Silicon Rollers

Printer and copier rollers are used for handling paper media within printing and copy machines. They create an electrical charge or transfer thermal energy so that ink or toner is transferred to the paper and permanently fused. Typically, the paper travels through a fuser assembly that includes both a fuser roll and a pressure roll. Each roll is coated with silicone rubber, a polymeric substance that retains its flexibility resilience and tensile strength over a wide temperature range. We use pair of these rollers with spring mechanism due to this job of any thickness can easily passed through we can couple one of the roller with motor and other will be free.[13,14]

AVR atmega8 Microcontroller

The ATmega8 is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega8 achieves throughputs approaching 1MIPS per MHz, allowing the system designed to optimize power consumption versus processing speed.[3, 15, 16, 17]

Features

• High-performance, Low-power Atmel® AVR® 8-bit Microcontroller[18, 19]

• Advanced RISC Architecture [19]

−130 Powerful Instructions – Most Single-clock Cycle Execution

−32 × 8 General Purpose Working Registers

−Fully Static Operation

−Up to 16MIPS Throughput at 16MHz

−On-chip 2-cycle Multiplier

• High Endurance Non-volatile Memory segments [19]

−8Kbytes of In-System Self-programmable Flash program memory

−512Bytes EEPROM

−1Kbyte Internal SRAM

−Write/Erase Cycles: 10,000 Flash/100,000 EEPROM

−Data retention: 20 years at 85°C/100 years at 25°C(1)

−Optional Boot Code Section with Independent Lock Bits In-System Programming by On-chip Boot Program True Read-While-Write Operation

− Programming Lock for Software Security

• Peripheral Features

−Two 8-bit Timer/Counters with Separate Rescale, one Compare Mode

−One 16-bit Timer/Counter with Separate Presale, Compare Mode, and Capture

−Mode

−Real Time Counter with Separate Oscillator

−Three PWM Channels

−8-channel ADC in TQFP and QFN/MLF package

−Eight Channels 10-bit Accuracy

−6-channel ADC in PDIP package

−Six Channels 10-bit Accuracy

−Byte-oriented Two-wire Serial Interface

−Programmable Serial USART

−Master/Slave SPI Serial Interface

−Programmable Watchdog Timer with Separate On-chip Oscillator

−On-chip Analog Comparator

• Special Microcontroller Features

− Power-on Reset and Programmable Brown-out Detection

− Internal Calibrated RC Oscillator

− External and Internal Interrupt Sources

− Five Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, and

− Standby

• I/O and Packages
− 23 Programmable I/O Lines

− 28-lead PDIP, 32-lead TQFP, and 32-pad QFN/MLF

• Operating Voltages

− 2.7V - 5.5V (ATmega8L)

− 4.5V - 5.5V (ATmega8)

• Speed Grades

− 0 - 8MHz (ATmega8L)

− 0 - 16MHz (ATmega8)

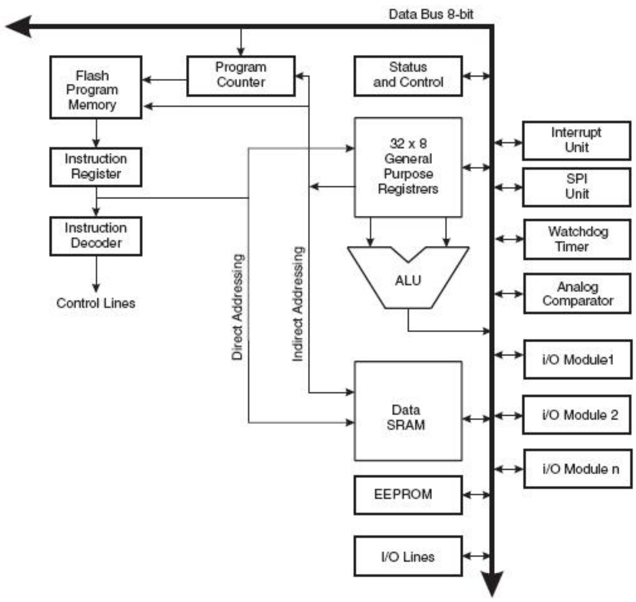
• Power Consumption at 4Mhz, 3V, 25 C

− Active: 3.6mA

− Idle Mode: 1.0mA

−Power-down Mode: 0.5µA

Block Diagram of the AVR MCU Architecture[18]



We use two features of ATmega8 Microcontroller:

