Microprocessor Controlled Six Phase Asynchronous Motor using Arduino

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ABSTRACT
Every electric machine requires some form of controller to operate, for the purpose of achieving reliable and robust means of starting and stopping. Motor operation also requires torque regulation, variable speed drive and regulation in the direction of rotation which could be achieved through the use of electromechanical switching, or through the use of some power electronics devices. Multiphase ac drive arrangement is widely discussed when microprocessor drive for a six phase asynchronous motor is involved. This controller can be acknowledged in two of an asymmetrical arrangement. For the asymmetrical design, the two arrangements of three-phase controllers spatially shifted by 30^0. Therefore, the spatial shift between consecutive phases becomes non-equidistant. In the event that one of the inverters is faulty, the other can keep on powering the machine. Secondly, similar phase voltages can be accomplished with half the dc-link voltages on the two inverter inputs compared to the single - sided supply. This recorded achievement makes six phase machines more advantageous as regards fault tolerance.

1.0 INTRODUCTION
Of late, multi-phase machine drives [5]are becoming of great interest because of their advantages, for example, reduced harmonic currents, lower torque pulsation, stator current reduction, fault tolerant feature, increases in power in comparison to three phase machine and greater reliability [2,9,17].They are prominently applied in high power equipment such as electric aircraft, electric/hybrid electric vehicles and ship propulsion etc. [6]. An inverter topology uses two switches connected in series as one inverter pole [2,10] noting that the number of inverter poles determines the number of phases. Technique of switching of the three phase inverter is designed basically according to the number of phases through the application of microprocessor architecture. The SPWM [7,8] and (SVPWM) techniques are extended for multi-phases [3,4,16], also, the output waveforms contain more harmonics resulting in reduced fundamental component and efficiency.

1.1 ARDUINO UNO
A Wire libraryis usually embedded in the Arduino IDE[13] for ease of use of the I2C bus. An example of an Arduino UNO board is shown in figure 1.
Arduino Uno is made up of a microcontroller board configured on 8-bit ATmega328P microcontroller [14]. It is composed of serial communication bus, voltage regulator, crystal oscillator, an ICSP header, a reset button, fourteen input/output digital pins where six of the pins can be configured as PWM outputs,six analogue pins and a power barrel jack.

2.0: Circuit Analysis
This Arduino Uno board [15] controls the entire inverter which generates the six phase sinusoidal output at a frequency of 50Hz which are then driven and supplied to the transformers for step up. This board operates between 7V to 12V at the V_{in} input point on the board which is a means of supplying power to the board. The USB port could also be used to connect power of 5V to the board. The six phases generated from the Arduino comprises two asymmetrical three phases separated by 30 electrical degrees [1,2] which constitute the asymmetrical six phase power generated. The six phase signals are generated through pins 13, 12, 8, 7,

5, and 4, with pins 13, 12 and 8 are phases A, B and C respectively, representing the first three phase while pins 7, 5 and 4 are phases X, Y and Z respectively, representing the second three phase [13]
The analysis for the programming of the microcontroller is given equations (1) to (6).

