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# System Hardware Design for Single Phase Induction Motor Drive

[1]S. R. Kumbhar, [2]Neha Joshi. [3]Vaishali Patil, [4]Ashwini Patil,
[5]Vishal Lambe, [6]Uttam Harale, [7]Rohan Bansode
[1]Chintamanrao College of Commerce, Sangli
[2 to 7]Willingdon College, Sangli

**Abstract:** *Induction motor plays vital role in the industrial revolution and its drive design is necessary from the point of proper components to save the power and minimum efforts to design the drive. Selection of the various components of the drive is atmost given top priority in the industrial design. This research paper gives the idea of selection of components. The selection of transistor Bridge diode, filter capacitor as well as buffer and base driver circuit is designed and developed for the drive system. The overall system design is carried in the research work with the selected components.*

**Keywords:** Single phase drive, Buffer, Base drive system, Induction motor drive

## I. INTRODUCTION

The present chapter deals with the design of various hardware components to the drive. The inverter design with associated circuit is shown in the diagram. The design of buffer circuit for the transistor is discussed at length. Thermal considerations of the power transistor is taken into consideration to design the power heat sink required for the system.

## II. GENERAL REPRESENTATION OF SYSTEM DESIGN

Fig. 1 shows the block diagram of the proposed system, which consists of various blocks such as Buffer, Base drive circuit, Voltage source inverter, Rectifier, Motor Current sensing circuit. Voltage sensing circuit. Speed sensing circuit.

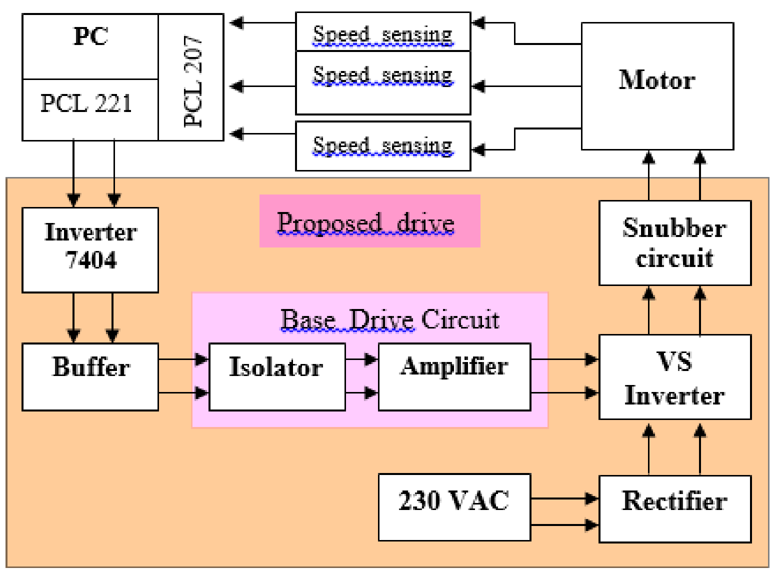


Fig. 1 Proposed system configuration

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The system shown in Fig. 1 can work in closed or open loop configuration. During open loop operation signal flows from computer to the motor through proper channel. During closed loop operation feedback is essential and different loops are used for control. In this work, multiple pulse width modulation is implemented by using the 8255 peripheral chip of PCL 221 of data acquisition card. The buffer circuit is added to protect and to avoid the loading effects on computer bus.

The base drive circuit consists of opto-isolator and amplifier. The opto-isolator isolates the firing circuit from the power circuit, while the driver amplify the signal which is sufficient to drive the power transistor of the voltage source inverter.

The basic inverter circuit consists of four power transistors with built-in anti-parallel diodes. The BU 508D power transistor is highly desirable switch. It operates at highest possible turn-on and turn-off speeds, reducing the switching losses and maintaining the most accurate operation of the inverter.

AC voltage from the source is rectified using the diode bridge and capacitor is used as a filter, the ripple present in the output of the bridge giving pure DC to the inverter. Depending upon the firing pulse width, the power supplied to the motor is varied. The speed of the motor is measured by using opto-interrupter device, which generates one pulse per revolution and these pulses are converted into proportional voltage by F to V converter. This proportional voltage is scaled into appropriate speed through software. The design of different blocks used in the system is explained in the following section one by one.

## III. TRANSISTOR BRIDGE INVERTER CIRCUIT

Fig. 2 shows the single phase PWM inverter circuit with combination of power transistors and anti-parallel fast recovery diodes capable of switching 600 A at 300 V peak [1,2]. The capacitor bank is connected across rectifier which serves to filter the AC input voltage. The capacitor bank provides a low impedance path for the high frequency currents generated by the inverter during the PWM switching [3,4]. Each power module is driven by separate base drive circuit with their own isolated power supply. A snubber is placed across each power module to maintain the instantaneous current and voltage switching loss within the ratings of the power transistors. A snubber is a electronic circuit used to suppress undesirable transients and ringing in switched mode circuits which contains parasitic inductance and capacitive elements. The choice of transistors is made because the transistors obviate the need by current controlled method.

