



## Design and Simulation of 80 kHz High Frequency Converter Using CD 4047IC CMOS

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### ABSTRACT

The electrical power appliances which convert source frequency to another frequency level is known as frequency converter. This research proposed a novel design method to achieve the 80 kHz high frequency converter. In this design, the circuits have been made which contains step-down transformer, inverter circuit using MOSFETs, CD 4047IC and step-up transformer. Single phase source is used as a source. Therefore, the rectification is used to convert the AC source to DC source and to supply the 12V by using voltage regulator. Inverter is used to convert DC to AC. Circuit simulation was done by using Proteus software.

**Keywords:** Analog RC oscillation, MOSFET high frequency switching, single phase frequency converter, full bridge power rectification, high frequency transformation

### I. INTRODUCTION

The research focuses to design single phase high frequency appliance, which necessary to process electrical power to suit various appliances used in environments where dissimilar frequencies are mandatory[1]. Solid state power or frequency converters are used for converting 50Hz utility line power to high frequency power. Many varied applications like switching mode power supplies, melting machine, radar, and communication equipment and so on. Major issue of using melting machine can operate at high frequency instead of conventional 50Hz which is to make equipment smaller, lighter and efficient [3]. In this research,, 50Hz frequency is converted to 80kHz output without changing line voltage for melting machine. CD 4047IC is used to generate required oscillation for

desired frequency by Ana log RC oscillation method. By changing the values of resistor and capacitor inputs of CD4047IC is applied to obtain 80 kHz frequency. To get alternating voltage, push transformer (centre tapped transformer) must be controlled by switching devices. There are three different forms of AC output generated: square wave, modified sine wave, and pure sine wave. The square wave type is the simplest method. Besides, it is best suited to low-sensitivity applications such as lighting and heating [9]. A modified sine wave can damage to devices like: laser printers, laptop computer, power tools, digital clocks and medical equipment.

The output of voltage regulator, DC regulated voltage is supplied to the inverter. Output of inverter is low voltage hence centre tapped transformer is used to step up the voltage up to 220 V. This voltage is used to drive the load. In Figure1.shows the block diagram of the model.

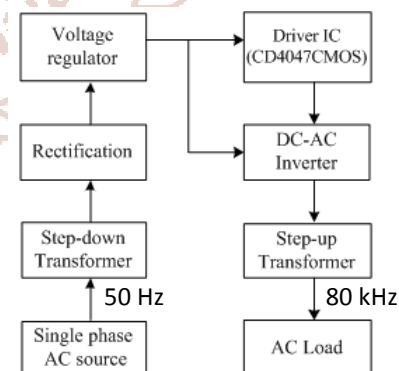


Figure.1. Block Diagram of the Purposed Model

### II. DESIGN SELECTION AND IMPLEMENTATION

The design circuit contains step-down transformation and rectification for frequency oscillation, DC regulations, RC oscillations for desired frequency, DC

to AC inversion and step-up transformation voltage level. Step-down Transformer, Rectification, Voltage Regulator, RC oscillator and MOSFET switching inverter are main components of the proposed model.

**A. Step-down Transformer**

A transformer is a device that transforms voltage and current level to another without changing its power rating and frequency. In this proposed converter system 220/24V step-down transformer is selected to transform high voltage into low voltage level for implementation.

**B. Rectification**

Rectification is a process of converting alternating current or voltage into direct current or voltage, which converts bidirectional voltage to unidirectional voltage. They are classified as uncontrolled and controlled rectifiers by switching characteristic. Uncontrolled rectifier makes use of power semiconductor device while controlled rectifier makes use SCR, GTO, MOSFET, thyristor. They are half wave and full wave rectification into two groups of uncontrolled rectification [6]. Full bridge rectification is used for efficiency purpose.

**C. Voltage Regulator**

A voltage regulator is an integrated circuit (IC) that provides a constant fixed output voltage regardless of a change in the load or input voltage. The rectified DC power supply is regulated to 12V using voltage regulator LM 7812 and it is used to provide step-up transformer. And LM 7805 IC has been used to supply 5V oscillation generator IC CMOS CD4047. This IC has a built-in protection from the high current. In voltage regulator, the capacitors have been used in order to minimize the voltage fluctuations in the circuit and maintain the constant voltage across the input as well as output of the circuit.

