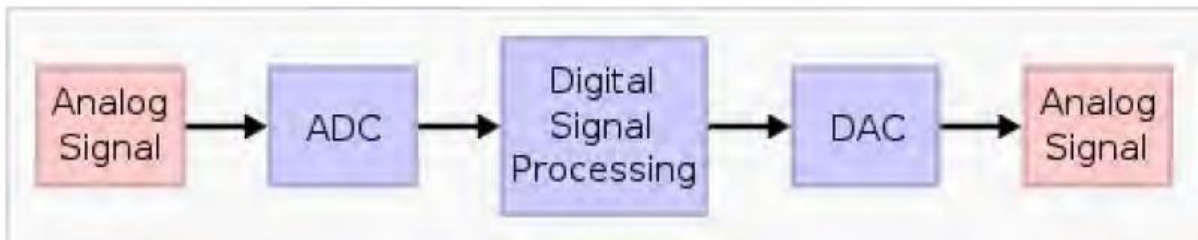


# DSP BASED MOTOR CONTROL

## Digital Signal Processor

Digital signal processing algorithms require a large number of mathematical operations to be performed quickly on a set of data. Signals are converted from analog to digital, manipulated digitally, and then converted again to analog form, as diagrammed below. Many DSP applications have constraints on latency; that is, for the system to work, the DSP operation must be completed within some time constraint.



A simple digital processing system

Most general-purpose microprocessors and operating systems can execute DSP algorithms successfully. But these microprocessors are not suitable for application of mobile telephone because of power supply and space limit. A specialized digital signal processor, however, will tend to provide a lower-cost solution, with better performance and lower latency.

- DSP often use special memory architectures that are able to fetch multiple data and/or instructions at the same time:
  - Harvard architecture
  - Modified von Neumann architecture
- Use of direct memory access
- Memory-address calculation unit.

Modern signal processors yield greater performance. This is due in part to both technological and architectural advancements like lower design rules, fast-access two-level cache, (E)DMA circuit and a wider bus system.

## **Applications of DSP**

The main applications of DSP are audio signal processing, audio compression, digital image processing, video compression, speech processing, speech recognition, digital communications, RADAR, SONAR, seismology, and biomedicine. Specific examples are speech compression and transmission in digital mobile phones, room matching equalization of sound in Hifi and sound reinforcement applications, weather forecasting, economic forecasting, seismic data processing, analysis and control of industrial processes, computer-generated animations in movies, medical imaging such as CAT scans and MRI, MP3 compression, image manipulation, high fidelity loudspeaker crossovers and equalization, and audio effects for use with electric guitar amplifiers.

## **Implementation of DSP**

Digital signal processing is often implemented using specialized microprocessors such as the DSP56000, the TMS320, or the SHARC. These often process data using fixed-point arithmetic although some versions are available which use floating point arithmetic and are more powerful. For faster applications FPGAs might be used. Beginning in 2007, multicore implementations of DSPs have started to emerge from companies including Freescale and Stream Processors, Inc. For faster applications with vast usage, ASICs might be designed specifically. For slow applications, a traditional slower processor such as a microcontroller may be adequate.

Aim:

1. To control the speed of motor using DSP controller.
2. To study the variation in settling time and peak overshoot by the variation of the PID controller settings.

Apparatus required:

1. DSP Trainer Kit(TMS320F2407)
2. 3 phase induction motor (2.2kW, 415V, 4.4A, 50Hz, 1435rpm) with speed sensor
3. 3 phase autotransformer
4. IPM based power module
5. PC with DSP software(C2407 serial Monitor software).

#### Procedure:

1. Load the software to the PC
2. Open the software
3. Switch on the DSP trainer kit and the motor starter.
4. Connect the DSP kit and controller module
5. Open the folder and select the control required
6. Give the PID parameters
7. Run the program
8. Verify the speed response of the motor by varying the controller settings.

#### Description:

Speed of the AC induction motor can be controlled by varying the input voltage to the motor. This can be achieved by using a DSP kit to produce variable voltage. Variable voltage is produced by triggering the IGBT's in the power module at different angles. DSP processor is producing the necessary PWM gating signals for the IGBT triggering. Speed sensor will sense the speed and gives equivalent voltage signals to the power module. From power module, control signal are fed to the DSP through ADC. PWM signals from the DSP are given back to the power module which controls the speed of the motor. Hence it is a feedback system. We can vary the PI controller settings and verify the controller performance.

#### Observation:

Open loop control:

P	I	D	CURRENT	% OVERSHOOT	SETTLING TIME

Closed loop control:

P	I	D	CURRENT	% OVERSHOOT	SETTLING TIME

Result:

Speed of AC motor is controlled by using digital signal processor. The controller settings are varied and observed the behavior of the system according to the different settings.

### **Microcontroller Experiments**

**80196 Microcontrollers**

## Architecture

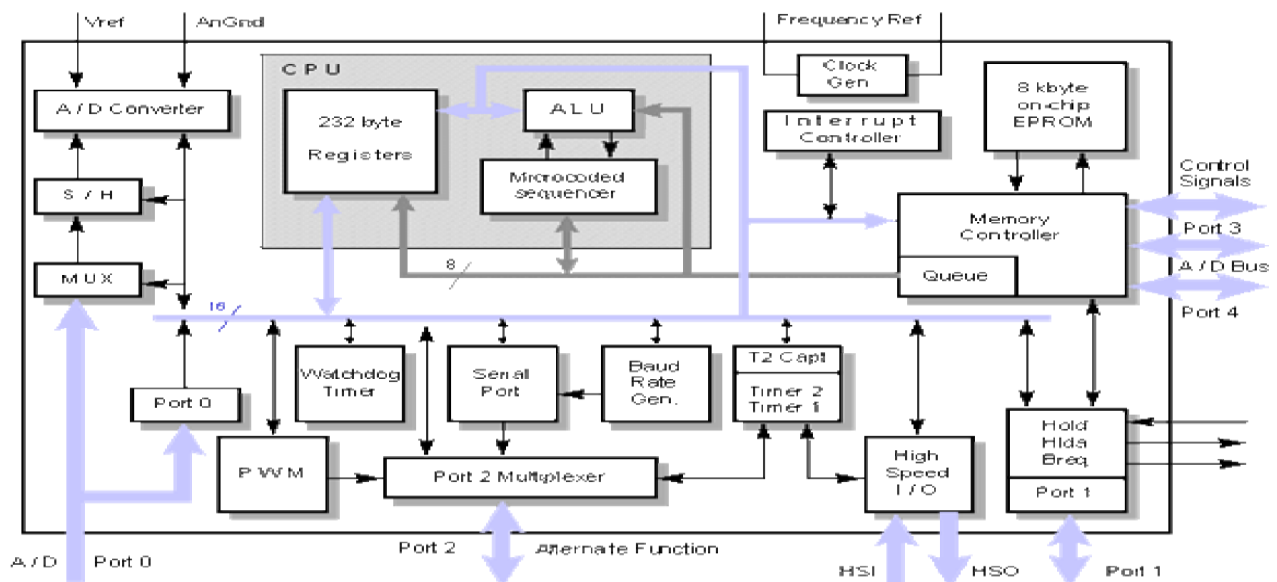
The 80c196 is mainly based on :

1. A CPU which is turn composed of a 16-bit ALU with temporary registers, a 256-byte RAM used as 24 special registers and 232 general registers, and a microprogrammed sequencer.
2. A memory controller with a 4-byte FIFO queue to prefetch instructions and data from the program memory.
3. A set of I/O interfaces.

The CPU gets his information only through the memory controller and the special registers also called Special Function Registers (SFRs).

The ALU, is associated to a set of temporary registers (with shifter, counter, constants) and thus called RALU (Register ALU). The RALU doesn't use an accumulator but instead is able to directly work with any of the 256 special or general registers.

All I/O operations are controlled through the SFRs.



## Memory controller

All of the program memory and external data memory are transferred to the CPU through the memory controller. The memory controller consists of a slave program counter, an instruction queue

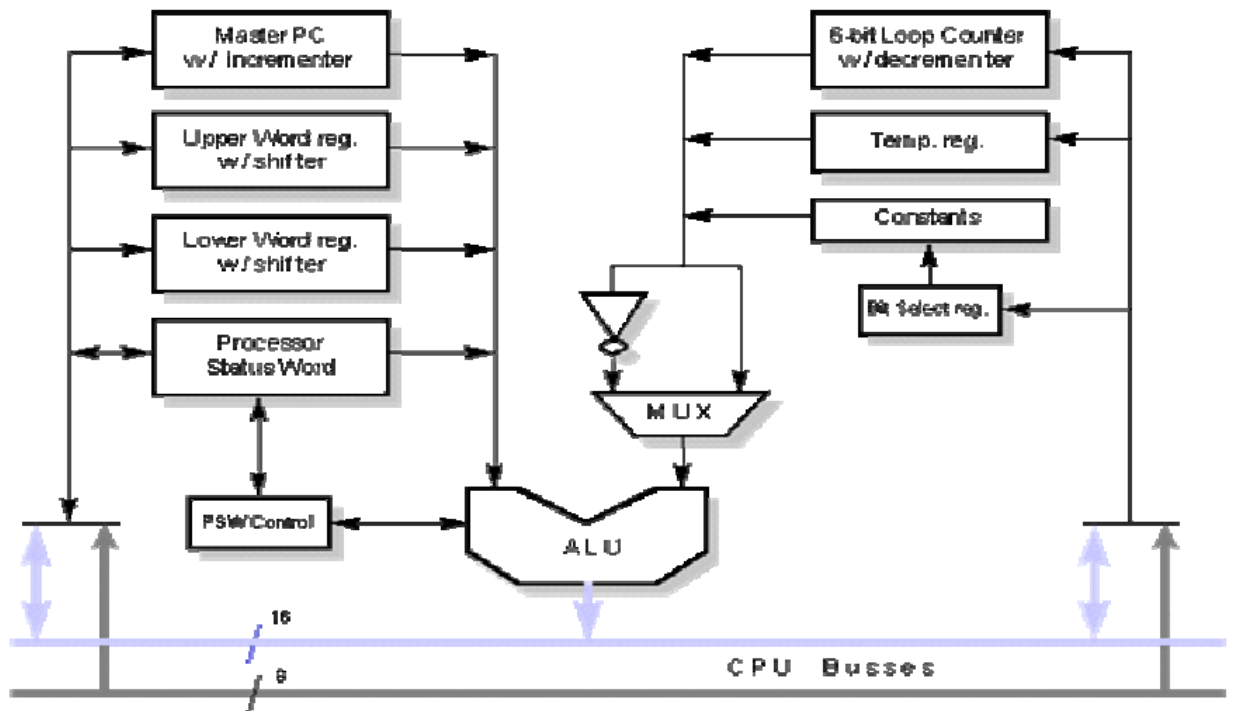
and a bus controller. The slave program counter keeps track of the instructions fetched from the program memory. Instructions fetched by the memory controller are stored in the queue. The slave program counter may be up to four bytes ahead of the main program counter (which is located in the RALU), because it is pre-fetching the instructions. The bus controller access program memory (on-chip EPROM) and external data memory and arbitrates between instruction fetches and data reads and writes. The bus controller supports both 8-bit and 16-bit external bus modes. Memory access requests to the bus controller can come from either the RALU or the queue, with priority given to the queue accesses. If the address sequence changes because of a jump interrupt, call or return, the slave PC is loaded with a new value, and the queue is flushed. Reloading the slave PC, flushing the queue and fetching the first byte of the new instruction stream takes 4 state times. This is reflected in the conditional jump taken/nottaken execution times.