Input AC voltage is fed to the bridge rectifier and the DC output is taken from the point A and B. The DC filter capacitor bank of value 750 μF / 500 V is used for the filtering action. If the input supply $V_D$ exceeds above the + $V_D$ (max) then the fuse will damage and circuit will act as open circuit. The positive rectified output is supplied to the collector of $T_1$ and $T_3$ while ground is connected to emitter of $T_2$ and $T_4$. Output of the base drive circuit $BD_1$ is connected simultaneously to the bases of $T_1$ and $T_2$ while the output of the other base drive circuit $BD_2$ is connected simultaneously bases of $T_3$ and $T_4$. When $T_1$ and $T_2$ are conducting, the $T_3$ and $T_4$ remainscutoff and vice versa. There must be some short duration between $T_1$ getting off and $T_3$ turning on. This duration must be >= turn-off time of transistor ( 2μS). When output of base drive $BD_1$ goes high, the transistor $T_1$ and $T_2$ conducts and current flows through A, $T_1$, M, $T_2$, B and back to A. Similarly output of base drive $BD_2$ goes high $T_3$ and $T_4$ conducts and current flows through A,$T_3$, M, $T_4$, B and back to A.


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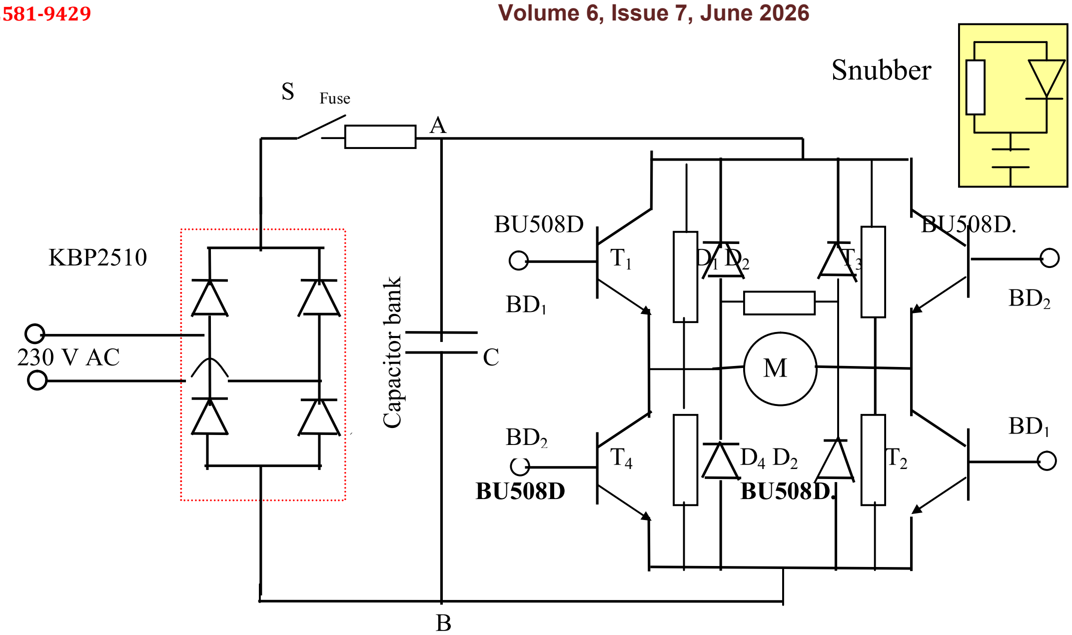


Fig. 2 PWM voltage source inverter.

### 3.1 Power Circuit

The inverter is designed for 1 HP 800 W single-phase induction motor with power factor 0.85. While designing the power circuit the values of the components are selected in such a way that the power circuit will withstand without any damage and at the same time power dissipation, voltage rating and cost is also taken into account which should be minimum. The components selected are having slight high ratings than the actual calculated ratings.