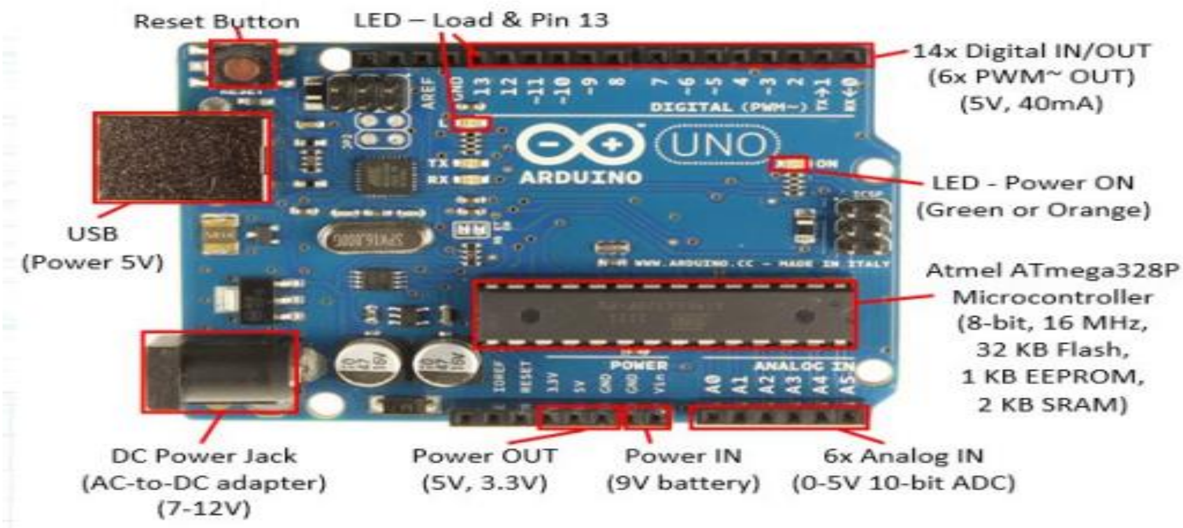

Figure 1**:** Arduino Uno, Pin Out of ATMEGA328P

The phase shifts and time differences for the six phases are captured in the table below.

S/N	PHASE	MATHEMATICAL EXPRESSION FOR PHASE SHIFT	PHASE SHIFT	TIME DIFFERENCE
1.	PHASE A	$V_A = Vcos(wt)$	0°	0.0ms
2.	PHASE B	$V_B = Vcos(wt + {}^{2\pi}/_{3})$	120° from Phase A	6.67ms after Phase A
3.	PHASE C	$V_C = Vcos(wt + {}^{4\pi}/_{3})$	240° from Phase A	6.67ms after Phase B
4.	PHASE X	$V_X = Vcos(wt + {}^{\pi}/_{6})$	30° from Phase A	1.67ms after Phase A
5.	PHASE Y	$V_Y = Vcos(wt + {}^{5\pi}/_{6})$	150° from Phase A	1.67ms after Phase B
6.	PHASE Z	$V_Z = Vcos(wt + {}^{9\pi}/_{6})$	270° from Phase A	1.67ms after Phase C

Table 1 Phase shift and time difference in the 6 phase inverter

Phase A starts at a time, t = 0,

The time difference for the remaining phases are deduced using the formula below,

$$Ps = \frac{360 \times td}{P}$$

Where

$Ps = Phase\ shift,$

$td = time\ difference,$

$P = Period$

2.1 CIRCUIT DIAGRAM

The circuit diagram of the six phase inverter shows the respective components used in the design and their interconnections with each other which also indicate the signal flow within the system as relating with the block diagram. The circuit diagram is shown below;