### **The CPU**

The CPU is controlled by a microcode sequencer and can perform operations on any byte, word or double-word in the 256-byte register space. Instructions to the CPU are taken from the prefetch queue and temporarily stored in the instruction register. The sequencer decodes the instruction and generates the correct sequence of events to have the RALU perform the desired operation.

### **The RALU**

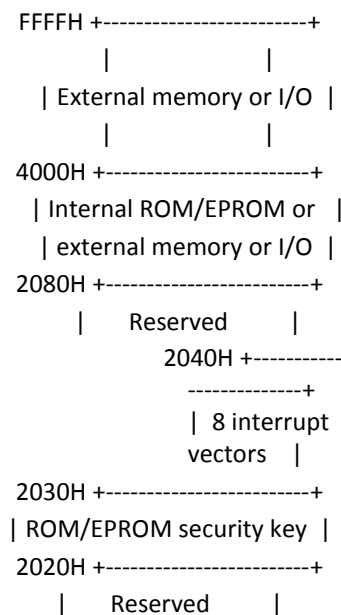
Most calculations performed by the 80c196 take place in the RALU. The RALU contains a 17bit ALU - Arithmetic and Logic Unit, the flag register also called PSW - Program Status Word, the main PC - Program Counter, a loop counter and three temporary registers. All registers are 16-bits or 17-bits wide. The PC has a separate incrementor as to access operands. However, PC changes due to jumps, interrupts, calls and returns are handled through the ALU. Two of the temporary registers have their own shift logic. These registers are used for the instructions which require logical shifts, including Normalize, Multiply and Divide. The upper word and lower word registers are used together for the 32-bit instructions and as temporary registers for many other instructions. Repetitive shifts are counted by the 6-bit loop counter. A third temporary register stores the second operand of two-operand instructions. To perform subtractions the output of this register can be complemented before being placed into the input of the ALU. The RALU also stores several constants such as 0,1 and 2 to speed up certain operations like getting a 2's complement, incrementing or decrementing.

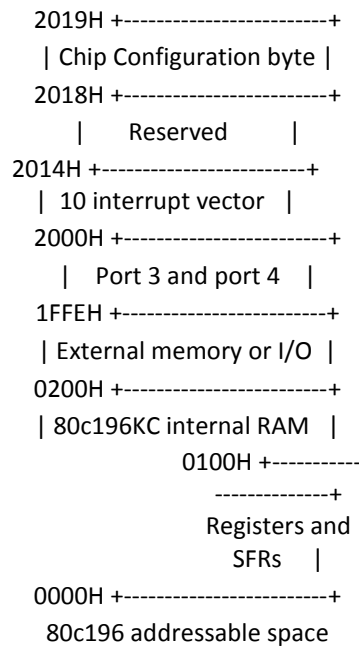


The Register Arithmetic and Logical Unit

### Addressable space

The addressable memory space of the 80c196 consists of 64k bytes. However, not all these addresses are available to the user. Addresses 0000H through 00FFH and 1FFE H through 207FH are reserved for special purposes. All other locations can be used for either program or data storage, or for memory-mapped I/O.





### Registers (internal RAM)

Locations 00H through OFFH contain the 232 general registers and the 24 SFRs - Special Function Registers. The RALU can operate on any of these 256 internal register locations, but code cannot be executed from them. If attempt is made to execute instructions from locations 00H through OFFH, the instructions will be fetched from external memory. This section of external memory is generally used by the Intel development tools. Locations 018H through OFFH are the general registers. These locations can be accessed as byte, word or double-word registers, and can be essentially considered as 232 accumulators. Locations 018H and 019H contain the stack pointer. Operations to the stack cause it to be built down and the stack pointer is decremented, so the stack must be initialized by the user program to 2 bytes above the highest stack location. The stack pointer **must** point to a word (even) address.

### Special Function Registers (SFRs)

Locations 00H through 017H are the I/O control registers or SFRs. All of the peripheral devices of the 80c196 except ports 3 and 4 are controlled through these registers. SFR functions are controlled through 3 windows. Switching between the windows is done using the WSR - Window Select Register located at address 014H. SFR windows other than WSR = 0 are out of the scope of this course. Some of the Special Function Registers have different meanings if read from or written to.

### Reserved memory locations

Locations 1FFEh and 01FFFh are used for Ports 3 and 4 respectively. Many reserved and special locations are in the memory area between 2000H and 2080H. The 18 interrupt vectors, the chip configuration byte and the security key are located in this area. All the addresses marked *Reserved* in



this area have to be programmed with value 0FFH. 2080H is the normal program start address. A *reset* interrupt restarts the program at address 2080H.

Exp No:                    GENERATION OF PWM SIGNAL USING

Date:

## 80196 MICRO CONTROLLERS

Aim:

To generate PWM signals using 80196 micro controllers.

Apparatus required:

1. 80196 Trainer kit
2. Key board
3. CRO
4. Connecting probes Theory:

The Intel 80196 features quick register to register transfers. The quick transfers are made possible by the absence of an intervening accumulator that would otherwise constrict data flow. The architecture has at least 230 bytes on chip RAM that may be operated upon as bytes, words, or double words. The RAM registers can interconnect through a 16 bit bus with themselves and a 16 bit ALU with the idea that each of the 232 registers is an "accumulator". The ALU of the 80196 has two 17 bit input ports (16bits + sign) denoted as "A" and "B" respectively. Temporary "Upper T1" and "Lower T1" word registers give input to the A port while Temporary "T2" and "Constant" registers input to the B port. The "Upper" and "Lower" registers have independent shift capabilities, but may be coupled and shifted together as a 32 bit unit. These registers are used for the repeated shift and add (shift and subtract) operations of multiplication (division). In between the "Temporary" and "Constant" registers and the ALU B port is a multiplexed inverter. The inverter gives a 1's complement of the "Temporary" register. A further edition of 1 from the "Constant" register gives a 2's complement.

Program:

Address	Op-code	Label	Mnemonic	Description
---------	---------	-------	----------	-------------

		A1	EQU 1A	
8200	B0 16 1A		LDB A1,16	Load register byte
8203	91 01 1A		ORB 1A, #1	Overwrite byte
8206	C4 16 1A		STB 1A, 16	Store byte
8209	B1 7F 17		LDB 17, #7F	Load byte
8206	27 FE		SJMP 810C	Termination of program

Procedure:

1. Enter the above program
2. Using an oscilloscope, observe the PWM output at 12<sup>th</sup> pin of the analog I/O connector P2 (now the duty cycle is 50%) Output:

Frequency:

Amplitude:

Result:

PWM signal is generated using 80196 micro controller kit, with 50% duty ratio.

Exp No:

GENERATION OF SAW-TOOTH SIGNAL USING

Date:

## 80196 MICRO CONTROLLERS

Aim:

To generate SAW-TOOTH signals using 80196 micro controllers.

Apparatus required:

- 1 80196 Trainer kit
- 2 Key board
- 3 CRO
- 4 Connecting probes Theory:

The Intel 80196 features quick register to register transfers. The quick transfers are made possible by the absence of an intervening accumulator that would otherwise constrict data flow. The architecture has at least 230 bytes on chip RAM that may be operated upon as bytes, words, or double words. The RAM registers can interconnect through a 16 bit bus with themselves and a 16 bit ALU with the idea that each of the 232 registers is an "accumulator". The ALU of the 80196 has two 17 bit input ports (16bits + sign) denoted as "A" and "B" respectively. Temporary "Upper T1" and "Lower T1" word registers give input to the A port while Temporary "T2" and "Constant" registers input to the B port. The "Upper" and "Lower" registers have independent shift capabilities, but may be coupled and shifted together as a 32 bit unit. These registers are used for the repeated shift and add (shift and subtract) operations of multiplication (division). In between the "Temporary" and "Constant" registers and the ALU B port is a multiplexed inverter. The inverter gives a 1's complement of the "Temporary" register. A further edition of 1 from the "Constant" register gives a 2's complement.

Program:

Address	Label	Mnemonics		Description
		Operator	Operand	

		ORG	8200H	
	DACPRT:	EQU	0FF10H	
	50:	EQU	50H	
	52:	EQU	52H	
8200	START	LD	50,#FF10	Loading the AX register with FF10H location
8204		LD	52,#00	Loading the BX register with 00H location
8208		ST	52,[50]	Storing Accumulator content to BX register
820B		ADD	52,#01	Pointing BX register to next location
820F		CMP	52,#0FFFH	Comparing BX location with 0FFFH
8213		JNE	8208	Jump to location 8208H
8215		SJMP	8200	To get next cycle

Procedure:

- 1 Enter the above program
- 2 Using an oscilloscope, observe the SAW-TOOTH output at the

Port output:

Frequency:

Amplitude:

Result:

The SAW-TOOTH wave is generated using 80196 micro controller kit.

## 80C51 Microcontroller :-

All 80C51 devices have separate address spaces for program and data memory, as shown in Figures 1 and 2. The logical separation of program and data memory allows the data memory to be accessed by 8-bit addresses, which can be quickly stored and manipulated by an 8-bit CPU. Nevertheless, 16-bit data memory addresses can also be generated through the DPTR register. Program memory (ROM, EPROM) can only be read, not written to. There can be up to 64k bytes of program memory. In the 80C51, the lowest 4k bytes of program are on-chip. In the ROM less versions, all program memory is external. The read strobe for external program memory is the PSEN (program store enable). Data Memory (RAM) occupies a separate address space from Program Memory. In the 80C51, the lowest 128 bytes of data memory are on-chip. Up to 64k bytes of external RAM can be addressed in the external Data Memory space. In the ROM less version, the lowest 128 bytes are on-chip. The CPU generates read and write signals, RD and WR, as needed during external Data Memory accesses. External Program Memory and external Data Memory may be combined if desired by applying the RD and PSEN signals to the inputs of an AND gate and using the output of the gate as the read strobe to the external Program/Data memory.