**1) 12V Regulation**

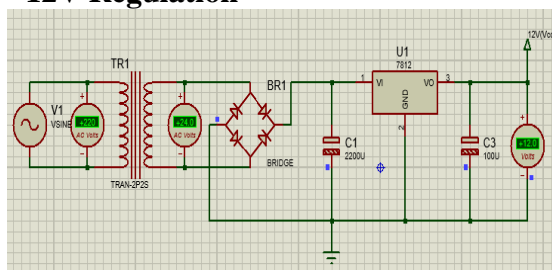


Figure.2 Structure of 12V Power Supply

The turn ratio of step-down transformer in this design is equal to 9 from eq (1). Then, it is utilized to

calculate parameter primary inductance ( $L_p$ ) and secondary inductance, ( $L_s$ ) respectively. AC is converted to DC by using bridge rectifier circuit. Next, capacitor can be calculated from eq (3). Finally, it is reduced to 12V (V cc) with 7812 regulator. This voltage is to supply step-up transformer.

$$a = \frac{N_p}{N_s} = \frac{V_p}{V_s} \tag{1}$$

$$\frac{V_s}{V_p} = CP \times \sqrt{\frac{L_s}{L_p}} \tag{2}$$

$$C = \frac{10^{-4} \times I_{dc}}{0.48V_{dc}} \tag{3}$$

Where, CP=coupling factor  
C =capacitor

**2) 5V Regulation**

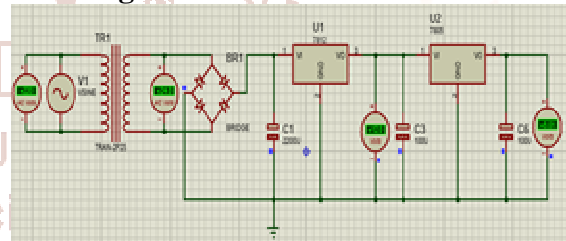


Figure.3 Complete structure of 12V to 5V Power Supply

LM 7812 regulator output, 12V has to be chopped to 5V for frequency generator IC. Finally, it is reduced to 5V with LM 7805 regulator.

**D. Inverter**

An inverter is an electrical circuit capable of turning DC power to AC power, while at the same time regulating the voltage, current and frequency of the signal. Inverters are constructed with various sensitive electronic and electrical components such as MOSFET, IGBT, transistors (FET, JFET), Bi-stable multi vibrators etc. There are different types of MOSFET available but this inverter is designed by using IRFZ44N channel type of MOSFET. IRFZ44N is power MOSFET which handles high frequency, voltage and current. N-channel is more efficiency than p-channel. This MOSFET has been used turning on and off at 80 kHz frequency as source to drive the output of two MOSFET is connected in parallel to the input of transformer.

**III. METHODOLOGY**

The CD4047IC is capable of operating in either the monostable or as astable mode. In astable mode, it

requires an external capacitor (between pins 1 and 3) and an external resistor (between pins 2 and 3) to determine the output frequency in the as table mode. As table operation is enable by a high level or low level at the as table input. The output frequency depends on the timing components. CD 4047IC is a low power CMOS IC that can operate between 3 to 15volts DC.

If 28kΩ resistor and 100pF capacitor are used, 80 kHz frequency will be achieved. Then R<sub>1</sub> and C<sub>1</sub> can be made by adjustments and measure the result with the oscilloscope. When using a value of 100pF for C<sub>1</sub> and 28kΩ for R<sub>1</sub> the theoretical frequency is 81.16 kHz; however in simulation resulted with a frequency of 80 kHz approximately. The desired frequency is varied by the value of R<sub>1</sub> and C<sub>1</sub> as shown in Table I.

