A Simple Mains Inverter

12 V DC in, 230 V AC out

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Circuits that convert a DC supply into a 50 Hz AC supply are called inverters. Commercial units are notable for their small size, high efficiency and high power output. A simpler approach using a standard mains transformer is however more than adequate to power a TV set and satellite receiver from a 12 V vehicle battery.

The task of converting an alternating voltage to a higher or lower voltage is most often performed by a transformer; it offers good efficiency and provides galvanic isolation between the two voltages. Generating a higher voltage level from a DC source is not quite so simple, before we can use any form of transformer it is first necessary to use a circuit which converts DC into AC.

BACK TO BASICS

There are basically two configurations used for mains inverter designs:
- direct conversion using a 50 Hz mains transformer;
- conversion using a switch mode inverter.

The direct conversion principle shown in **Figure 1** switches a low voltage DC supply through the low voltage winding of a standard mains transformer. The switch configuration steers the current alternately in one direction and then the other through the winding. A 50 Hz switching signal produces a high voltage 50 Hz square wave AC output, the voltage level is governed simply by the 'turns ratio' of the mains transformer. This approach has the advantage of simplicity; all the electronics are confined to the low voltage side of the circuit but the main drawback is the size and weight of the transformer. Designs of inverters with ratings greater than around 200 W begin to get quite cumbersome.

Converters using the switch-mode principle (**Figure 2**) interrupt or switch the DC input voltage passing through a transformer winding. The switching frequency used is much higher, generally in the region of 30 to 100 kHz which allows the transformer design to be much smaller and lighter. The transformer high voltage output also alternates at the same switching frequency so it is necessary to first rectify it and then use some fairly complex electronics including four semiconductor switches in a bridge configuration to convert the high voltage DC into a 50 Hz AC output. The drawbacks of this design are firstly that the high frequency (HF) transformer is not a standard off-the-shelf component; it will need to be specially made using a ferrite core. The high frequency switching waveforms also produce substantial levels of EMI (Electro Magnetic Interference) which must be suppressed with filters. All-in-all this type of inverter is not an ideal construction project for a newcomer to electronics.

The inverter design suggested here uses a standard mains transformer switched by a 50 Hz signal derived from a crystal oscillator. The frequency accuracy ensures that any mains equipment with a built-in clock (or time switch) will keep good time when it is powered by this unit.

STRAIGHTFORWARD

The inverter circuit diagram is shown in **Figure 3** and is quite straightforward; there are no traps to catch out the unwary constructor. The integrated circuit IC1 (74HC4060) is a binary counter with an integral oscillator. A 3.2768 MHz crystal connected across the oscillator inputs produces a divided-down square wave signal of 200 Hz at output Q14 of the counter chip. The 74HC112 JK flip flop (IC2) performs a divide-by-two function on this signal while the second half of this chip divides the frequency by two once again to produce a 50 Hz square wave at pin 5 together with an inverted version at pin 6 (i.e. phase shifted by 180°).

The four MOSFETs V1 to V4 are configured in a so-called H bridge configuration with the low voltage transformer winding forming the central arm of the bridge. Transformers with two low voltage 6 V windings can also be used if the two windings are connected in series to form a single 12 V winding. Similarly a transformer with two independent 12 V low voltage windings can be used if these two windings are connected in parallel. In both cases ensure correct phasing of the winding connections.

Power MOSFETs have a relatively high input (gate) capacitance of a few nF, which slows down their maximum switching rate. The driver stage using transistors Q1 and Q2 has a low impedance output to help overcome this capacitance and speed up switching times.

The drive signals to transistors Q1 and Q2 are derived from the complementary outputs (Q and Q) of IC2A. The oscillator can stop running when the supply battery voltage falls too low so capacitors CE2 and CE3 provide AC coupling of the control signals to Q1 and Q2. The pull-up resistors R8 and R9 then ensure that both Q1 and Q2 become conducting, turning off V1and V2 which holds the ends of the transformer winding at the same potential so that there is no path available for destructive current to flow through the winding and MOSFETs.