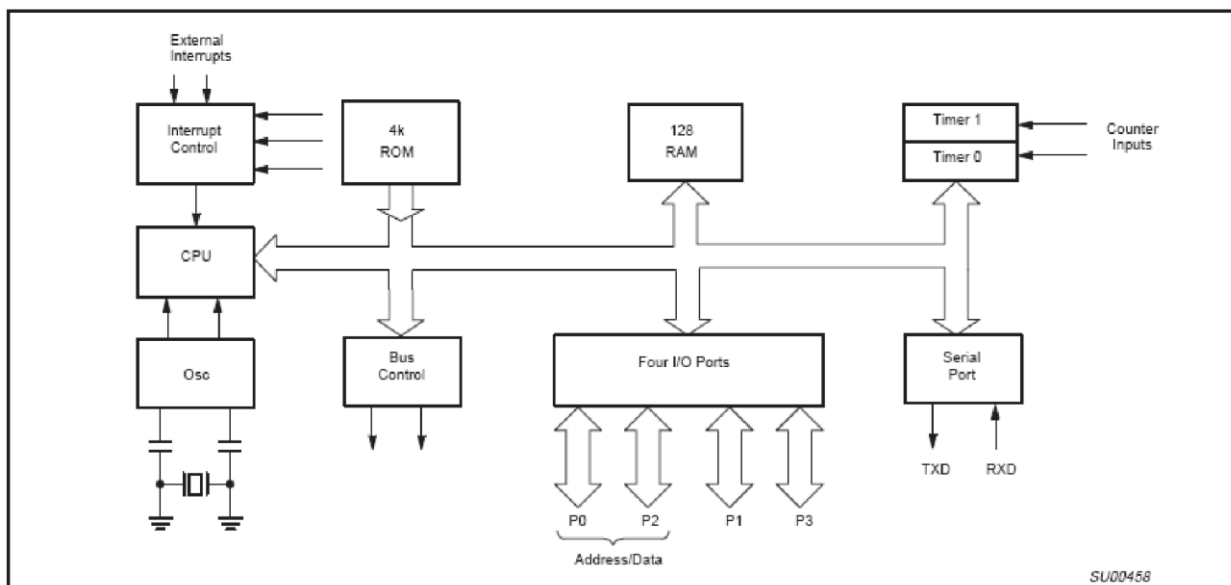


Figure 1. 80C51 Block Diagram

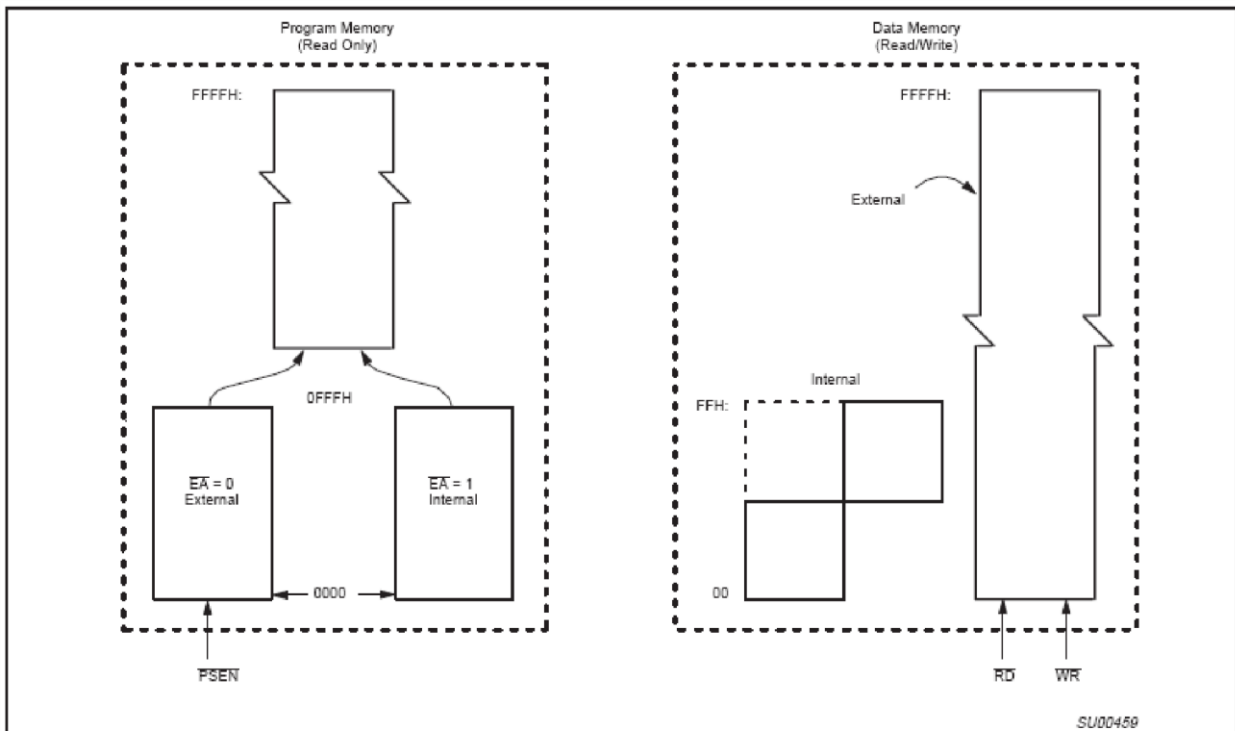


Figure 2. 80C51 Memory Structure

### Program Memory

Figure 3 shows a map of the lower part of the Program Memory. After reset, the CPU begins execution from location 0000H. As shown in Figure 3, each interrupt is assigned a fixed location in Program Memory. The interrupt causes the CPU to jump to that location, where it commences execution of the service routine. External Interrupt 0, for example, is assigned to location 0003H. If External Interrupt 0 is going to be used, its service routine must begin at location 0003H. If the interrupt is not going to be used, its service location is available as general purpose Program Memory.

The interrupt service locations are spaced at 8-byte intervals: 0003H for External Interrupt 0, 000BH for Timer 0, 0013H for External Interrupt 1, 001BH for Timer 1, etc. If an interrupt service routine is short enough (as is often the case in control applications), it can reside entirely within that 8-byte interval. Longer service routines can use a jump instruction to skip over subsequent interrupt locations, if other interrupts are in use.

The lowest 4k bytes of Program Memory can either be in the on-chip ROM or in an external ROM. This selection is made by strapping the EA (External Access) pin to either VCC, or VSS. In the 80C51, if the EA pin is strapped to VCC, then the program fetches to addresses 0000H through 0FFFH are directed to the internal ROM. Program fetches to addresses 1000H through FFFFH are directed to external ROM.

If the EA pin is strapped to VSS, then all program fetches are directed to external ROM. The ROM less parts (8031, 80C31, etc.) must have this pin externally strapped to VSS to enable them to execute from external Program Memory.

The read strobe to external ROM, PSEN, is used for all external program fetches. PSEN is not activated for internal program fetches. The hardware configuration for external program execution is shown in Figure 4. Note that 16 I/O lines (Ports 0 and 2) are dedicated to bus functions during external Program Memory fetches. Port 0 (P0 in Figure 4) serves as a multiplexed address/data bus. It emits the low byte of the Program Counter (PCL) as an address, and then goes into a float state awaiting the arrival of the code byte from the Program Memory. During the time that the low byte of the Program Counter is valid on Port 0, the signal ALE (Address Latch Enable) clocks this byte into an address latch. Meanwhile, Port 2 (P2 in Figure 4) emits the high byte of the Program Counter (PCH). Then PSEN strobes the EPROM and the code byte is read into the microcontroller.

Program Memory addresses are always 16 bits wide, even though the actual amount of Program Memory used may be less than 64k bytes. External program execution sacrifices two of the 8-bit ports, P0 and P2, to the function of addressing the Program Memory.

### **Data Memory**

The right half of Figure 2 shows the internal and external Data Memory spaces available to the 80C51 user. Figure 5 shows a hardware configuration for accessing up to 2k bytes of external RAM. The CPU in this case is executing from internal ROM. Port 0 serves as a multiplexed address/data bus to the RAM, and 3 lines of Port 2 are being used to page the RAM. The CPU generates RD and WR signals as needed during external RAM accesses. There can be up to 64k bytes of external Data Memory. External Data Memory addresses can be either 1 or 2 bytes wide. One-byte addresses are often used in conjunction with one or more other I/O lines to page the RAM, as shown in Figure 5.

Two-byte addresses can also be used, in which case the high address byte is emitted at Port 2. Internal Data Memory is mapped in Figure 6. The memory space is shown divided into three blocks, which are generally referred to as the Lower 128, the Upper 128, and SFR space.



Internal Data Memory addresses are always one byte wide, which implies an address space of only 256 bytes. However, the addressing modes for internal RAM can in fact accommodate 384 bytes, using a simple trick. Direct addresses higher than 7FH access one memory space, and indirect addresses higher than 7FH access a different memory space. Thus Figure 6 shows the Upper 128 and SFR space occupying the same block of addresses, 80H through FFH, although they are physically separate entities.

The Lower 128 bytes of RAM are present in all 80C51 devices as mapped in Figure 7. The lowest 32 bytes are grouped into 4 banks of 8 registers. Program instructions call out these registers as R0 through R7. Two bits in the Program Status Word (PSW) select which register bank is in use. This allows more efficient use of code space, since register instructions are shorter than instructions that use direct addressing.

The next 16 bytes above the register banks form a block of bit-addressable memory space. The 80C51 instruction set includes a wide selection of single-bit instructions, and the 128 bits in this area can be directly addressed by these instructions. The bit addresses in this area are 00H through 7FH.

All of the bytes in the Lower 128 can be accessed by either direct or indirect addressing. The Upper 128 (Figure 8) can only be accessed by indirect addressing.

Figure 9 gives a brief look at the Special Function Register (SFR) space. SFRs include the Port latches, timers, peripheral controls, etc. These registers can only be accessed by direct addressing. Sixteen addresses in SFR space are both byte- and bit-addressable. The bit-addressable SFRs are those whose address ends in 0H or 8H.



## **Stepper Motor Rotation in Forward And Backward Direction by using 8051 Microcontroller**

**Aim:-** To run a stepper motor in Forward and Backward Direction using 8051 microcontroller.

**Apparatus:-**

1. 8051 Microcontroller.

2. Keyboard
3. Stepper Motor
4. Interfacing Kit

**Procedure:-**

1. Interface the 8051 Microcontroller kit with the stepper motor.
2. Enter the program.
3. Call the program and observe the rotation of stepper motor.

**Program:**

ADDRESS	OPCODE	LABEL	MNEMONICS	COMMENTS
4100			ORG	4100H
		SMOD52		
4100	7C 33	START	MOV R4, #33H	Initialize count
4102	90 41 44	L2	MOV DPTR,#FORWARD	Initialize pointer
4105	12 41 1C		LCALL L1	Long jump to loop1
4108	DC F8		DJNZ R4,L2	Decrement R4
410A	12 41 3B		LCALL DELAY	
410D	7C 33		MOV R4,#33H	Initialize count
410F	90 41 48	L3:	MOV DPTR,#REVERSE	Initialize pointer
4112	12 41 1C		LCALL L1	Long call loop1
4115	DC F8		DJNZ R4,L3	Decrement R4
4117	12 41 3B		LCALL DELAY	Wait for subroutine
411A	80 E4		SJMP START	Short jump to start
411C	78 04	L1:	MOV R0,#04H	Move 04 to reg R0
411E	E0	LOOP:	MOVX A,@DPTR	
411F	C0 83		PUSH 83H	
4121	C0 82		PUSH 82H	
4123	90 FF C0		MOV DPTR,#FFC0H	Move FFC0 data to DPTR
4126	7A 04		MOV R2,#04H	Move 04 to reg R2
4128	79 05	L7:	MOV R1,#05H	Move 05 to reg R1
412A	7B FF	L6:	MOV R3, #FFH	Move FF to

				reg R3
412C	DB FE	L4:	DJNZ R3,L4	Decrement R3 go to L4
412E	D9 FA		DJNZ R1,L6	Decrement R1 go to L6
4130	DA F6		DJNZ R2, L7	Decrement R2 go to L7
4132	F0		MOVX@DPTR,A	Move A to DPTR
4133	D0 82		POP 82H	
4135	D0 83		POP 83H	
4137	A3		INC DPTR	Increment pointer
4138	D8 E4		DJNZ R0,LOOP	
413A	22		RET	
413B	7D 01	DELAY:	MOV R5,#01H	Move 01 to reg R5
413D	7A 01	L9:	MOV R2,#01H	Move 01 to reg R2
413F	DA FE	L8:	DJNZ R2,L8	Decrement R2
4141	DD FA		DJNZ R5, L9	Decrement R5
4143	22		RET	
4144	09 05 06 0A	FORWARD:	DB 09H, 05H,06H,0AH	
4148	0A 06 05 09	REVERSE:	DB 0AH,06H,05H,09H	

**Run a stepper motor for required angle within  $360^{\circ}$  which is equivalent to 256 steps.**

**Aim;-** To run a stepper motor for required angle within  $360^{\circ}$  which is equivalent to 256 steps using 8051 microcontroller.