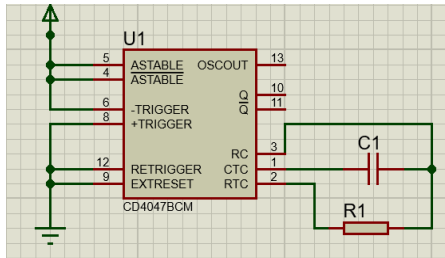


Figure.4. Pin Configuration of CD 4047IC

The circuit diagram in Figure (4) is the typical application of the CD 4047IC in the as table mode. The timing elements are capacitor C<sub>1</sub> and resistor R<sub>1</sub>. By a combination of pins 8, 9 and 12 are connected into ground, output pulse will be available from pins 10 and 11.

$$T = 4.4R_1C_1 \tag{4}$$

$$f = \frac{1}{T} = \frac{0.227}{R_1C_1}$$

A frequency (f) adjustment control has been provided by R<sub>1</sub>. There is no theoretical limitation on the values of either R<sub>1</sub> or C<sub>1</sub>. To ensure frequency stability, however, C<sub>1</sub> must be greater than the stray capacitances associated with the circuit design, and R<sub>1</sub> should be much larger than the CMOS 'on' resistance with which it is in series.

TABLE I

Frequency adjustment by R<sub>1</sub>

Variable Resistor	Period	Frequency
28k	80.40μs	94.51kHz
26.6k	11.41μs	87.64kHz
25.2k	11.83μs	84.5kHz
23.8k	12.45μs	80.32kHz
22.4k	13.10μs	76.33kHz
21k	13.98μs	71.53kHz
19.6k	14.72 μs	67.93kHz

IV. DESIGN CALCULATION

C. Design Calculation of Transformer

Flux density 1.2 Tesla is assumed.

The e.m.f per turn,

$$E_t = 1.2\sqrt{kVA} \tag{5}$$

Area of core,

$$A_i = \frac{1}{4.44fB_m T_e} \tag{6}$$

LV winding current,  $I_s = \frac{P_{out}}{V_s}$  (7)

Conductor size,  $a = \frac{\text{current}}{\text{current density}}$  (8)

Number of turns= turn per volts × volts (9)

Volume of conductor= Area × length (10)

Weight = density × volume (11)

Output power = secondary power

Input power P<sub>in</sub> = 1.1 × P<sub>o</sub> (12)

Primary power = Input power  
 $V_p \times I_p = P_{in}$  (13)

$$I_p = \frac{P_{in}}{V_p}$$

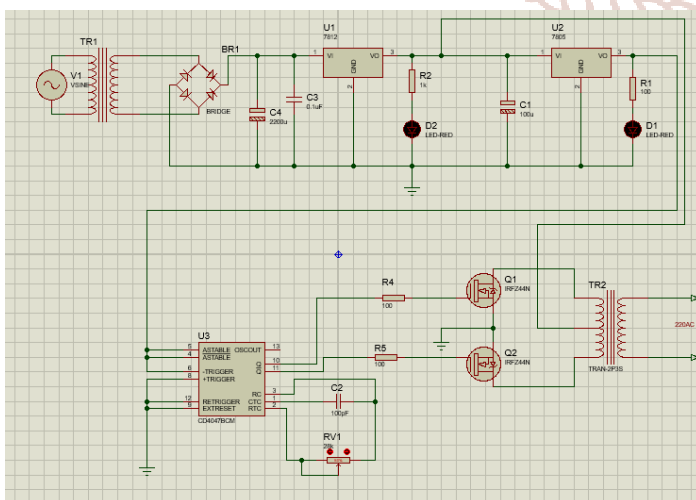


Figure.5. Circuit Diagram of Frequency Converter

Total losses = copper losses + iron losses (14) = 32.54 V

$$\text{Efficiency} = \frac{P_{\text{out}} \times p.f}{P_{\text{out}} + \text{total losses}} \times 100\% \quad (15)$$

$$V_{\text{avg}} = \frac{2V_{o(\text{max})}}{\pi} = 20.175V \quad (18)$$

A transformer is a device that transforms voltage and current level from one AC system to another. In table II, frequency conversion of transformer has been designed. For frequency 50 Hz step down transformer, output voltage 24 V and high efficiency 85 % can be used in inverter design as well as battery charger. With the aid of rectifier, the output voltage could be set and use to supply DC load. But, applied load is required 80 kHz to reduce the effective cross section of the conductor, loss and size. So, frequency 80 kHz is used for step up transformer.