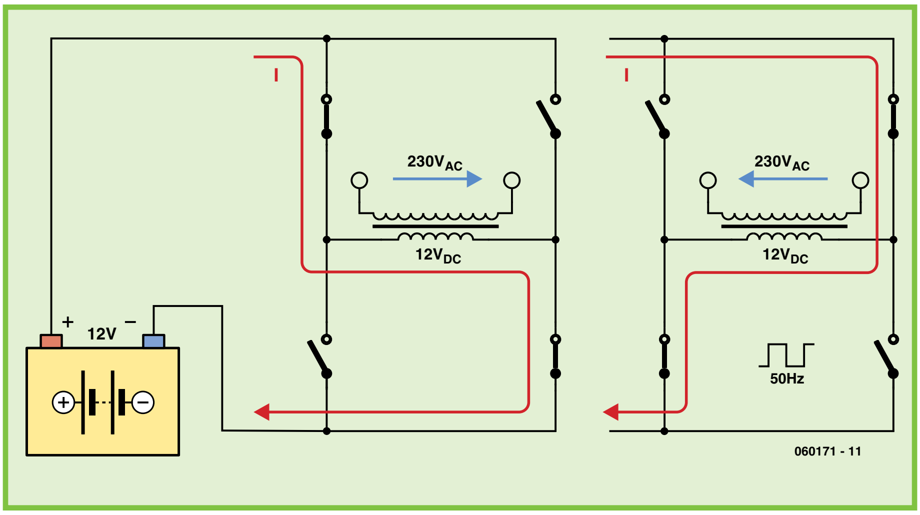


Figure 1. A simple inverter using a mains transformer. Four semiconductor switches in a bridge configuration produce an AC signal in the low voltage winding of a mains transformer by alternately reversing the low voltage DC source.

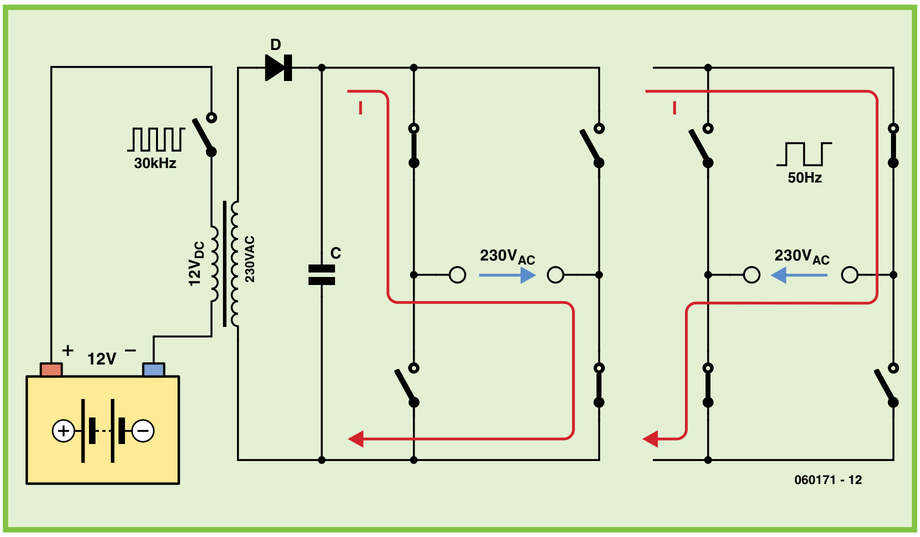


Figure 2. High power inverters switch at high frequency. The high voltage is rectified and smoothed, then converted to a 50 Hz AC mains voltage using high-voltage semiconductor switches in a bridge configuration.