**Apparatus:-**

1. 8051 Microcontroller.
2. Keyboard
3. Stepper Motor
4. Interfacing Kit

**Procedure:-**

1. Interface the 8051 Microcontroller kit with the stepper motor.
2. Enter the program.
3. Call the program and observe the rotation of stepper motor.

**Program:-**

ADDRESS	OPCODE	LABEL	MNEMONICS	COMMENTS
4100			ORG	4100H
4100	7C FF		MOV R4, #FFH	Hex data for 360 <sup>0</sup>
4102	90 41 44	START:	MOV DPTR,#LOOK UP	Initialze pointer
4105	78 04		MOV R0, #04H	Move 04 to reg R0
4107	E0	JO:	MOVX A,@DPTR	
4108	C0 83		PUSH DPH	
410A	C0 82		PUSH DPL	
410C	90 FF C0	L3:	MOV DPTR,#FFC0H	Initialize pointer
410F	F0		MOVX@DPTR,A	Move A to DPTR
4110	DC 06		DJNZ R4,CALL	Decrement R4
4112	80 FE	HLT:	SJMP HLT	Short jump to HLT
4114	09 05 06 0A	LOOK UP:	DB 09H ,05H,06H,0AH	
4118	7A 03	CALL:	MOV R2, #03H	Move 03 to reg R2
411A	79 FF	DLY2:	MOV R1,#FFH	Move FF to reg R1
411C	7B FF	DLY1:	MOV R3,#FFH	Move FF to ref R3
411E	DB FE	DLY:	DJNZ R3,DLY	Decrement R3 go to DLY
4120	D9 FA		DJNZ R1,DLY1	Decrement R1 go to DLY 1
4122	DA F6		DJNZ R2,DLY 2	Decrement R2 go to DLY 2
4124	D0 82		POP DPL	
4126	D0 83		POP DPH	
4128	A3		INC DPTR	Increment pointer
4129	D8 DC		DJNZ R0, JO	
412B	80 D5		SJMP START	
412D			END	

Result:

The stepper motor was made to rotate for required angle within  $360^{\circ}$  which is equivalent to 256 steps using 8051 Microcontroller.

# **LINEAR INDUCTION MOTOR CONTROLLER**

**(Model No : PEC16LM01)**

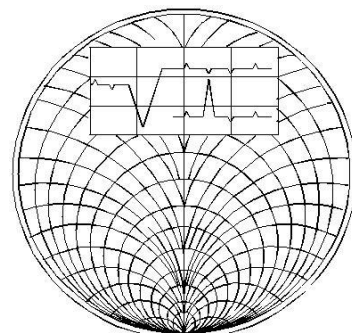


## **User Manual Version 1.0**

**Technical Clarification /Suggestion :**

**/**

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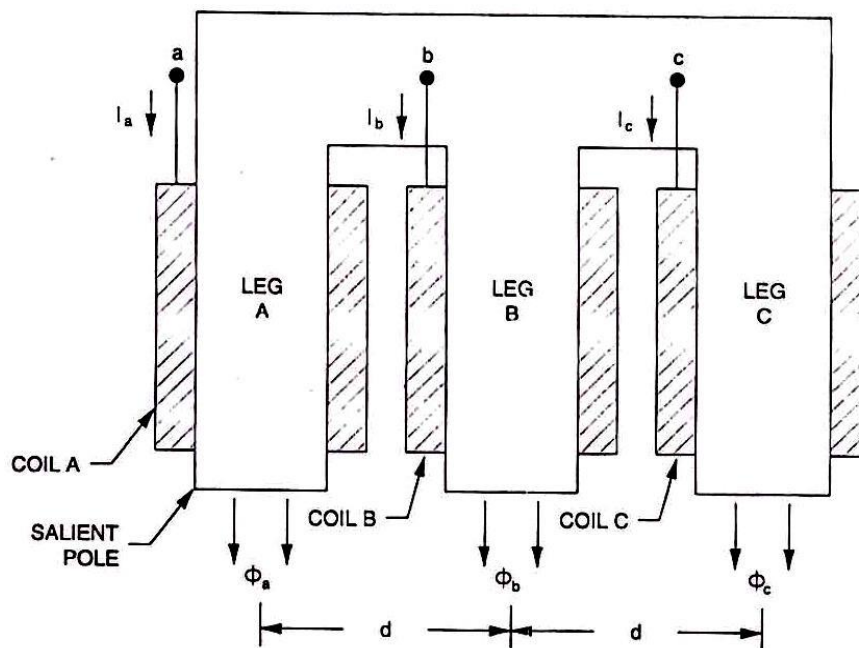
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## INTRODUCTION

The Linear Motor is composed of two main parts a movable vehicle and a stationary rail is a simple aluminium plate mounted on an iron support. The movable vehicle contains stator of the linear motor and the stationary rail of the rotor. This is contrary to an ordinary rotating motor in which the stator is stationary and the rotor is moving.

The stator is composed of a three-legged laminated iron core upon which are mounted three identical coils A, B, C, A cross section view is shown in Figure 1. The three coils, powered by a three-phase source, can be connected either in wye or delta (Figure 2). Unless otherwise stated,



The coils produce in each leg and corresponding salient pole, fluxes that are labeled  $\phi_a$ ,  $\phi_b$  and  $\phi_c$ . These fluxes are created by the currents  $I_a$ ,  $I_b$ ,  $I_c$  that flow in the respective windings; consequently, the fluxes are  $120^\circ$  out of phase. This phase shift means that the fluxes attain their maximum values at different times, separated by intervals of  $1/3f$  where  $f$  is the frequency of the source. For example, if the frequency is 50Hz, and the phase sequence is A-B-C, flux  $\phi_b$  will attain its maximum value  $1/150$  s after  $\phi_a$ . Similarly,  $\phi_c$  will reach its maximum value  $1/150$  s after  $\phi_b$ . Thus, by referring to Figure 1, it can be seen that the flux continually shifts from left to right across the face of the salient poles. If two of the supply lines are interchanged, the phase sequence will reverse, and the flux will shift from right to left across the poles.

Knowing the distance  $d$  between the center of the poles, we can calculate the speed at which the flux moves. This is called the synchronous speed  $V_s$  because it is directly related to the frequency of the power supply. The synchronous speed is given by

Equation (1)

$$V_s = 3df \text{ ----- (1)}$$

in which  $V_s$  = synchronous speed [m/s]  
 $d$  = distance between poles [m]  
 $f$  = frequency [Hz]

**In this Model -  $d = 0.048\text{m}$  (48mm)**

F is 50Hz , the linear synchronous speed is

$$V_s = 3 d f = 3 \times 0.048 \times 50 = 7.2\text{m/s}$$

This corresponds to a speed of about 25.92km/h [( 7.2/1000)\*3600].

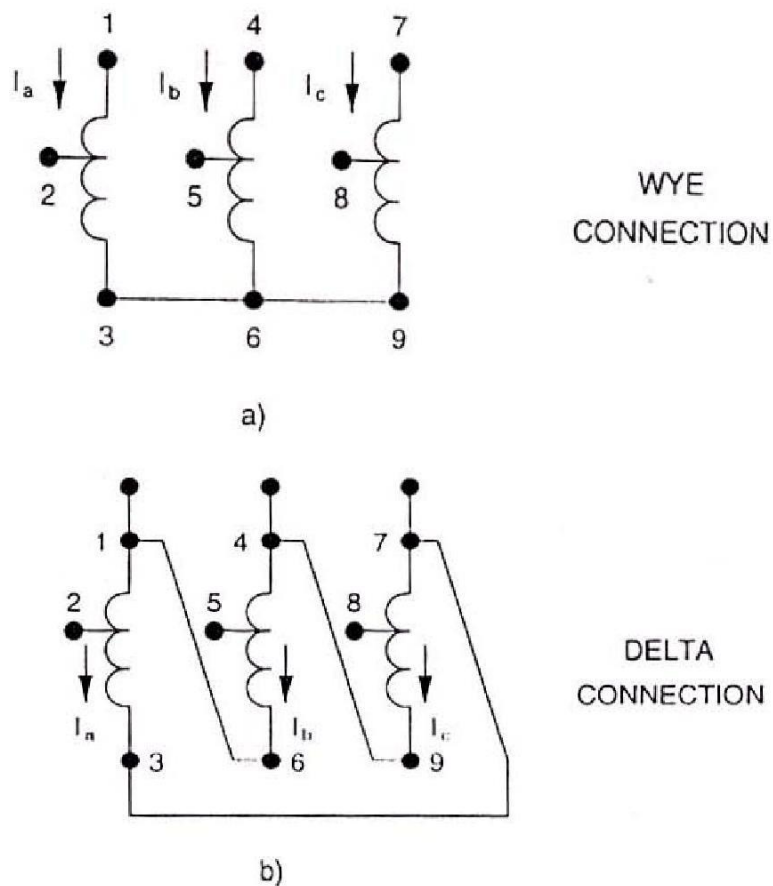
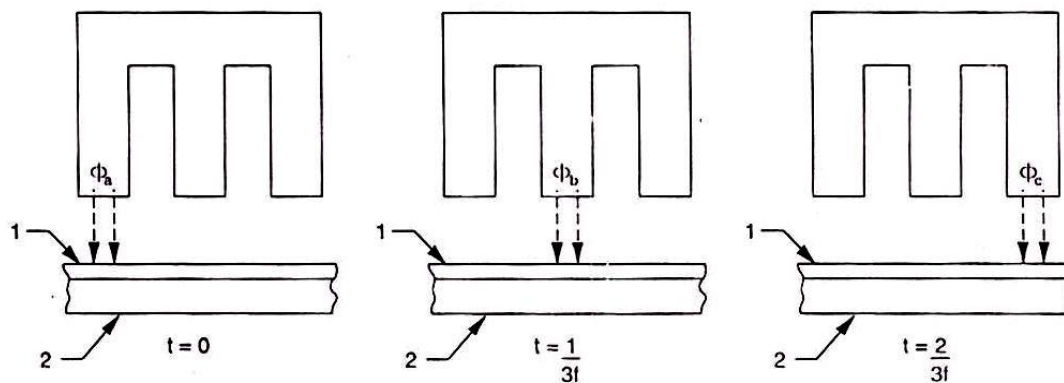


Figure 2: a) Wye connection; b) Delta connection

### Principle of a linear induction motor

Consider now an aluminium plate 1 mounted on a iron support 2, that faces the salient poles of the stator (figure 3). The iron support also offers a high permeability path for the magnetic flux coming from the poles. As the flux sweeps from left to right across the aluminium plate, it will induce a current according to principle of Faraday's law. This current is in the path of the very flux that created it, and so a tractive force, or electromagnetic thrust, will be exerted upon the plate, tending to drag it along with the moving flux. Therefore, if the vehicle is stationary, the plate will tend to move to the right. But if the plate is fixed, and the vehicle is free to move, the latter will start moving to the left. As the vehicle picks up speed, the flux will continue to sweep across the plate (now called a rail and the thrust would fall to zero. As a result, the vehicle would immediately begin to slow down. The final steady-state speed would be that where the friction and drag on the vehicle is exactly equal to the thrust exerted on the rail by the moving flux.