For Figure 2, 220 V to 24V AC step-down transformers can be used because the calculated secondary voltage is 20.715 V.

Choose,  $C_1 = 2200 \mu F$ ,  $I_{dc} = 1 A$

$$\text{Capacitor, } C_1 = \frac{T \times I_{dc}}{2 \times V_{r(pp)}} \quad (19)$$

$$V_{r(pp)} = 4.54V$$

$$V_{dc} = V_{o(\text{max})} - \frac{V_{r(pp)}}{2} = 30.27V \quad (20)$$

**TABLE II**

Frequency Conversion in Transformer

Parameter	Step-down Transformer 115VA, 220/24V, f=50Hz	Step-up Transformer 100VA, 12/220V, f=80kHz
Current	$I_p = 0.6A$ $I_s = 4.79A$	$I_p = 9.2A$ $I_s = 0.45A$
Area of core	$A_i = 0.001451m^2$	$A_i = 0.000069m^2$
Conductor Size	$a_p = 0.26mm$ $a_s = 2.08mm$	$a_p = 3.06mm$ $a_s = 0.15mm$
Number of turns	$N_p = 570 \text{ turns}$ $N_s = 60 \text{ turns}$	$N_p = 3 \text{ turns}$ $N_s = 50 \text{ turns}$
Volume of conductor	$V = 4.914 \times 10^{-5} m^3$	$V = 4.7 \times 10^{-6} m^3$
Weight	W= 440 grams	W= 24grams
Total losses	16.235W	2.2799W
Efficiency	85%	97%

In this circuit, capacitor  $C_1 = 2200 \mu F$  is used and selected to give suitable value for regulated power supply. Since the operational DC current for control circuit can be less than the desired output current, the standard 2200  $\mu F$  capacitor is chosen for  $C_1$ . It is also used to be more good the storage capacity.

**E. Calculation of MOSFET Switching Losses**

In this system, for power MOSFET IRFZ44N driver, consideration for power losses has two sources. They are the on-state loss, the off-state loss, the turn-on switching loss and the turn-off switching loss. The required values can be obtained from the datasheet of IRFZ44N.

Internal resistance of MOSFET,  $R_{DS} = 22m\Omega$ , Drain to source current,  $I_D = 49A$ , Leakage current,  $I_{DSS} = 250 \mu A$ , Rise time,  $t_r = 75nS$ , Fall time,  $t_f = 40nS$  from datasheet [7].

The switching frequency  $f = 16 \text{ kHz}$

**D. Calculation of Power Control Circuit**

For bridge rectifier circuit,

Input voltage = 220 V, 50 Hz , AC source

The secondary voltage of transformer,  $V_s(\text{rms}) = 24 \text{ V}$

The desired output current,  $I_{DC} = 0.5 \text{ A}$

The diode cut-in voltage is assumed to be  $V_r = 0.7 \text{ V}$  (0.7V for Si and 0.3 for Ge)

$$V_{s(\text{max})} = \sqrt{2} V_{s(\text{rms})} = 33.94 \text{ V} \quad (16)$$

$$V_{0(\text{max})} = V_{s(\text{max})} - 2V_r \quad (17)$$

$$\text{Output current, } I_{\text{out}} = \frac{P_{\text{out}}}{V_{\text{out}}} = 0.435A \quad (21)$$

$$\text{Drain current} = I_D = \frac{P_{\text{in}}}{V_{\text{in}}} \quad (22)$$

$$\eta = 85\% , \quad P_{\text{in}} = \frac{P_{\text{out}}}{\eta} = 117.64W$$

$$I_D = 9.8 \quad (23)$$

$$T = \frac{1}{f} \quad (24)$$



$$=62.5\mu\text{sec}$$

Assume  $d = 50\% = 0.5$

$$T = t_{\text{on}} + t_{\text{off}} + t_r + t_f$$

$$62.5 \times 10^{-6} = t_{\text{on}} + t_{\text{off}} + 75\text{nS} + 40\text{nS}$$

$$t_{\text{on}} = t_{\text{off}} = \frac{(T - t_r - t_f)}{2} = 0.2 \mu\text{sec}$$