1. Analog to Digital Conversion
2. Analog Comparator

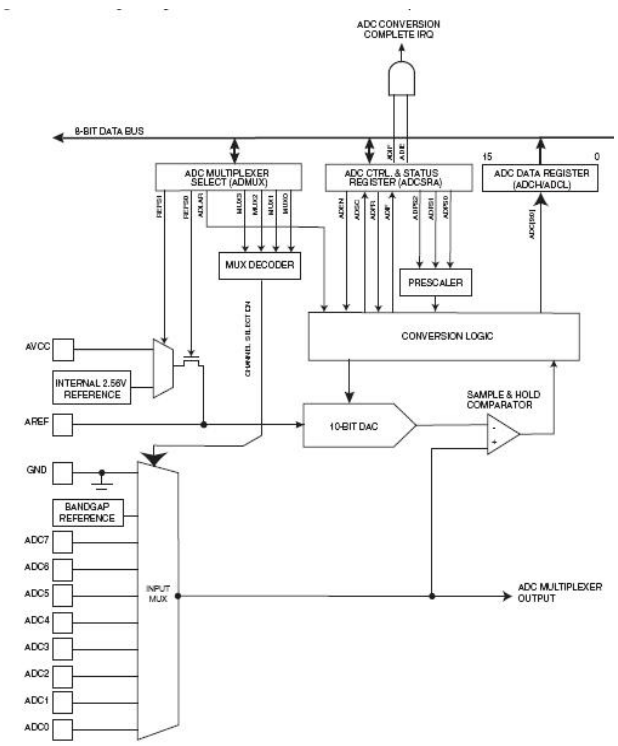
1. Analog to digital Conversion

The ADC converts an analog input voltage to a 10-bit digital value through successive approximation. The minimum value represents GND and the maximum value represents the voltage on the AREF pin minus 1 LSB. Optionally, AVCC or an internal 2.56V reference voltage may be connected to the AREF pin by writing to the REFSn bits in the ADMUX Register. The internal voltage reference may thus be decoupled by an external capacitor at the AREF pin to improve noise immunity.[20, 21, 23]
The analog input channel is selected by writing to the MUX bits in ADMUX. Any of the ADC input pins, as well as GND and a fixed band gap voltage reference, can be selected as single ended inputs to the ADC. The ADC is enabled by setting the ADC Enable bit, ADEN in ADCSRA. Voltage reference and input channel selections will not go into effect until ADEN is set. The ADC does not consume power when ADEN is cleared, so it is recommended to switch off the ADC before entering power saving sleep modes.
The ADC generates a 10-bit result which is presented in the ADC Data Registers, ADCH and ADCL. By default, the result is presented right adjusted, but can optionally be presented left adjusted by setting the ADLAR bit in ADMUX.[20, 22]
If the result is left adjusted and no more than 8-bit precision is required, it is sufficient to read ADCH. Otherwise, ADCL must be read first, then ADCH, to ensure that the content of the Data Registers belongs to the same conversion. Once ADCL is read, ADC access to Data Registers is blocked. This means that if ADCL has been read, and a conversion completes before ADCH is read, neither register is updated and the result from the conversion is lost. When ADCH is

read, ADC access to the ADCH and ADCL Registers is re-enabled.[21, 23]

The ADC has its own interrupt which can be triggered when a conversion completes. When ADC access to the Data Registers is prohibited between reading of ADCH and ADCL, the interrupt will trigger even if the result is lost.

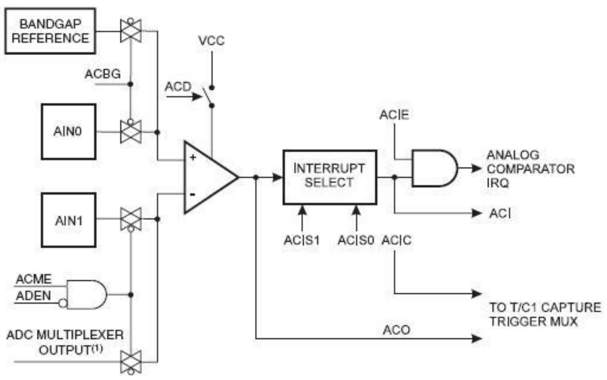
Analog to Digital Converter Block Schematic Operation



2. Analog Comparator

The Analog Comparator compares the input values on the positive pin AIN0 and negative pin AIN1. When the voltage on the positive pin AIN0 is higher than the voltage on the negative pin AIN1, the Analog Comparator Output, ACO, is set. The comparator's output can be set to trigger the Timer/Counter1 Input Capture function. In addition, the comparator can trigger a separate interrupt, exclusive to the Analog Comparator. The user can select Interrupt triggering on comparator output rise, fall or toggle. A block diagram of the comparator and its surrounding logic is shown in figure[23, 24]