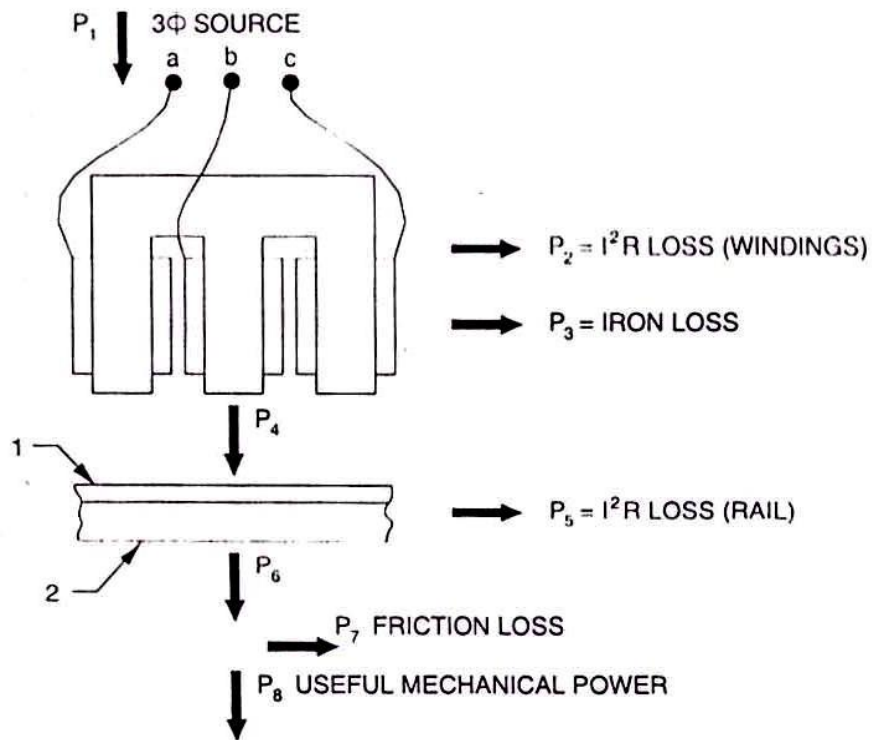


**Figure 3: Flux sweeps across the aluminium rail.**

When the vehicle is not moving, the stator and rotor together function just like a three-phase transformer. The stator is the primary and the rail behaves like a single-turn secondary that is short circuited on itself. However, the flux created by the primary has to flow across the long air gap that separates the iron core of the stator from the U-shaped iron support underneath the aluminium rail. The air gap comprises not only the air itself, but also the thickness of the aluminium rail. The reason is that aluminium has the same permeability as air. On account of this long air gap a large magnetizing current is needed to produce the flux. Consequently, the linear motor tends to draw a lot of reactive power from the source, and so its power factor tends to be low. This low power factor condition continues to exist even when the vehicle is moving.

### Active power flow in a linear motor

It is important to observe the power aspects of the linear induction motor. Referring to Figure the active power (watts)  $P_1$  from the sources flows into the windings and a portion  $P_2$  is dissipated in the form of heat due o the  $I^2R$  copper losses.



**Figure 4: Power flow in linear induction motor**

Another portion  $P_3$  is lost due to the iron losses in the laminated core. The iron losses amount to about 10 W, at rated voltage. The remaining power  $P_4$  is then transmitted across the air gap to the aluminium rail. A large portion  $P_5$  is dissipated in the form of heat, due to the  $I^2R$  losses of the current induced in the rail. The power  $P_6$  that remains is the mechanical power developed by the motor. A small portion  $P_7$  is used up to overcome the friction losses, and the final amount  $P_8$  is the power that actually drives the motor.

The ratio  $P_8/P_1$  is the efficiency of the motor. The efficiency of small linear motors is low, being typically of the order 10 % or less. The reason is that unlike rotating motors, the flux does not flow smoothly from one pole to the next, but cuts off sharply at the front and rear of the linear motor. Because of this "end effect", only a fraction of the power  $P_4$  transmitted to the rail is available to produce the desired linear thrust. The thrust (in newton) of a linear motor corresponds to the torque (in newton meters) of a rotating motor.

In an ideal linear motor the thrust is given by the formula

Equation (2)

$$F = \frac{P_4}{V_s} \quad \text{-----} \quad (2)$$

where in

F	=	Thrust in newton [N]
P <sub>4</sub>	=	Power transmitted to the rail [W]
V <sub>s</sub>	=	Synchronous speed [m/s]

In linear motors, the actual thrust is only 30% to 60% of the theoretical value given by equation (2).

However, in the case of large linear motors of several hundred horsepower, the thrusts are close to the theoretical value. Furthermore, the efficiencies are of the order of 90%.

As mentioned previously, in addition to the active power, the linear motor draws considerable reactive power (vars) from the 3-phase source. In small linear motors the reactive power can even exceed the active power consumed by the motor.

### Dynamic behavior

Starting from rest, how quickly will the vehicle pick up speed? To answer this question, we first have to calculate the acceleration.

**The mass (m) of the vehicle is known to be 6.9 kg**

From Newton's second law of motion we know that

Equation (3)

$$\text{Force } F = ma, \text{ and} \text{-----} \quad (3)$$

Equation (4)

$$\text{Acceleration } A = \text{distance in meter} / (\text{time in sec})^2 \text{-----} \quad (4)$$

To demonstrate the dynamic aspects of the linear induction motor, it can be connected as shown in figure. Power from the three-phase supply is fed into a box RS that contains a reversing switch. The output from RS is fed into the stator, as shown. When power is applied, the vehicle starts moving to the right, say. A moment before it strikes buffer 2, it trips lever S2. This reverse the switch in box RS, causing the flux in the vehicle to reverse. This slows the vehicle down before it hits the buffer. The buffer contains a spring that absorbs energy when it is compressed. When the vehicle strikes the buffer, it rapidly slows down until its speed falls to zero.

### **Traction Test**

1. Set the gap of the vehicle to 5mm. This is the gap between the pole faces of the stator and the aluminium rail. The actual gap is equal to 5mm plus the thickness of the aluminium rail which is about 3.2mm. (By way of comparison, the gap in a rotating motor of equivalent power would be about 0.4mm).
2. Set the vehicle on the track and connect terminals R,Y,B connector to module.
3. Connect terminals R,Y,B of the Linear Motor to a variable, three phase, 50Hz source through three appropriate ac ammeters.
4. Place the vehicle in horizontal position.

Note that the active power P is considerably greater than when the vehicle was not coupled to the aluminum rail (Table 1). The reason is that currents are induced in the rail, and so it dissipates power, causing the rail to heat up. The exciting current is also lower because the iron support underneath the aluminium rail reduces the effective length of the air gap, on account of its high permeability.

1. The synchronous speed  $V_s$  of the linear motor is given by Eq. (1),

$$V_s = 2df \quad m/s$$

Experiments;

- i. Traction Test ( Air Gap = \_\_\_\_\_ mm )

S.No	Frequency -Hz	Modulation Index	Acceleration	Force-Newton	Synchronous speed
1.	15HZ				
2.	20HZ				
3.	25HZ				
4.	30HZ				
5.	35HZ				

Table 1



**FEATURES OF PEC16LM01**

- \* The iron support also offers a high permeability path for the magnetic flux coming from the poles.
- \* This current is in the path of the very flux that created it, and so a tractive force, or electromagnetic thrust, will be exerted upon the plate, tending to drag it along with the moving flux.
- \* As the vehicle picks up speed, the flux will continue to sweep across the plate (now called a rail and the thrust would fall to zero.
- \* The stator is the primary and the rail behaves like a single-turn secondary that is short circuited on itself.
- \* The air gap comprises not only the air itself, but also the thickness of the aluminium rail.
- \* On account of this long air gap a large magnetizing current is needed to produce the flux.

VIEW OF THE MODULE

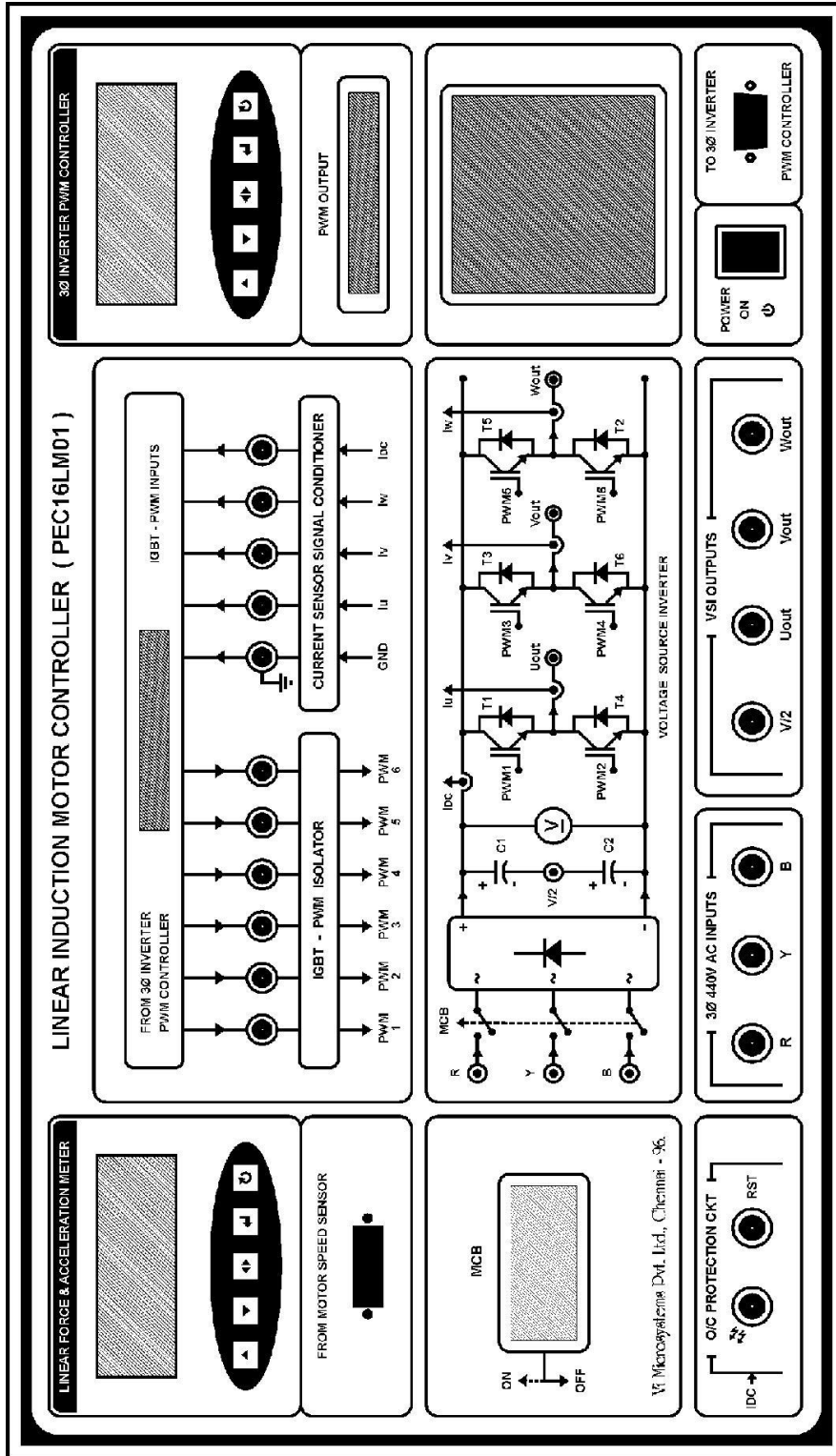


Linear Induction Motor controller



Linear Induction Motor on rail

FRONT PANEL VIEW








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




**FRONT PANEL DESCRIPTION OF PEC16LM01**

- MCB - To switch ON three phase input to the module.
- R,Y,B - Terminals for three phase supply input to the module.
- Uout,Vout, Wout - Terminals for connecting the linear induction motor.
- Power ON/OFF - To switch ON/OFF power to the controller module.

