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A practical design of a primitive low wattage inverter with its duty cycle and efficiency calculation

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ABSTRACT

A primitive low wattage electronic inverter has been designed using very few low cost and easily available electronic components such as resistors, capacitors, transistors, MOSFETS, transformer and battery only and its duty cycle is theoretically calculated and also experimentally measured at a few representative and practically viable values of resistors and capacitors. Measurements are done by using a Digital Oscilloscope – 'Scientech ST201C' and a sophisticated Source Meter – 'Keithley 2401' with high accuracy in our laboratory. The measured values of the duty cycles well match with the theoretically calculated ones. This designed circuit, though primitive in nature, is well acceptable from the practical point of view.

INTRODUCTION

An inverter is an electronic device that coverts a direct current (d.c.) in to alternating current (a.c.) which is used to run a.c. loads, such as bulbs, fans, motors, etc. (Kelley, A. W. and Yadusky, W. F., 1992.).

The inverter that has been designed in our laboratory consists of very few elements such as transistors, MOSFETS, resistors, capacitors, transformer and battery only. The portability and simplicity of the circuit gives a boost towards the practical utility of the mini inverter.

THEORY

The basic principle of an inverter circuit is to produce oscillating signal (current / voltage) using a battery (or a given DC source). These signals are amplified and then fed across the secondary of the transformer. This voltage is then stepped up to a higher voltage depending upon the number of turns in primary and secondary coils of the transformer (Figure 1).

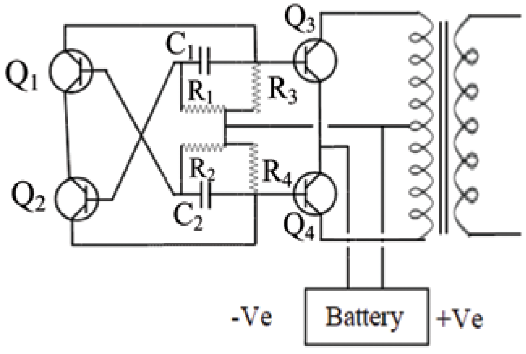

Figure 1. Mini inverter circuit diagram

There are two sections or the two halves of the circuit (upper and lower halves in our case) which operate in a regenerative manner. No matter how much they are matched, these two sections of

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**Corresponding author's Email: s.phys.res@gmail.com* the circuit always have a slight imbalance in the values of the parameters surrounding them. Due to this imbalance both the sections can't conduct together at one instant. The circuit actually works with a push pull kind of operation where the transistors *Q*1 and *Q*2 form a simple astable multivibartor thereby creating an approximate frequency of 50 Hz (Sze and Lee, 2010).

Let it be assumed that the upper half transistor Q_1 conducts first. Obviously it gets the biasing voltage through the lower half of the winding of the transformer via the biasing resistor R_2. The moment it conducts fully and saturates, the entire battery voltage is pulled through its collector to the ground. This sucks-out dry any voltage through R_2 to the base of the upper half transistor Q_1 and it immediately stops conducting. The lower transistor Q_2 now gets an opportunity to conduct with the biasing voltage through the upper half of the winding of the transformer via the biasing resistor R_1. The cycle keeps on repeating automatically. The whole circuit thus starts to oscillate. Thus the current through the transformer coil keeps alternating at the same frequency. This in turn induces ac voltage across the secondary coil of the transformer where the load remains connected.

The base emitter resistors R_3 and R_4 (along with the capacitors C_1 and C_2) are used to maintain a particular threshold for their conduction, i.e., they help to fix a base biasing reference voltage level. Reduction in the values of the resistors R_1 and R_2 result in increase in the output power of the transformer or vice-versa. The power of the inverter can mainly be increased by increasing the number of MOSFETs in the form of cascades.

Electrical Waveforms, Technically speaking, are basically graphical representations of the variation of a voltage or current over time (Fig.2).

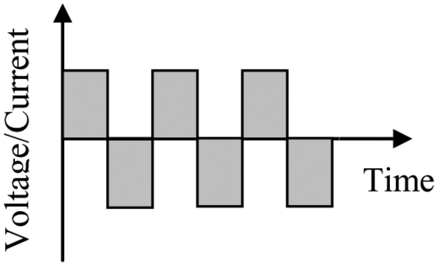

Figure 2. Square waveform in ideal form

Square electrical waveforms are, in general or ideally, symmetrical in shape, i.e., both the halves of the cycle are identical. The time interval of the positive pulse is equal to that of the negative halve. The time interval of the positive pulse is known as the 'Duty Cycle' (Rashid, M. H., 2001).

The time interval corresponding to the positive pulse of the square waveform is 'ON' time and that corresponding to the negative pulse is called 'OFF' time. In digital electronics, the positive pulse is used to represent 'logic level 1' or 'high' and the negative pulse is used to represent 'logic level 0' or 'low' (https://www.popsci.com). The positive and negative pulse widths of a square wave are sometimes called as 'Mark' and 'Space' respectively. The ratio of the Mark time to the Space time is called 'Mark-to-Space' ratio. For a symmetric square wave, 'Mark-to-Space' ratio is one (http://www.circuitstoday.com and http://visionics.a.se/html).

In a symmetric square waveform, 50% duty cycle means the time interval of the positive pulse is half of its time period. If the duty cycle of the waveform is any other value than 50%, the resulting waveform would then be called a **rectangular waveform. If the** 'ON' time is really small it is simply called a pulse (Babarinde, Adeleke, Adeyeye, Ogundeji, and Ganiyu, 2014).