Analog Comparator Block Diagram



Operation of Machine

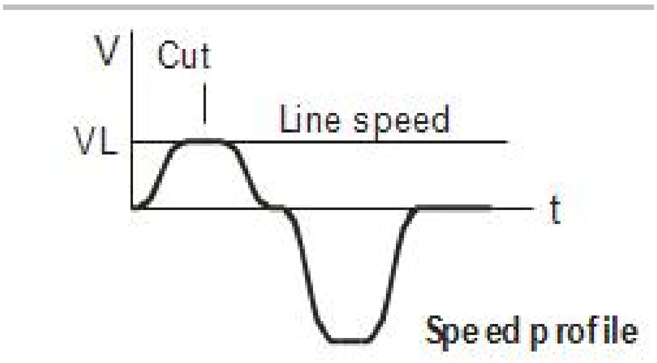
The shear (or blade) is fixed on a AC motor that can move forward and reverse under control of a +/- 220V speed reference voltage of the carriage drive. Normally, a 4 quadrant DC servo motor is used for driving the rollers. For lower requirements in performance, the Fbs-20ma unit can also control

AC motor is attached with ball screw to convert circular motion into linear motion through which blade moves vertically up or down and Weight of motor used as a load on the blade trough which wire shear easily without any delay.

The built-in encoder DC servo motor counts the length from the line encoder (feed roll or measuring wheel) and also derives the rollers;

The Fatek Fb20ma controls dc servo motor when the desire length counted the encoder gives feedback signal to the plc and plc gives signal to the AC induction motor and induction motor become on and cut the job and comes to its home position.

The two limit switches are used for sensing the lower and upper limit of the blade. A "Ready to cut" signal is generated in order to start the cutting process, while the shear moves fully synchronous with the cutting position on the material. When the cut is completed, the PLC must receive a "cut complete" signal. This will cause a deceleration and a reversal of the carriage until it has reached its home position again. All speed transitions occur with a smooth sin² speed profile for absolutely careful treatment of screws and other mechanicals parts The PLC control continuously measures the line speed and calculates an anticipation value to start the carriage before the cutting length is reached. Thus the shear will exactly match the cutting position of the material upon completion of the acceleration ramp and no over swing or oscillation will take place prior to the cut. This saves time and increases the cutting efficiency of the shear system considerably.[24, 25]



Problems and Troubleshooting

Accuracy considerations

It is easy to understand that the PLC functions are based on correct information from the encoders. When you observe the LED at the moment when a cut takes place, you can easily see what the theoretical cutting error can be. In practical applications, with the drive and the unit properly adjusted, the cutting error should be limited to 4-7 encoder increments and the resolution of the encoders will give the real error expressed in length units. Where you find the real errors are more than indicated by the LED, you must check for the following items:[25]

- Slip of the feed roll or the measuring wheel...

- Measuring wheel not exactly orthogonal to the material line or not exactly round, or tolerance in diameter.
- Length change of the material between the measuring wheel and the position where the cut takes place (i.e. shrinking of hot material that cools down or stretching due to mechanical deformation prior to cut).
- Clearance or backlash of the carriage drive or the cutting tool etc.
- Noise on the line encoder signal or the carriage encoder signal.
- Noise on the encoder signals can cause cutting errors as well. Noise on the carriage encoder signal can easily be detected because it causes the home position of the carriage to shift.
- Noise on the line encoder signal can be detected by reading the register "<5" (see "8. Auxiliary register and command codes").This register must always contain the number of pulses of the line encoder (including multiple edge count). If the contents of this register varies by more than
- +/- 1 encoder increment there is noise on the line encoder signal that involves cutting errors. Using this function requires the Z and Z' outputs of the line encoder to be connected to the FS150 controller.
- An incorrect synchronous ratio (values of parameters "Pulses Line/1000" or "Pulses Cut/1000" incorrect) can cause considerable cutting errors that are particularly big when the line speed changes. To check your synchronous ratio proceed as follows: First check the parameter "Pulses Cut/1000" (either by calculating it from your theoretical machine data or – if you are not 100% sure that the theoretical data are correct - by measuring it).

To measure this parameter you can use the carriage position counter ":4" that counts the carriage encoder pulses. Next move the line forward until there is material under the shear, stop the line and perform a flying cut. Then switch the Start/Stop-Input to high and start the line. Measure the first piece of material that has been cut after the line has been started and compare its length with the length preset of the FS150 controller. If the measured length is shorter than the length preset the value of parameter "Pulses Line/1000" is too low and must be increased. If the measured length is longer than the length preset the value of parameter "Pulses Line/1000" is too high and must be decreased. Repeat this procedure until you have found the correct setting of "Pulses Line/1000" (measured length and length preset are equal). If all of the above points have been checked and eliminated the remaining cutting errors can basically consist of two components: The electronic cutting error caused by the PLC (which can be seen on the LED display) and the error caused by the length measurement (slip of the measuring wheel etc.). There is a fundamental difference between these two errors: The electronic error is independent of the cutting length whereas the length measurement error generally is proportional to the cutting length. Hence the two errors can be separated by a linear correlation function.