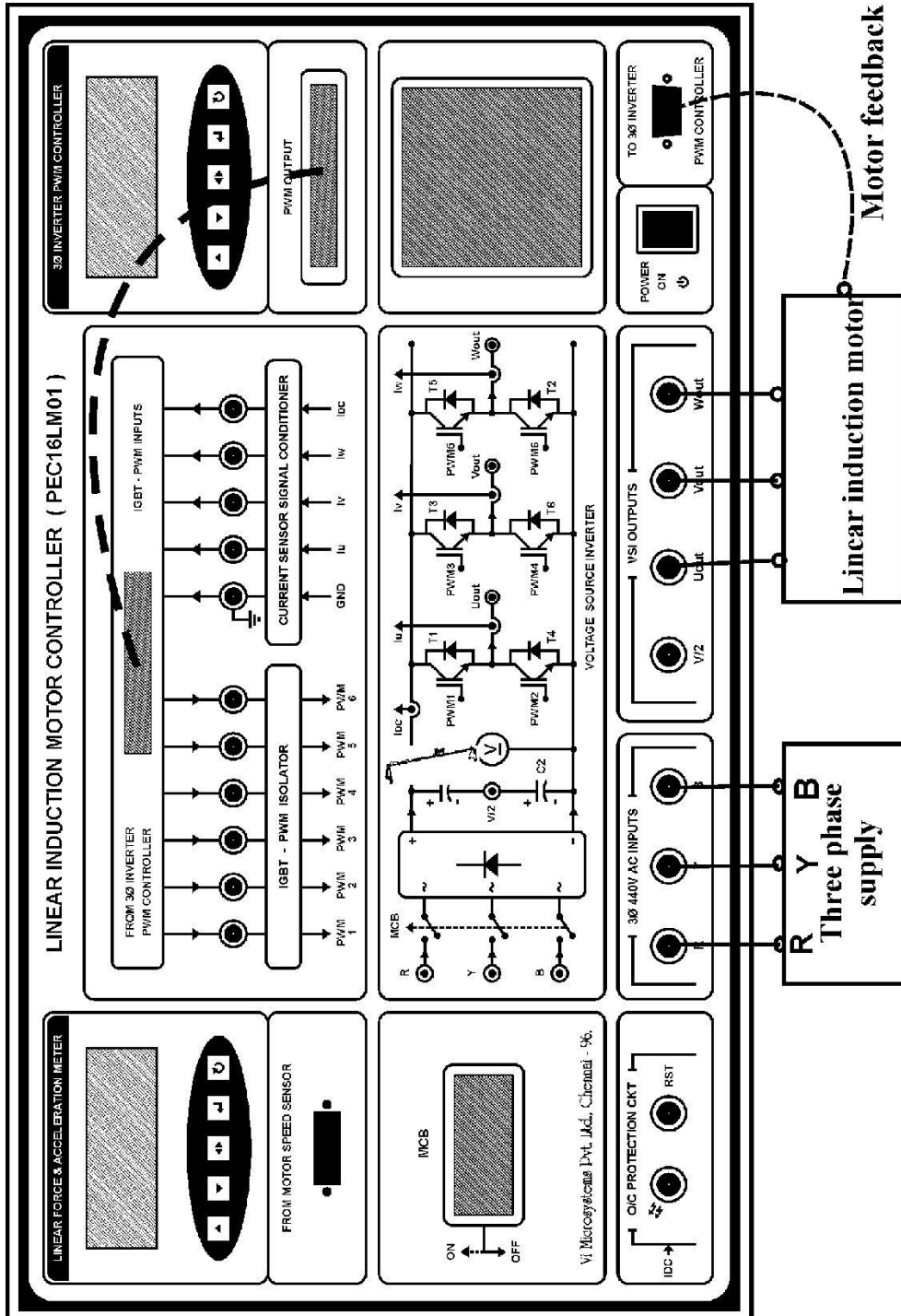
**3 INVERTER PWM CONTROLLER**

-  - To Increment the frequency value
-  - To decrement the frequency value
-  - To Increment the modulation index value
-  -
-  - To reset the pwm controller.

**LINEAR FORCE & ACCELERATION METER**

-  - Cursor movement
-  - To incremental value
-  - No connection
-  - Enter key
-  - Reset

CONNECTION DIAGRAM



# ***Experimental Section***

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**EXP:NO:1****AIM:**

To study the linear induction motor and perform traction test on it.

**APPARATUS REQUIRED:**

1. PEC16LM01 trainer.
2. Pulse cable.
3. Linear Induction Motor.

**FORMULA USED:**

The synchronous speed **V<sub>s</sub>** of the linear motor is given by ,

$$V_s = 3df$$

Where,

V <sub>s</sub>	=	synchronous speed [m/s]
d	=	distance between poles [m]
f	=	frequency [Hz]

**In this Model**

$$d = 0.048 \text{ m (48mm)}$$

$$F = \text{Mass x Acceleration}$$

Where,

**Mass** - The mass (m)of the vehicle is known to be **6.9 kg**

**Acceleration** - Distance in meter/(time in sec)<sup>2</sup>.

**CONNECTION PROCEDURE**

- \* Connect the controller module to the supply main.
- \* Connect 1 variable AC input supply to the controller module.
- \* Connect pwm output of the controller module to pwm input of the controller module using pulse cable.
- \* Connect linear induction motor input to the controller output (Uout,Vout,Wout) module.
- \* Connect motor speed feed back from motor to the feed back input of the controller module.





**EXPERIMENTAL PROCEDURE**

1. Verify the connection as per the connection procedure.
2. Switch on the power on/off switch in the controller module.
3. Manually Set the frequency between 1HZ to 50HZ.
4. Manually Set the modulation index between 0% to 90%.
5. The five sensor found in rail of linear induction motor, it is used to measure the time taken by the motor to travel between any two particular sensors.
6. Select any two sensor (eg . 1& 2, 1&3, 2&4, etc,.) and measure the time.
7. The consecutive sensors are separated by a distance of 0.4m.
8. The movable part one end to another end reach .that time Automatically change to forward and reverse direction shown in display mode.
9. Now the LCD display of 3 inverter pwm controller displays the following one by one with a delay of few seconds,



VI MICRO SYSTEMS PVT. LTD.,



FREQUENCY : 1HZ  
MODULATION INDEX : 0  
DIRECTION : FORWARD  
END 1 : OFF      END 2 : OFF

10. Now select the frequency, by using Key  
11. Now select the modulation index, by using Key  
12. Now vary the 1 input supply by using auto transformer.
13. Now motor starts running in any one direction at the speed corresponds to the frequency & modulation index value.
14. When motor reaches are end of rail the direction in automatically “**REVERSED**” through the sensor.
15. The speed of motor can be varied. By varying the frequency and modulation index value, while the motor in motion.
16. Now reduce the 1 input supply to zero.
17. For traction test set the value as following display of linear force and acceleration meter display will show

SET LENGTH - 000  
SET MASS - 000  
START SENSOR - 000  
END SENSOR - 000

18. Now select the set length by using key 
19. Now select the set mass by using key 
20. Now vary the single phase input supply by using single phase auto transformer.

21. The sensor sensing one end to another end and measure the time and speed should be calculated by using stop clock.
22. Repeat the same procedure of different frequency of output voltage.

**NOTE:**

The active power P is considerably greater than when the vehicle was not coupled to the aluminium rail. The reason is that currents are induced in the rail, and so it dissipates power, causing the rail to heat up. The exciting current is also lower because the iron support underneath the aluminium rail reduces the effective length of the air gap, on account of its high permeability.

\* **d = 0.048 m (48mm)**

\* **The mass (m) of the vehicle is known to be 6.9 kg.**

**TABULATION**

1. Traction Test ( Air Gap = \_\_\_\_\_ mm )

S.No	Frequency -Hz	Modulation Index	Acceleration	Force - Newton	Synchronous speed
1.	10HZ				
2.	15HZ				
3.	20HZ				
4.	25HZ				
5.	30HZ				

**RESULT**

Thus the linear induction motor and perform traction test has been studied.

# VARIABLE FREQUENCY DRIVE

## INTRODUCTION

A **variable-frequency drive (VFD)** is a system for controlling the rotational speed of an alternating current (AC) electric motor by controlling the frequency of the electrical power supplied to the motor. A variable frequency drive is a specific type of adjustable-speed drive. Variable frequency drives are also known as adjustable frequency drives (AFD), variable-speed drives (VSD), AC drives, micro drives or inverter drives. Since the voltage is varied along with frequency, these are sometimes also called VVVF (variable voltage variable frequency) drives. Variable-frequency drives are widely used. For example, in ventilations systems for large buildings, variable-frequency motors on fans save energy by allowing the volume of air moved to match the system demand. Variable frequency drives are also used on pumps, conveyor and machine tool drives.

## OPERATING PRINCIPLE

The synchronous speed of an AC motor is determined by the frequency of the AC supply and the number of poles in the stator winding, according to the relation:

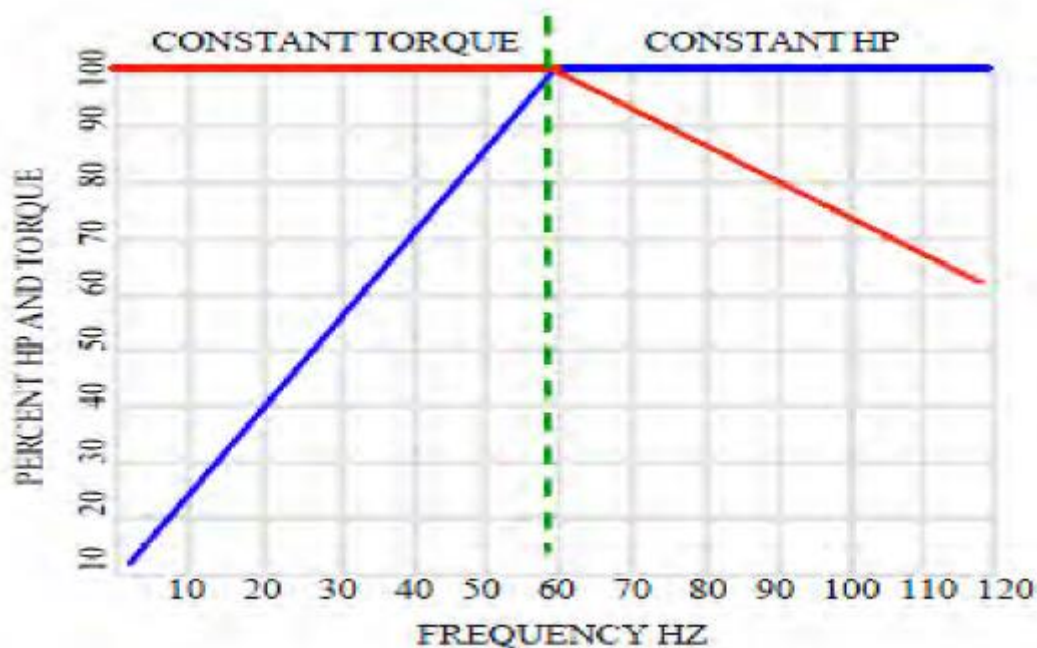
$$\text{RPM} = \frac{120 \times f}{P}$$

Where RPM = Revolutions per minute,  $f$  = AC power frequency (hertz),  $p$  = Number of poles (an even number).