#### 3.1.1 Selection of Main Power Transistor

The transistor is selected on the basis of current rating and type of supply given to the load [5]. The maximum line current drawn by the motor with 0.75 efficiency is –

$$I_{max} = \frac{\text{Wattage}}{V_D \text{ x power factor x efficiency}} \quad \text{-------------------- (1)}$$

$$I_{max} = \frac{800}{206.72 \text{ x } 0.85 \text{ x } 0.75}$$

$$I_{max} = 6.07 \text{ Ampere}$$

$$I_{peak} = 12.14 \text{ Amp. (Peak)} \quad \text{-------------------- (2)}$$

Assuming the safety factor of 0.5 the device current rating is

$$I_{max} = 12.14 \text{ x } 0.5$$

$$I_{max} = 6.07 \text{ Amp.} \quad \text{-------------------- (3)}$$

The maximum voltage to the diode bridge is –

$$230 + 10\% = 253 \text{ Volt.} \quad \text{-------------------- (4)}$$

The maximum output of bridge is -

$$253 \text{ x } \sqrt{2} = 357.74 \text{ V DC.} \quad \text{-------------------- (5)}$$

Thus taking all factors into account the requirement of minimum device rating must be 700 V. With these requirements a switching transistor BU 508D is selected. This transistor has built in integrated anti-parallel diode. Heat sink is also provided to each power transistor.

*3.1.2 Selection Of Diode Bridge*

A single-phase diode bridge is designed for low power motor with capacitor filter bank. The maximum input voltage is 230 + 10% = 253 V.

The maximum output of the bridge is ( 253 x √ 2) = 357.7 V DC. ----------- (6)

Thus the diode must withstand 357 x 1.5 = 536.5 V with derating [6]. The KBP2510 package of bridge fulfils the above voltage condition.

The maximum current drawn by the filter capacitor is

$$I_c = \frac{\text{Wattage}}{V_D \text{ x power factor x efficiency}} \quad \text{-------------------- (7)}$$

$$I_c = \frac{800}{206.72 \text{ x } 0.85 \text{ x } 0.75}$$

$I_c$ = 6.07 Ampere

$I_c$ ≅ 6 Ampere

$$I_c \text{ Avg.} = \frac{607}{2} = 3.035 \text{ A} \quad \text{-------------------- (8)}$$

Thus the diode bridge of KBP2510, with specifications given below are selected.

*Max average forward current = 25 A*

*Max peak forward surge current = 300 A*

*Forward voltage drop = 1 V. 12.5 A.*

*Max reverse current = 10 μA, 50 V*

**3.1.3 Selection of Filter Capacitor**

Assuming the voltage drop of 5 % when the input voltage is 230 V. The capacitor voltage

ΔV = 230 x 0.05 x √ 2

ΔV = 16.261 Volt. -------------------- (9)

The DC current drawn at full load is $I_{dc}$ which is 6.07 Ampere. -----------(10)

The capacitor value will be a large hence charging time is assumed to be negligible [7].

$$I_{dc} = C\, \Delta V / \Delta t \quad \text{-------------------- (11)}$$

At Δt = 2 m Sec.

$$C = \frac{I_{dc} \text{ x } \Delta t}{\Delta V}$$

$$C = \frac{6.07 \text{ x } 2 \text{ x } 10^{-3}}{16.261} = 746 \ \mu\text{F / 500 V.}$$

Selected capacitor, C ≅ 750 μF / 500 V.


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## IV. BUFFER CIRCUIT

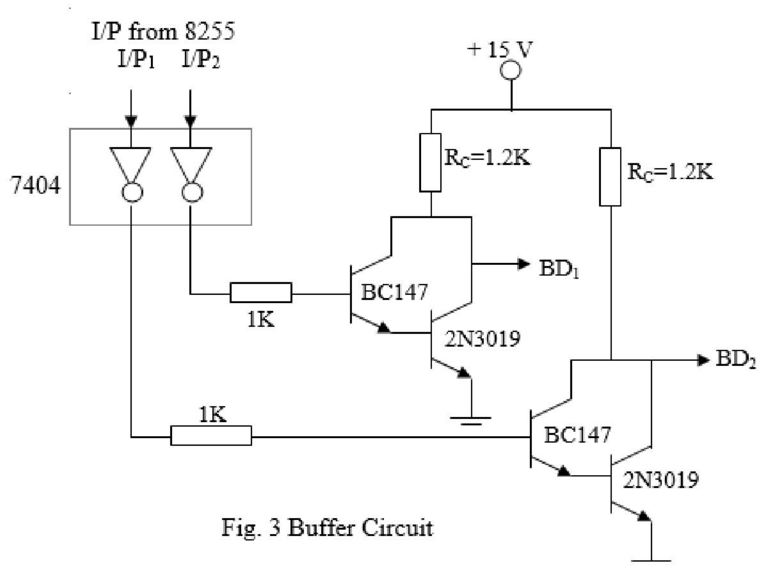


Fig. 3 Buffer Circuit

The PWM pulses are generated through the PCL 221 card by using 8255 peripheral chip. The 8255 signal is not sufficient to drive the opto-isolator. To over come this difficulty, buffer circuit is introduced between 8255 and opto-isolator. Fig. 4.7 shows the circuit diagram for the buffer circuit.