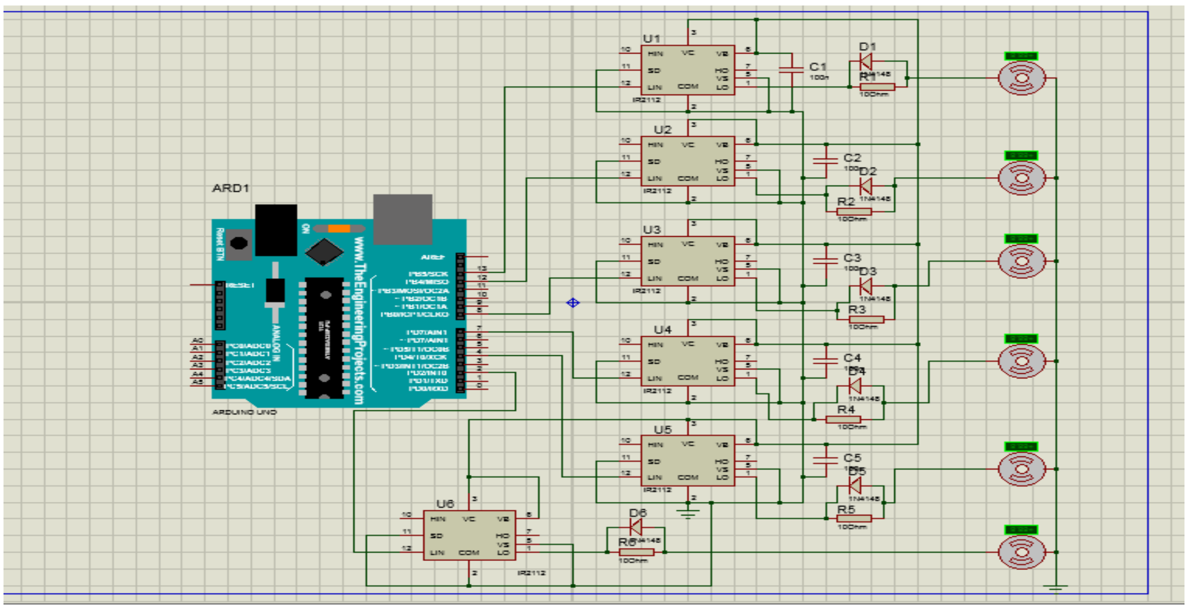

Figure 2 Circuit diagram of a six-phase inverter

The circuit diagram was designed and simulated using Proteus Design Suite [14]. From the circuit diagram, Arduino IDE was used to write the code that makes it function as the signal generator. The Arduino produces phases A, B and C (the first three phases) from pins 13, 12 and 8 respectively while phases X, Y and Z (the second three phases) are produced through pins 7, 4 and 2 respectively. Also, six IR2112 MOSFET are being used to drive the six phases of the specimen motors.

3.0PROGRAMMING OF THE ARDUINO

The Arduino was programmed using C++ and C languages [13] which are common languages Arduino easily compiles and runs. The respective time differences per phase is considered when writing the code so as to reflect the respective phase shifts as expected. The code was written to generate six phase square wave power output from the pins mentioned above. The code is shown below,

/* PROGRAM FOR A SIX PHASE INVERTER FOR ASYNCHRONOUS MOTOR DRIVE

WRITTEN ON ARDUINO IDE

```
void setup(){
 // Initialize digital pins 13, 12, 8, 7, 4 and 2 as Outputs
pinMode(13,OUTPUT);  // Phase A
pinMode(12,OUTPUT);  // Phase B
pinMode(8,OUTPUT);  // Phase C
pinMode(7,OUTPUT);  // Phase X
pinMode(4,OUTPUT);  // Phase Y
pinMode(2,OUTPUT);  // Phase Z
 }
void loop(){
intvar = 0;
digitalWrite(13,HIGH);   // Phasze A turned ON
digitalWrite(12,LOW);
digitalWrite(8,LOW);
delay(1.67);
digitalWrite(7,HIGH);   // Phase X turned ON
delay(5.00);
digitalWrite(12,HIGH);   // Phase B turned ON
while(var == 0){
delay(1.67);
digitalWrite(4,HIGH);   // Phase Y turned ON
delay(1.66);
digitalWrite(13,LOW);    // Phase A turned OFF
delay(1.67);
digitalWrite(7,LOW);      // Phase X turned OFF
delay(1.66);
digitalWrite(8,HIGH);      // Phase C turned ON
delay(1.68);
digitalWrite(2,HIGH);      // Phase Z turned ON
delay(1.66);
digitalWrite(12,LOW);      // Phase B turned OFF
delay(1.67);
digitalWrite(4,LOW);       // Phase Y turned OFF
delay(1.66);
```

```
digitalWrite(13,HIGH);      // Phase A turned ON
delay(1.67);
digitalWrite(7,HIGH);      // Phase X turned ON
delay(1.66);
digitalWrite(8,LOW);      // Phase C turned OFF
delay(1.68);
digitalWrite(2,LOW);      // Phase Z turned OFF
delay(1.66);
digitalWrite(12,HIGH);      // Phase B turned ON
delay(1.67);
digitalWrite(4, HIGH);      // Phase Y turned ON
  }
 }
```

From the code captured above, no two or more phases turn on at the same time so as to create the expected phase shift. As phase A turns on, a delay of 1.67ms takes place then phase X turns on then after a total delay of 6.67ms from the turn on of phase A, phase B turns on. This is the basic principle employed in the other phases.

4.0 PRESENTATION OF RESULTS

The simulated result clearly shows the behavior and performance of the six phase inverter as being tested with model single phase motors using the Proteus design suite software.

4.1 WAVEFORMS SHOWING VARIABLE/NO-LOAD RESPONSES

The waveforms of each phase of the six phase inverter are simulated using the Matlab/Simulink with different graphs to show system responses at load/no-load conditions.

4.2 WAVEFORMS SHOWING PHASE SHIFT

The waveforms of the six phase inverter are simulated using the Proteus Oscilloscope and also the graph to show the waveform behavior and phase shift.