The constant, 120, is 60 cycles per minute multiplied by 2 poles per pole pair. Sometimes 60 is used as the constant and  $p$  is stated as pole pairs rather than poles. By varying the frequency of the voltage applied to the motor, its speed can be changed. Synchronous motors operate at the synchronous speed determined by the above equation. The speed of an induction motor is slightly less than the synchronous speed.

An inverter is an electronic power unit for generating AC power. By using an inverter type AC drive, the speed of a conventional AC motor can be varied through a wide speed range from zero through the base (60 Hz) speed and above (often to 90 or 120 hertz). When the frequency applied to an induction motor is reduced, the applied voltage must also be reduced to limit the current drawn by the motor at reduced frequencies. (The inductive reactance of an

AC magnetic circuit is directly proportional to the frequency according to the formula,  $X_L = 2\pi fL$ . Variable speed AC drives will maintain a constant volts/hertz relationship from 0 – 60 Hertz. To calculate this ratio divides the motor voltage by 60 Hz. At low frequencies the voltage will be low, as the frequency increases the voltage will increase. (Note: this ratio may be varied somewhat to alter the motor performance characteristics such as providing a low-end boost to improve starting torque.) Depending on the type of AC Drive, the microprocessor control adjusts the output voltage waveform, by one of several methods, to simultaneously change the voltage and frequency to maintain the constant volts/hertz ratio throughout the 0 - 60 Hz range. On most AC variable speed drives the voltage is held constant above the 60 hertz frequency. The diagram below illustrates this voltage/frequency relationship.



In Constant Torque Area - VFD supplies rated motor nameplate voltage and motor develops full horsepower at 60 hertz base frequency. In Constant Horsepower Area – VFD delivers motor nameplate rated voltage from 60 Hertz to 120 hertz (or drive maximum). Motor horsepower is constant in this range but motor torque is reduced as frequency increases.

Initially standard AC motors were employed on inverter drives. Most motor manufacturers now offer Inverter Duty Motors which provide improved performance and reliability when used in Variable Frequency Applications. These special motors have insulation designed to withstand the steep-wave-front voltage impressed by the VFD waveform, and are redesigned to run smoother and cooler on inverter power supplies.

## VARIABLE VFD TYPES

All VFDs use their output devices (IGBTs, transistors, thyristors) only as switches, turning them only on or off. Attempting to use a linear device such as transistor in its linear mode would be impractical, since power dissipated in the output devices would be about as much as power delivered to the load.

Drives can be classified as: Constant voltage, Constant current, Cycloconverter.

In a constant voltage converter, the intermediate DC link voltage remains approximately constant during each output cycle.

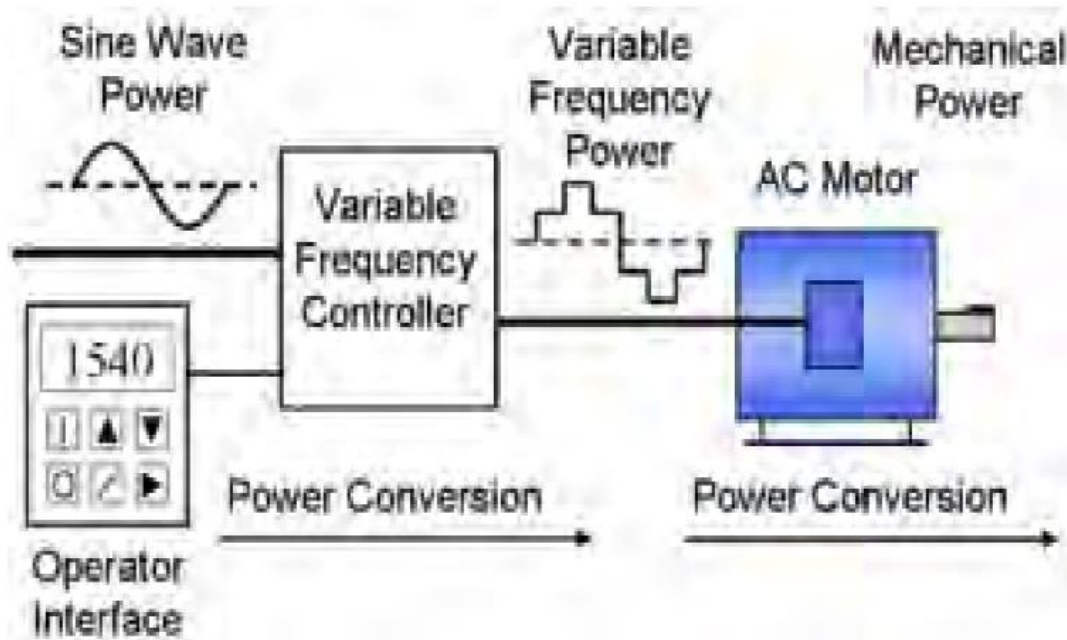
In constant current drives, a large inductor is placed between the input rectifier and the output bridge, so the current delivered is nearly constant.

A Cycloconverter has no input rectifier or DC link and instead connects each output terminal to the appropriate input phase.

The most common type of packaged VF drive is the constant-voltage type, using pulse width modulation to control both the frequency and effective voltage applied to the motor load.

## VFD SYSTEM DESCRIPTION

A variable frequency drive system generally consists of an AC motor, a controller and an operator interface.



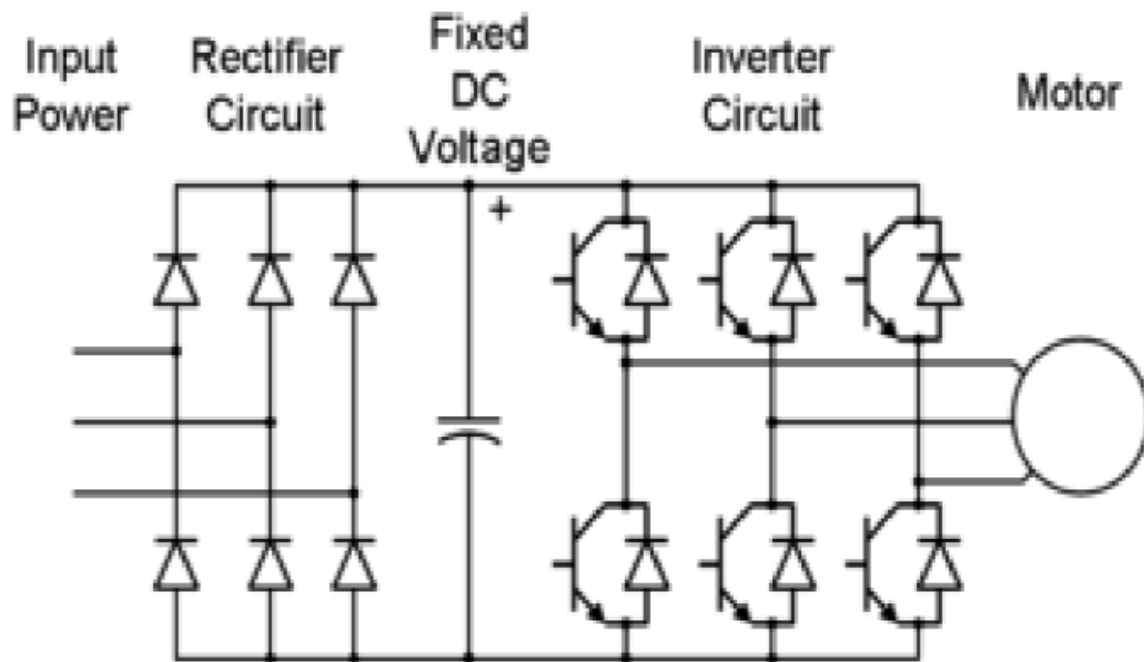
## VFD MOTOR

The motor used in a VFD system is usually a three-phase induction motor. Some types of single-phase motors can be used, but three-phase motors are usually preferred. Various types of synchronous motors offer advantages in some situations, but induction motors are suitable for most purposes and are generally the most economical choice. Motors that are designed for fixed speed mains voltage operation are often used, but certain enhancements to the standard motor designs offer higher reliability and better VFD performance.

## VFD CONTROLLER

Variable frequency drive controllers are solid state electronic power conversion devices. The usual design first converts AC input power to DC intermediate power using a rectifier bridge. The DC intermediate power is then converted to quasi-sinusoidal AC power

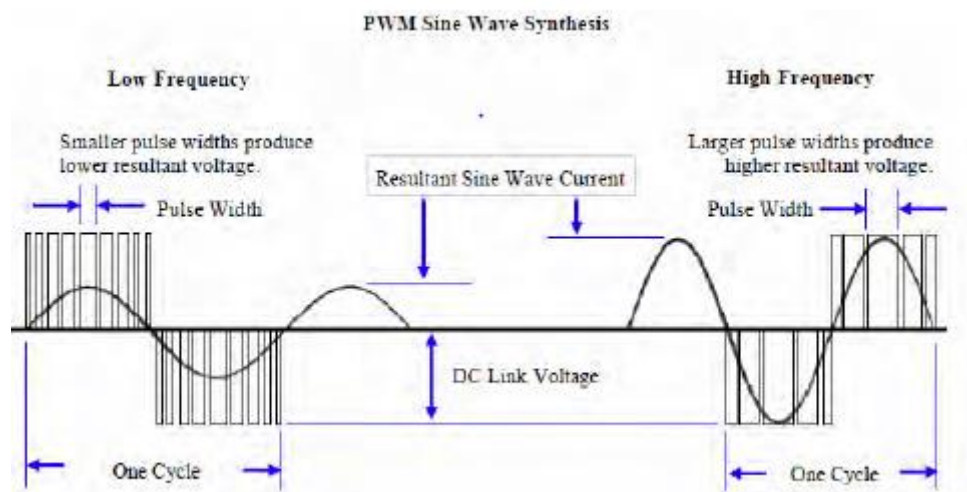
using an inverter switching circuit. The rectifier is usually a three-phase diode bridge, but controlled rectifier circuits are also used. Since incoming power is converted to DC, many units will accept single-phase as well as three-phase input power (acting as a phase converter as well as a speed controller); however the unit must be derated when using single phase input as only part of the rectifier bridge is carrying the connected load. As new types of semiconductor switches have been introduced, these have promptly been applied to inverter circuits at all voltage and current ratings for which suitable devices are available. Introduced in the 1980s, the insulated gate bipolar transistor (IGBT) became the device used in most VFD inverter circuits in the first decade of the 21st century. AC motor characteristics require the applied voltage to be proportionally adjusted whenever the frequency is changed in order to deliver the rated torque. For example, if a motor is designed to operate at 460 volts at 60 Hz, the applied voltage must be reduced to 230 volts when the frequency is reduced to 30 Hz. Thus the ratio of volts per hertz must be regulated to a constant value ( $460/60 = 7.67 \text{ V/Hz}$  in this case). For optimum performance, some further voltage adjustment may be necessary, but nominally constant volts per hertz are the general rule. This ratio can be changed in order to change the torque delivered by the motor



The usual method used for adjusting the motor voltage is pulse-width modulation (PWM). With PWM voltage control, the inverter switches are used to divide the quasi-sinusoidal output waveform into a series of narrow voltage pulses and modulate the width of the pulses. Operation at above synchronous speed is possible, but is limited to conditions that do not require more power than nameplate rating of the motor. This is sometimes called "field weakening" and, for AC motors, is operating at less than rated volts/hertz and above synchronous speed.