RESULTS

The oscilloscope screen shot in **Figure 4** shows current and voltage waveforms at the output of the transformer when it is driving a resistive load (a 60 W mains lamp). Using a fully charged 12 V car battery (14 V terminal voltage) as a power source the input current was 4.9 A giving a power consumption of 67 W. Power in the load was measured at 54 W (215 V at 0.25 A) which yields an operating efficiency of around 80%, not bad for such a simple design!

Losses incurred in the transformer and switching transistors mean that the output voltage does not quite reach 230 V but is within the supply tolerance of the majority of electrical appliances. An 11 V mains transformer would help compensate for the voltage losses but these are not widely available. A standard 12 V toroidal mains transformer can however be modified; these generally have the low voltage winding wound over the top of the mains winding so it is a relatively easy job to take off a few turns (around 10 %) to produce an 11 V secondary winding.

The MOSFET heatsinks specified allow the use of a transformer with a rating up to around 150 W. Larger heatsinks must be used if a higher power transformer is required (the MOSFET data sheet indicates that they can switch 50 A max).

The half-eurocard sized PCB layout shown in **Figure 4** is, like the circuit, also quite straightforward. Fit the two wire links to the board before the rest

Components list

Resistors
R1 = 2MΩ2
R2,R8,R9 = 10kΩ
R3, R5 = 100kΩ
R4, R6 = 220Ω
R10 = 22Ω

Capacitors
C1 = 47pF
C2 = 27pF
C3, C4 = 100nF
CE 1 = 4700µF
CE2,CE3 = 100µF

Semiconductors
IC1 = 74HC4060
IC2 = 74HC112
Q1,Q2 = BC547
V1,V2 = IRF4905
V3,V4 = IRF3205
ZD1 = 10V /0.5W (zener diode)

Miscellaneous
PL1,PL2 = 2-way PCB terminal block
XT1 = 3.2768MHz quartz crystal
PCB, ref. 060171-1 from The PCBShop