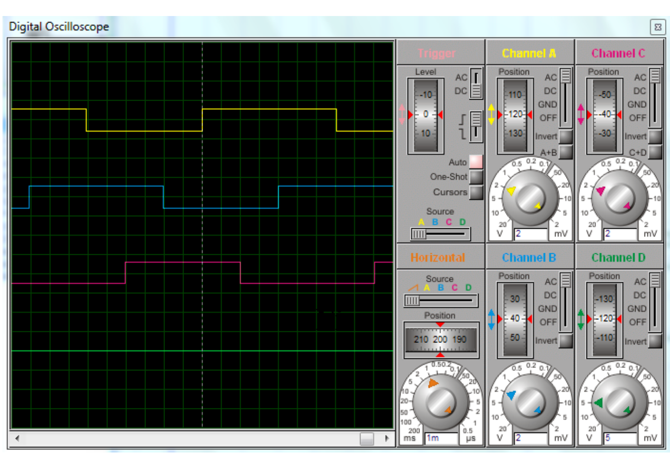

Fig.3 Waveforms for the first three phases (A, B, C)

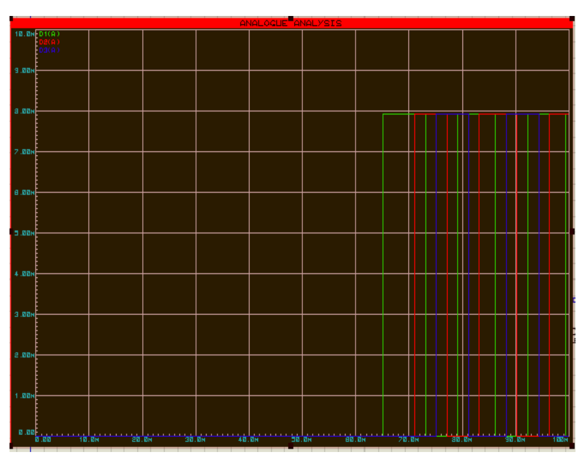

Fig. 4 Graph for the first three phases (A, B, C)