Example, a 100 hp, 460 V, 60 Hz, 1775 RPM (4 pole) motor supplied with 460 V, 75 Hz ( $6.134 \text{ V/Hz}$ ), would be limited to  $60/75 = 80\%$  torque at 125% speed (2218.75 RPM) = 100% power.

An embedded microprocessor governs the overall operation of the VFD controller. The main microprocessor programming is in firmware that is inaccessible to the VFD user. However, some degree of configuration programming and parameter adjustment is usually provided so that the user can customize the VFD controller to suit specific motor and driven equipment requirements. At 460 Volts, the maximum recommended cable distances between VFDs and motors can vary by a factor of 2.5:1. The longer cable distances are allowed at the lower Carrier Switching Frequencies (CSF) of 2.5 kHz. The lower CSF can produce audible noise at the motors. The 2.5 kHz and 5 kHz CSFs cause less motor bearing problems than caused by CSFs at 20 kHz. Shorter cables are recommended at the higher CSF of 20 kHz. The minimum CSF for synchronize tracking of multiple conveyors is 8 kHz.



## VFD OPERATOR INTERFACE

The operator interface, also commonly known as an HMI (Human Machine Interface), provides a means for an operator to start and stop the motor and adjust the operating speed. Additional operator control functions might include reversing and switching between manual speed adjustment and automatic control from an external process control signal. The operator interface often includes an alphanumeric display and/or indication lights and meters to provide information about the operation of the drive. An operator interface keypad and display unit is often provided on the front of the VFD controller. The keypad display can often be cable connected and mounted a short distance from the VFD controller. Most are also provided with input and output (I/O) terminals for connecting pushbuttons, switches and other operator interface devices or control signals. A serial communications port is also often available to allow the VFD to be configured, adjusted, monitored and controlled using a computer.

## VFD OPERATION

When a VFD starts a motor, it initially applies a low frequency and voltage to the motor. The starting frequency is typically 2 Hz or less. Starting at such a low frequency avoids the high inrush current that occurs when a motor is started by simply applying the utility (mains) voltage by turning on a switch. When a VFD starts, the applied frequency and

voltage are increased at a controlled rate or ramped up to accelerate the load without drawing excessive current. This starting method typically allows a motor to develop 150% of its rated torque while drawing only 50% of its rated current. When a motor is simply switched on at full voltage, it initially draws at least 300% of its rated current while producing less than 50% of its rated torque. As the load accelerates, the available torque usually drops a little and then rises to a peak while the current remains very high until the motor approaches full speed. A VFD can be adjusted to produce a steady 150% starting torque from standstill right up to full speed while drawing only 50% current.

With a VFD, the stopping sequence is just the opposite as the starting sequence. The frequency and voltage applied to the motor are ramped down at a controlled rate. When the frequency approaches zero, the motor is shut off. A small amount of braking torque is available to help decelerate the load a little faster than it would stop if the motor were simply switched off and allowed to coast. Additional braking torque can be obtained by adding a braking circuit to dissipate the braking energy or return it to the power source.

## **APPLICATION CONSIDERATIONS**

The output voltage of a PWM VFD consists of a train of pulses switched at the carrier frequency. Because of the rapid rise time of these pulses, transmission line effects of the cable between the drive and motor must be considered. Since the transmission-line impedance of the cable and motor are different, pulses tend to reflect back from the motor terminals into the cable.

If the cable is long enough, the resulting voltages can produce up to twice the rated line voltage, putting high stress on the cable and eventual insulation failure. Because of the standard ratings of cables, this phenomenon is of little concern for 230 volt motors, may be a consideration for long runs and 480 volt motors, and frequently a concern for 600 v motors.

## **AVAILABLE VFD POWER RATINGS**

Variable frequency drives are available with voltage and current ratings to match the majority of 3-phase motors that are manufactured for operation from utility (mains) power. VFD controllers designed to operate at 110 volts to 690 volts are often classified as low voltage units. Low voltage units are typically designed for use with motors rated to deliver 0.2 kW or ¼ horsepower (hp) up to at least 750 kW or 1000 hp. Medium voltage VFD controllers are designed to operate at 2400/4160 volts (60 Hz), 3000 volts(50 Hz) or up to 10 kV. In some applications a step up transformer is placed between a low voltage drive and a medium voltage load. Medium voltage units are typically designed for use with motors rated to deliver 375 kW or 500 hp and above. Medium voltage drives rated above 7 kV and 5000 or 10000 hp should probably be considered to be one-of-a-kind (one-off) designs.

## **A FEW CONSIDERATIONS WHILE SELECTING VFD FOR SPEED CONTROL**

- Motors operated by VFD's run hotter than motors operated across the line. Heat deteriorates motor insulation over time. When supplying motors for variable frequency operation, manufacturers typically use more expensive motors with a higher insulation class than motors used in a similar non-drive application.
- The motor manufacturer should be consulted for operational limitations. Most variable frequency drives restrict the minimum continuous speed to some percentage of the nameplate speed. Below this minimum speed, temperature rise may damage the motor. Every 10°C rise above the rated temperature in a motor reduces the insulation



life by half. The motor manufacturer should be consulted before applying a VFD to an existing motor. In addition to higher temperatures, non-VFD motors may have component natural frequencies that will conflict with the drive output frequencies, resulting in noise, vibration, and premature failure.

- Explosion proof motors must be rated as certified for VFD operation before they can be used with a VFD. Qualified motors will state on the nameplate that they are certified as explosion proof for VFD operation, as well as any operational limitations.
- Variable frequency drives should be placed near the motor. A large distance between the drive unit and the motor may result in increased motor voltages and temperatures that stress the conductor insulation. Special inverter duty motors are available that are made to withstand these higher voltages. When installing long cables, special filters may be required to reduce these effects.
- Another problem that has come to light in recent years is stray electrical currents induced into the motor shaft by the variable frequency drive output signal. These stray currents cause electrostatic discharges across the bearings, resulting in bearing damage. To avoid this problem, brushes or slip rings are applied to provide a different path to ground for these currents.
- Some centrifugal pumps have integral shaft driven circulation devices to support bearing or mechanical seals. The pump manufacturer should be consulted regarding the minimum speed at which these devices will operate properly. This newsletter touches just a few of the issues that should be considered when applying a variable frequency drive. All of these potential problems are avoidable by working closely with the manufacturer in the selection and application of the drive and motor. Variable frequency drives provide very economical and reliable control when selected properly and applied to the right applications.

Exp no:

Date:

## **COMPARISON OF PERFORMANCE OF CENTRIFUGAL PUMP BY THROTTLING AND VARIABLE FREQUENCY DRIVES**

**Aim:**

To compare and study the performance of centrifugal pump by throttling and variable frequency drives.

**Objective:**

1. To operate the pump to give different discharges using throttling with a valve
2. To operate the pump to give different discharges using a variable frequency drive.
3. To compare the performance of the pump with valve operation and variable frequency drive.

**Apparatus Required:**

1. Centrifugal pump with starter
2. Variable Frequency Drive
3. Throttling valve
4. Power analyzer for input measurement.

**Motor Name Plate Details:**

0.7kW, 415 V, 2870 rpm, 50 Hz, 3 phase, 6/22.5 m Head.

**Tank Dimensions:**

Length: 1.35m, Breadth: 0.68m, Height: 0.34m, Head: 2.8m.

**Procedure:****Throttling:**

Keep the valve at different position and run the pump at rated frequency. Observe and measure the required parameters for efficiency calculation.

**Variable Frequency Drive(VFD):**

Run the pump at different frequency using VFD by keeping valve fully opened position. Observe and measure the required parameters for efficiency calculation. Calculate the efficiency for both the cases and compare the result by plotting the efficiency curve.

**Observation****Throttling**

Sl.no	Valve position	Initial height (cm)	Final height (cm)	Time (sec)	Discharge $m^3/sec$	Head (m)	o/p (w)	I/p (w)	Efficiency (%)
1.	Fully opened								
2	Quarter closed								
3	Half closed								
4	Quarter opened								

**Variable Frequency drive**

Sl.no	Frequency (hz)	Initial height (cm)	Final height (cm)	Time (sec)	Discharge $m^3/sec$	Head (m)	o/p (w)	I/p (w)	Efficiency (%)

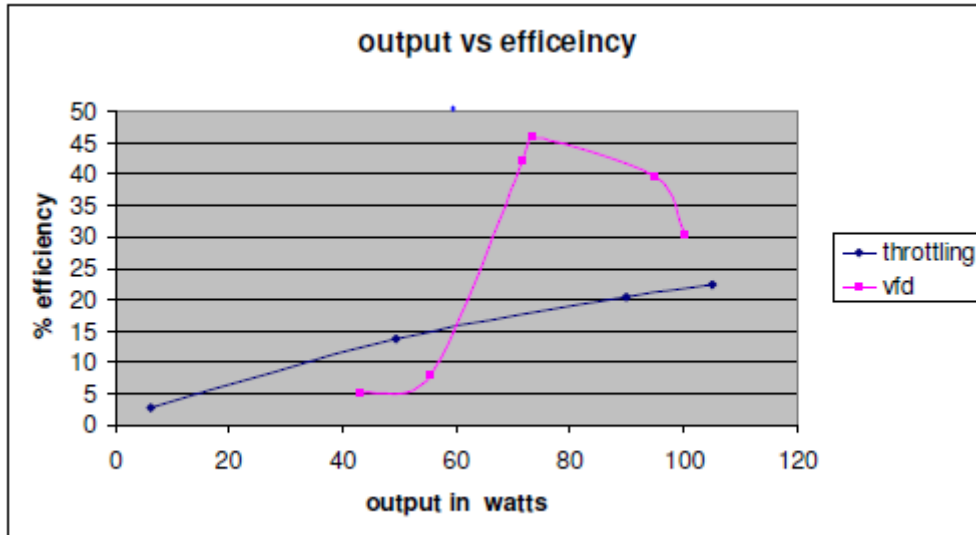
**Sample Calculation:**

Discharge = Volume of water pumped/ Time  
= (Final Height-Initial Height) \* Base Area of the tank / Time  
= .....m3/sec

Output = Water Density \* Discharge \* g \* Head  
= .....watts

Input = ..... watts

Efficiency = (Output power) / (Input power) x 100 %



**Result:**

The performance of the centrifugal pump with throttling and variable frequency drive is studied.