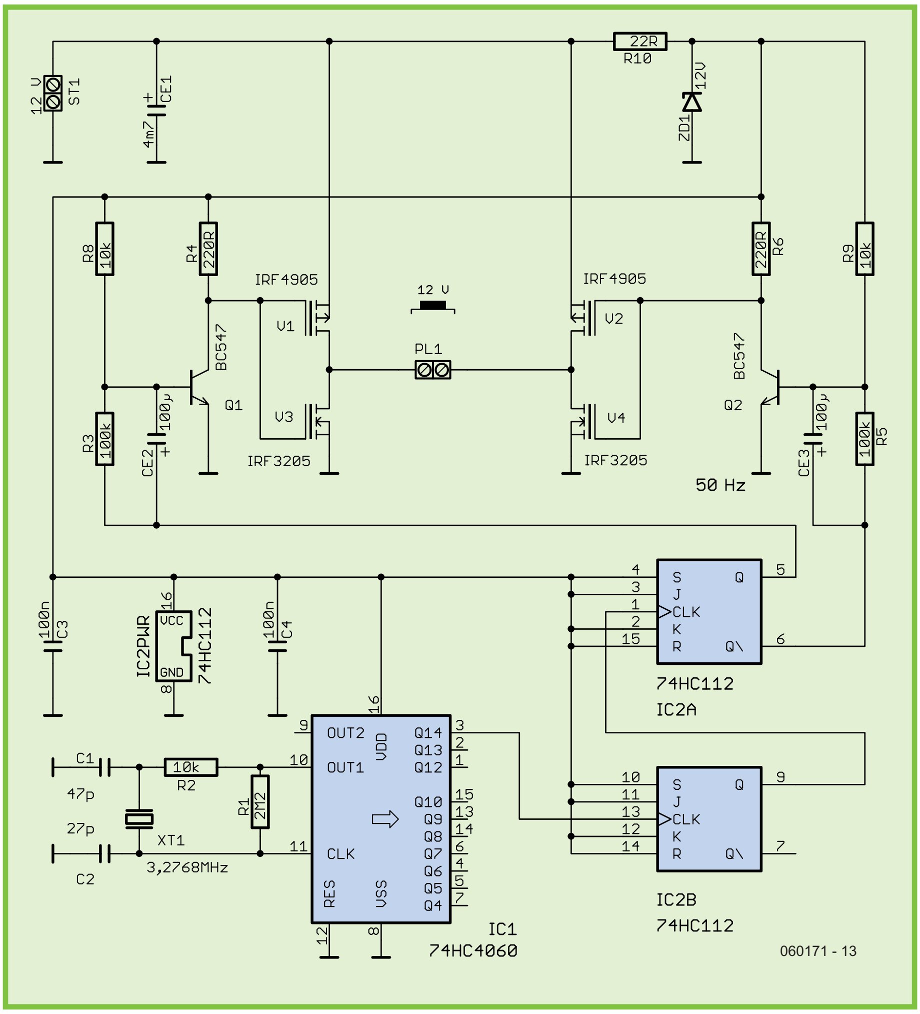
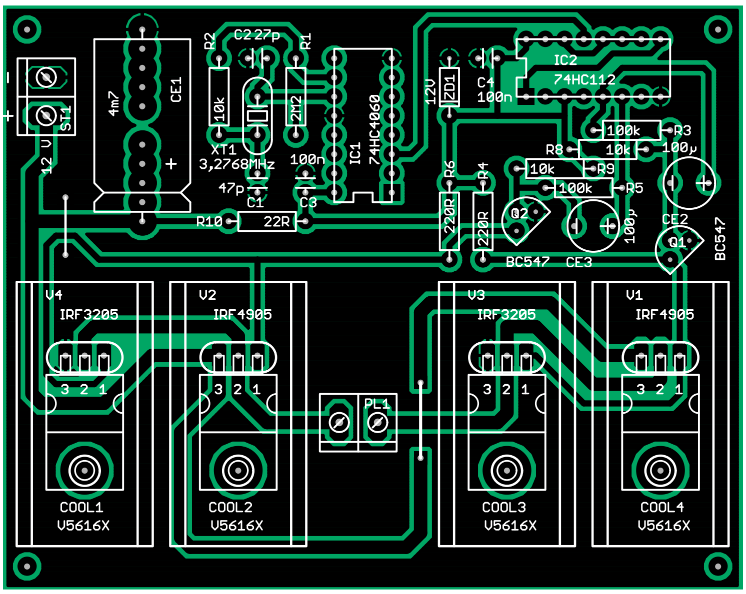


Figure 3. The circuit uses a crystal oscillator to give an accurate and stable 50 Hz operating frequency.



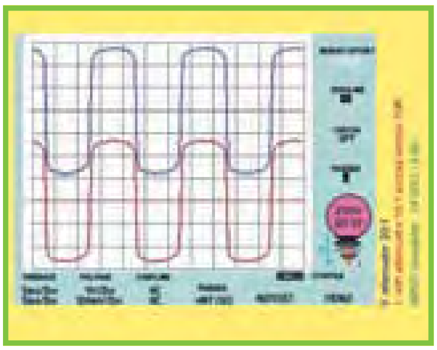


Figure 4. Component placement on the single sided PCB.

of the components are mounted. The ICs can be mounted to the board using sockets. Each MOSFET has its own heatsink so it is possible to mount them without any form of electrical insulating gaskets provided that the heatsinks are never allowed to make electrical contact with any other part of the circuit during operation (it sometimes pays to be pessimistic; Murphy's law states whatever can go wrong will go wrong so its probably safer to fit insulation). The two terminal blocks used for connecting the battery and transformer should be the correct size for the cables used. Ensure that the cable to the battery is of sufficient cross-sectional area to handle the input current to the inverter and also be sure to fit an in-line fuse between the inverter and battery. A rating of 15 A (slow) should be sufficient for operation of the unit up to around 150 watts.

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