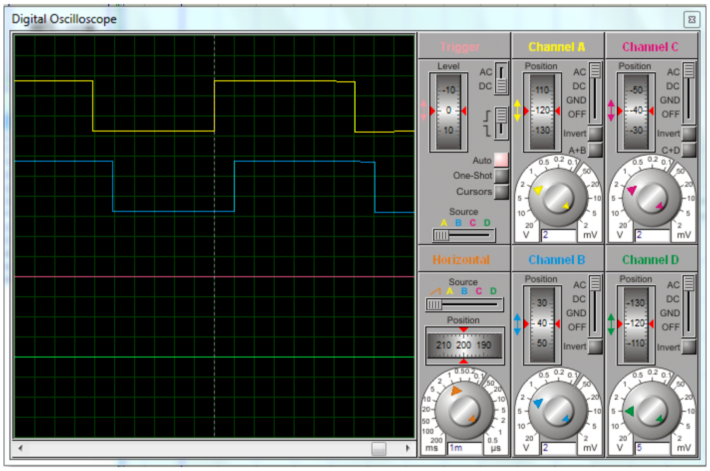

Fig 5: Waveforms for phases A and X

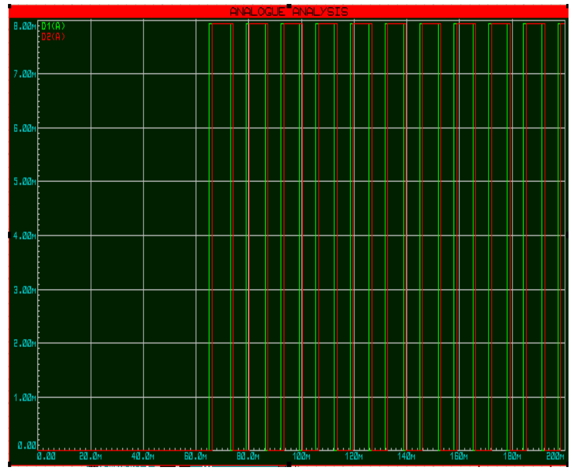

Fig. 6: Graph for phases A and X

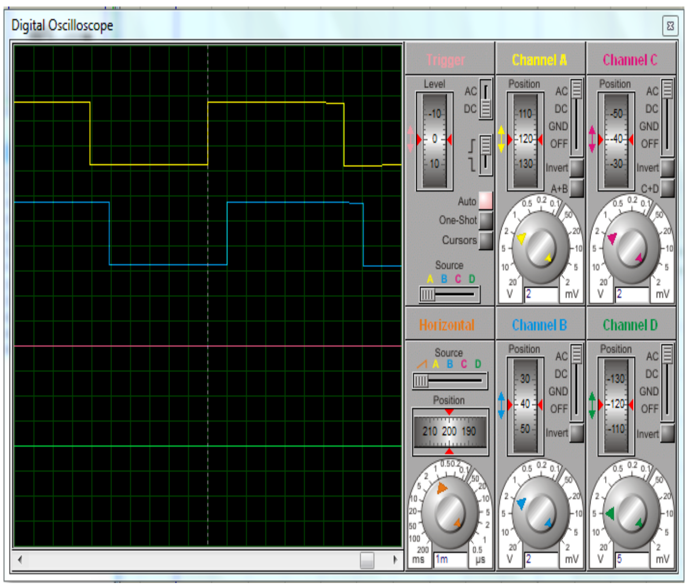

Fig. 7 :Waveform for phases B and Y

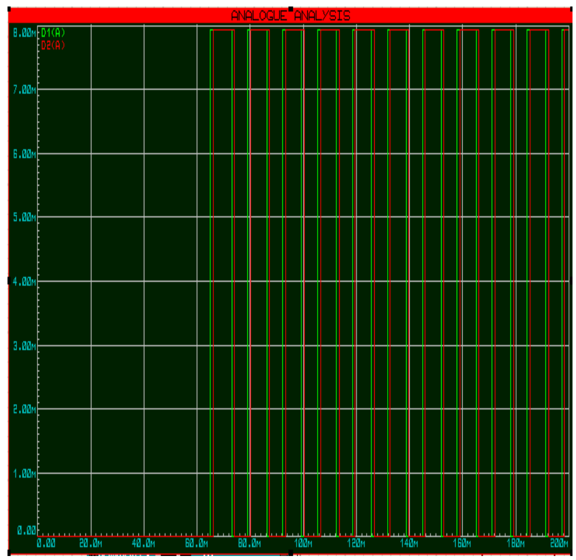

Fig. 8: Graph for phases B and Y

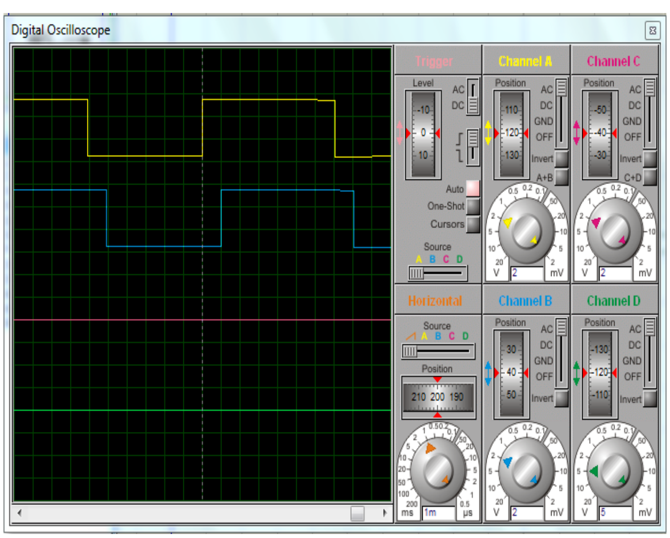

Fig. 9: Waveforms for phases C and Z

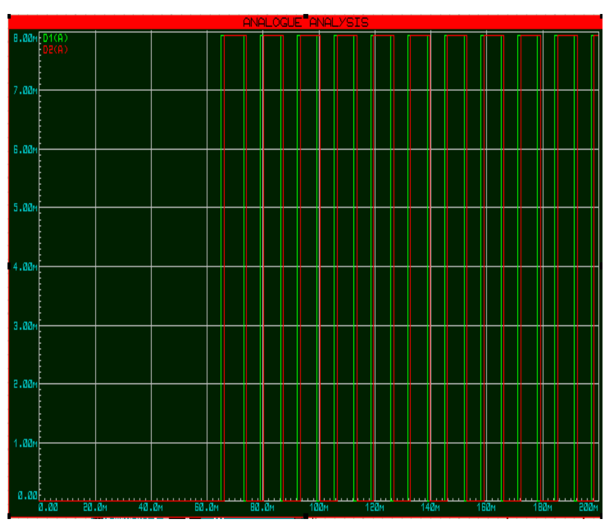

Fig. 10: Graph for phases C and Z

CONCLUSION

The phase shift in a typical three phase system is expected to be strictly 120 degrees. This consideration is employed here in this design in accordance the standard of a three phase power system. The six phase inverter comprises two three-phase inverters separated by 30 degrees. This consideration for this technique is employed so as to create an asymmetric six phase inverter system. Here it is seen that phase X lags behind phase A with an angle of 30 degrees; same applies to phases B and Y and also phases C and Z.

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