Example:

Measuring 100 pieces of L = 0.5m, 1m and 2m at the same line speed has shown the following cutting errors: L = 0.5m			L =	0.4mm	L = 1.0m
L =	0.5mm	L = 2.0m	L =	0.7mm Hence, we have the following	
equation for L :		= 0 .3mm	0 .2 mm		
L = m	x L.				

Consequently the electronic cutting error (that is independent of the length) is ± 0.3mm and the length measurement error (that is proportional to the length) is ± 0.2mm/m.

It must be pointed out that the front LED's are a reliable means to judge the cutting error. A rough estimation of the electronic cutting error can be obtained by reading the registers ";5" and ";6" that store the minimum and the maximum of the carriage position error from the "ready to cut"- to the "cut complete"-signal (unit: carriage encoder pulses; must be converted to length units by using parameter "Pulses Cut/1000"). When the line and/or the carriage do not move smoothly, you could find 4 or even more LED's ON at the time where we cut takes place. This however, in general, does not mean higher cutting errors. The LED's are updated with a 100 µsec scan and display any kind of vibration, whilst the drive operates in a millisecond range and performs the average of what the LED's say.

Interfacing PLC with Microcontroller

As we wired the components we faced the problem of interfacing between PLC and microcontrollers. Because there is a difference between the microcontroller output voltages and plc input voltages so we eliminate that compatibility problem by using signal conditioning circuitry.[26, 27, and 28]

Frequency Matching

When we connect shaft encoder with plc the counter of PLC doesn't counting the pulses of encoder. We examine the output of encoder on oscilloscope and note the frequency then we sees the frequency of PLC counter there is a difference in the values of frequency output. The frequency of encoder is 38 kHz while the frequency of PLC I/O was 20 KHz. We have two options to resolve that problem[29, 30]

1. Replace fatek PLC fb14ma with fb14mc.

2. Use microcontroller for pulse counting

   Replacing the PLC was very expensive option so we go for microcontroller option and due to this problem we can learn both PLC and Microcontroller in our project tenure.[29]

Power Supply

We design 24v dc power supply for the project when we connect all the components and test run the machine the machine was restarting automatically. So we examine the circuitry and after hard struggle we find the fault. When the load increases the voltages of supply was dropped. So we design another Power supply and distribute the load. After that the problem would be resolved.[31, 32]

Proposed Solutions and Results:

- The drives used must be dimensioned correctly with respect to power and dynamics required. The PLC can never provide good operation outside the physical limits of the drives. Both drives must be adjusted for a proper stand-alone operation with no oscillation, by means of a remote speed reference voltage. The reference inputs must be potential free.
- The resolution of the TTL-encoders, in principle, should be as high as possible, in order to keep the mechanical phase error as small as possible when the controller "plays" a few encoder increments around the zero error position. However it would be nonsense to choose the number of paper much higher than needed or reasonable. If, for example, a gear box with several 0.1 mm of clearance is installed, a 0.01 mm resolution of the encoder could cause slight stability problems.
- The PLC loads each encoder channel with a current of 15 mA. For this reason, one encoder is unable to supply the impulse input of several target units at a time, as needed with some multi drive systems. In such applications, our impulse distributor must be used to feed several controllers from one encoder.
- Please note, that not all types of cables are suited to transmit frequencies as high as 300 kHz! However, with proper installation and screening, the RS 422 lines provide perfect transmission even over long distances.
- The cross section of encoder cables must be chosen with consideration of voltage drop on the line. The power supply provides a 5.2 V encoder supply and at the other end the encoder must at least receive it‘s minimum supply voltage! (See encoder specifications). Please observe the unit accepts at maximum 300 kHz of encoder frequency.
- You must strictly observe all rules and specifications given in the drive manual and all general safety and installation standards. Use shielded power cables for the motors. Keep distance between power cables and electronic cables. Put filters to all inductive equipment installed in the same cabinet (i.e. RC filters in parallel to coils of AC contactors, diodes in parallel to electromagnetic DC values etc.) Make sure your cabinet and your machine have a solid earthing/grounding system. PLC possesses excellent features with EMC immunity, but it can fail under poor electrical environment conditions.
- If you need to switch electronic signals by relay contacts, it is necessary to use relays with gold contacts.

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