The signal from 8255 is given to inverter which drives BC147 and 2N3019 Darlington transistor pair. Output of which is given to opto-isolator. The design of buffer circuit is given below.

The output of 8255 provides the base biased to the BC 147

∴ Output voltage of the inverter IC is = 5 V

The required current to turn-on BC 147 is = 4 mA

∴ Base resistance to BC 147 is = 5V / 4 mA = 1.2K Ω

Current through BC 147 is $I_c = V_{CC} / R_c = 15\ V / 1.2\ K$

$I_c = 12.5mA$

$I_c = 13$ mA Approx. -------------------- (13)

## V. BASE DRIVE CIRCUIT

Fig. 4 shows the internal structure of optocoupler (MCT2E).

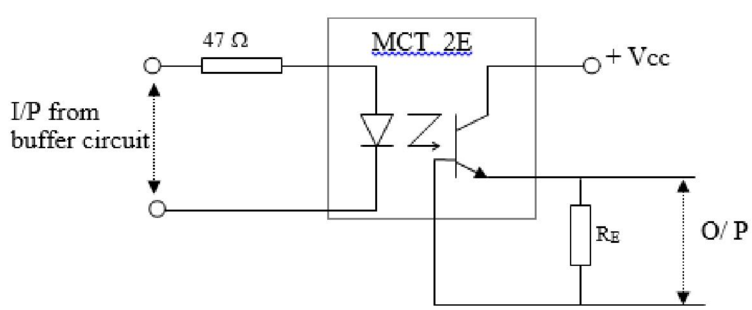


Fig. 4 Internal circuit of optocoupler.

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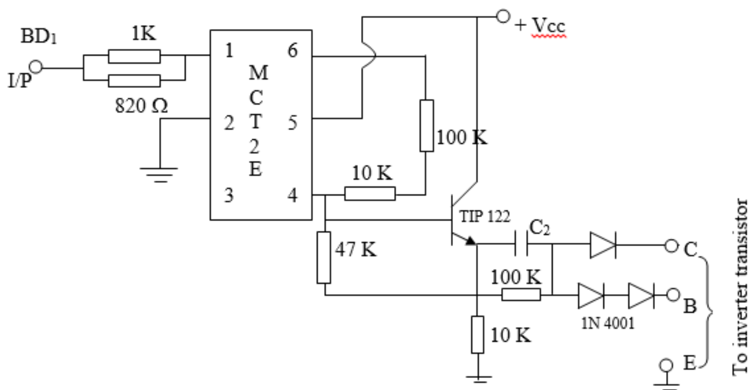
Optocoupler is a combination of light emitting diode (LED) and a silicon phototransistor. The rise and fall time of phototransistor is very small, with typical values of turn-on time $t_{on}$ = 2 –5 μS and turn-off time, $t_{off}$ = 300 nS. These turn-on and turn-off times limits the high frequency application. The phototransistor require a separate power supply and add to complexity, cost and weight of the drive circuit.

When the input is applied the light emitting diode is turn-on and light emitted by it fall on the base resistor of phototransistor. Therefore, photo transistors conducts and output is produced across emitter resistance ($R_E$). The emitter resistance can be calculated by using formula $R_E = (V_{CC} - V_{CE})/I_E$. The main function of optocoupler in the present application is to isolate the power circuitary from the control circuitary.




**Base Drive Amplifier Circuit**

Fig. 5 Base Drive Amplifier Circuit

With the selection of values of components, the base drive circuit is designed as shown in the Fig. 5

The base drive circuit is also called firing circuit. The function of base drive or firing circuit is to provide –

1) Sufficient base current to make the transistor go into quasi-saturation.
2) Reverse base current while turning off the transistor, so that turn-off time is reduced.

The optocoupler MCT2E isolates the control circuit from the power circuit. This isolation provides the high speed with delay of maximum 4 μS at a frequency more than 18 KHz. The signal then drives TIP 122 to provide required base drive to the power transistor. The required voltage and current is made available by the base driver circuit. When the input signal is cut off, the transistor TIP 122 is also cut off, since no signal is available at the base of power transistor, it is switched off. The switching speed can be increased by reducing turn-on time $t_{on}$ and turn-off time $t_{off}$. The $t_{on}$ can be reduced by allowing the base current peaking during the turn-on, resulting in the low forced β ($\beta_f$) at the beginning. After turn-on, $\beta_f$ can be increased to the sufficient high value to maintain the transistor in the quasi-saturation region. The $t_{off}$ can be reduced by increasing the base current and allowing the base current peaking during turn-off. Increasing the value of reverse bias current $I_b$ decreases the storage time. The diode network is used to prevent the transistor from going into hard saturation.

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