The on-state loss can be calculated by following equation,

$$P_{\text{on}} = \frac{I_{\text{D}}^2 \times R_{\text{DS(on)}} \times t_{\text{on}}}{T} \quad (25)$$

$$= 1.05\text{W}$$

The on-state power loss of MOSFET is 1.05 W.

From the datasheet,  $V_{\text{DS}} = 55\text{ V}$  and  $I_{\text{DSS}} = 250\text{ uA}$ .

The off-state loss can be calculated by following equation,

$$P_{\text{off}} = V_{\text{DS(max)}} \times I_{\text{DSS}} \times \frac{t_{\text{off}}}{T} \quad (26)$$

$$= 0.0068\text{ W}$$

The off-state power loss of MOSFET is 0.0068 W.

## V. OPERATION OF THE FREQUENCY CONVERTER

The circuit diagram of frequency converter using CD 4047IC and MOSFET IRFZ44N. In this circuit, 5V power supply is connected to the pin 4, 5 and 6. In them, the pin 4 and 5 are complement astable of the IC. Remaining pins are grounded. Next, 100pF capacitor is connected between the pin 1 and 3 a variable resistor 28kΩ is connected between pin 2 and 3 to generate the output frequency of the IC. The output frequency pin 10 and 11 are connected to the MOSFET through resistor  $R_2$  and  $R_3$  which to prevent to the load of the MOSFET. The current is made to flow positive half of the primary coil of transformer through  $Q_1$  this is done when the pin 10 becomes high and negative half is done by opposite current flow through  $Q_2$  the primary coil of transformer, this is done when pin 11 is high. By switching the two MOSFET current is generated AC [5].

## VI. SIMULATION RESULT OF SINGLE PHASE CONVERTER

Proteus is a powerful tool used to simulate and power electronics circuit designs. Proteus has large database of configurable power component models along with existing models from various semiconductor manufacturers. The powerful Proteus simulation

enables the evaluation of different power circuits of different ratings at an early design stage. Models for IGBT (or) MOSFET switches, electro-mechanical components, different active and passive components, and switching controllers can be used to evaluate power electronics systems accurately.

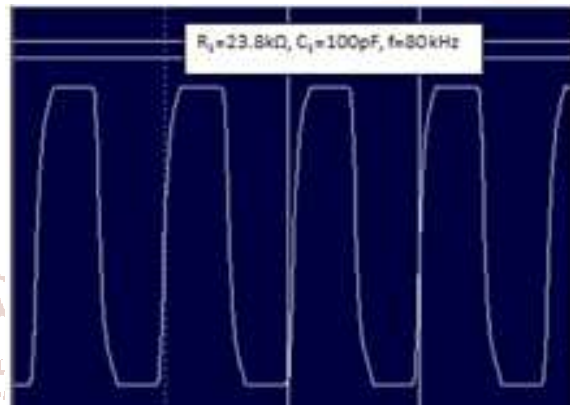


Figure6. Simulation of Frequency Converter using Proteus Software

## VII. CONCLUSION

In this research, the proposed design is described the method of high frequency converter. Design procedures were calculated and performance simulation was done by Proteus. The presented circuit is the sample of 80 kHz frequency converter. The target of this paper is frequency conversion from 50Hz to 80 kHz; 220V.AC system is not directly converted low frequency to high frequency. So, MOSFET switching devices are directly driven by the switching pulses of CD4047IC to convert high frequency 80 kHz. The output waveform of frequency converter will generate is approximately square wave. This method produces a much more similar AC waveform than that of others. Most of the electrical appliances are designed for the 80 kHz square wave like melting machine, radar in electrical power system. Finally, the basic demands defined by the operator have also been addressed, such as equipment smaller, lighter, high efficiently and long lifetime.

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