Thus the time period of a square wave may be expressed as –

$$T = ON\ time + OFF\ time$$

In terms of pulse time intervals –

$$T = T_{(positive\ pulse)} + T_{(negative\ pulse)}$$

In terms of Mark and Spaces –

$$T = T_{(Mark\ time)} + T_{(Space\ time)}$$

The formula for the frequency of square wave generated by the transistor astable multivibrator (Ommitola, Olatinwo, and Oyedare, 2014.) is given by

$$f = \frac{1}{1.38 \times R_2 \times C_1}$$

The values of R_2 and C_1 decide the frequency.

The time period is given by

$$T = \frac{1}{f} = 1.38 \times R_2 \times C_1$$

Duty cycle can be calculated from this T.

MATERIALS AND METHODS

This inverter has been designed using low cost and easily available simple electronic components such as MOSFETs, transistors, resistors, capacitors, transformer and battery only. Its duty cycle is theoretically calculated and also measured by using a Digital Oscilloscope – 'Aplab D36100C' and a sophisticated Source Meter – 'Keithley 2401' with high accuracy in our laboratory. Efficiencies are also measured at a few representative values of R_1 or R_2.

Construction of the circuit :

To begin with, the two power transistors (both are IRFZ44) are facilitated with proper heat-sinks (they are fixed to the heat-sinks and tightened enough with the help of nuts and bolts). The resistors are connected in a cross-coupled manner to the leads of the normal transistors Q_1 and Q_2. Capacitors are inserted in the requisite positions of the circuit. This assembly of components is now connected to the secondary winding of the transformer. A 12V 7Ah battery is hooked up in the proper position as per the circuit diagram (fig.1) and a 60 watt lamp, in the form of a small load, is attached to the output of the inverter.

RESULTS AND DISCUSSION

The experimentally measured and the theoretically calculated duty cycles enlisted in table-1 are found well-matched. The values of the duty cycles are found to be well close to 50% which indicates that this designed mini inverter also produces a very good symmetric square waveform in the output. The slight gradual increase in the values of duty cycle with increase in the values of resistor R_2 (C_1 is kept same for a comparative study of the results), is in accordance with the theoretical expectation.

Table 1. Experimentally measured duty cycles and their comparison with theoretically calculated ones at some representative sets of values of R_2 and C_1 .

Choices of R_2 and C_1	**Theoretically calculated Duty cycle**	**Experimentally measured Duty cycle**
$R_2 = 100\ \Omega$ $C_1 = 0.47\ \mu F\ \ (100V)$	48.4 %	47.7 %
$R_2 = 220\ \Omega$ $C_1 = 0.47\ \mu F\ \ (100V)$	49.0 %	48.3 %
$R_2 = 330\ \Omega$ $C_1 = 0.47\ \mu F\ \ (100V)$	49.2 %	48.5 %
$R_2 = 1000\ \Omega$ $C_1 = 0.47\ \mu F\ \ (100V)$	49.6 %	49.0 %

Table 2. Experimentally measured efficiency of the inverter at a few representative values of resistors R_1 and R_2.

Values of Resistors R_1 and R_2	Experimentally measured efficiency
$R_2 = R_2 = 100\ \Omega$	80.3 %
$R_2 = R_2 = 220\ \Omega$	78.1 %
$R_2 = R_2 = 330\ \Omega$	75.8 %
$R_2 = R_2 = 1000\ \Omega$	71.5 %

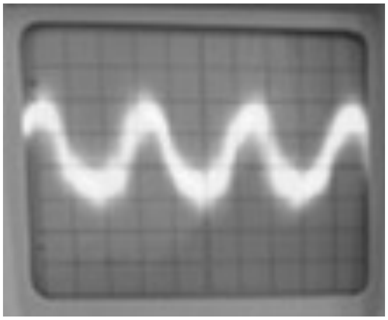

Figure 3. Image of the screen of the oscilloscope.

Duty cycle plays the most crucial role in maintaining the symmetry of the output waveform of an inverter. Its value in an inverter is expected to be very close to 50% so that both the positive and negative halves of the output wave have equal pulse widths thereby maintaining an excellent symmetry. The symmetric waveforms produce less noise in the loads when run.

The experimentally measured efficiencies at the same representative values of resistances R_1 and R_2 (i.e. at 100 Ω , 220 Ω , 330 Ω and 1000 Ω) and their comparison with theoretical values are enlisted in table-2. The measured values of the efficiencies of the inverter are found increasing with decrease in the values of resistances (as the resistances decrease, the transistors conduct more which results in increase in efficiency). A representative image of the screen of the oscilloscope is shown in fig.3.

The working of this type of mini inverter circuit is unique and different from the normal inverter which involves discrete oscillator stage for powering the power transistors. Normal inverter circuits are often very complicated and involve huge repairing cost.

CONCLUSION

This inverter circuit, though appears simple in design, can produce output voltage of excellent duty cycle and a reasonably high efficiency of around 75%. It can be used to light up LED and CFL lamps, to run drill machines, hair dryer, mobile chargers, etc. through a low ampere-hour battery, but not good or recommended for modern complex and costly electronic devices. Lastly, the simplicity of structure and low cost production become an added feature to be considered in such mini inverters.

The output voltage is observed to contain some spikes or fluctuations which could be minimized by inserting some filters (such as L- and Pi-section filters) across the primary coil of the transformer. These filters smoothen out the output voltage of the inverter making it more suitably usable for modern complex and costlier electronic devices. Such studies have also been performed. The results may be published in near future communications.

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