System Operation

4.1 Introduction

Design is a sine-wave stand-alone PWM voltage-source inverter (Not UPS) with PIC16F876A MCU, with parameters:

- Uin=12V DC
- Uo=230V AC
- F= 50Hz
- P=500W

Inverter have an integrated input under/over voltage protection, output voltage regulation, output current protection and overtemperature protection.

Output voltage is a pure sine-wave, generated with built-in PWM module of PIC MCU, with frequency 20Khz.

Carrier frequency is 20kHz (generated with buit-in PWM of the PIC MCU) and each half period (10ms) we have 32 changes in the PWM signal, this makes 64 changes in whole period (20ms). But we generated only the half period of the sine-wave and with the help of the direction signal we can get the whole period of the sine-wave in the output of the inverter.

Sinewave Lookup Table calculation:

Ki = PWMmax*sin(i*180/n),

where:
PWMmax=0-1023, (PWMmax=831)
i = 0,1,2,...,n

e.g
```
const long sine_wave[32] =
{81,162,241,318,392,462,527,588,642,691,733,768,795,
815,827,831,827,815,795,768,733,691,642,588,527,462,
                            392,318,241,162,81,0};
```

In this inverter we have a full-bridge power circuits with 4 transistors (paralleled-8 transistors), Q1, Q3, Q5 and Q7. Two of transistors works with low frequency - 50Hz (Q5 and Q7) depending on the state of the A/B (direction) signal (RC1). Other two transistors (Q1 and Q3) works with high-frequency (20kHz) of the sinewave PWM signal.

Efficiency of this inverter is around 80-85% and depends on the transformer design, MOSFET Quality (lower Rds, less power losses) and the Output Power (or Input Current). Higher input current through the MOSFETs leads to more power dissipation on transistors.

4.2 LED status:

1. Green -> Normal operation
2. Green Blinking -> Standby Mode (No load operation)
3. Red -> Low baterry (<10.8V)
4. Red Blinking -> Over Temperature of Power Transistors
5. Orange (Green+Red) Blinking-> Before going in Stanby Mode (for 5 sec).

The green LED (LED1) is connected to pin25 (RB4) and red LED - to pin26 (RB5). When inverter turned ON without load, after 5 sec inverter stops and going in standby mode. In this mode inverter starts only for short time for detecting the existence of the load. Time interval between this short start pulses is 1 sec. Before this mode begin to blink Green LED (for 5 sec). And after going in standby mode blinking Green and Red LEDs together (Use a single two color LED - Green and Red) and resulting color is orange.

4.3 Transformer:

For the output power transformer we use a low frequency (50Hz) conventional transformer, but decision is yours. Ferrite core transformers are more suitable in other type of inverters with double conversion stages,first stage for boosting the input 12V (or 24V) DC voltage to 350-400V dc (with HF PWM and ferrite transformer) and second for inverting this voltage to 230 Vac (without transformer).

4.4 Feedbacks:

There are many feedback input signal needed for proper work of the inverter:

From input DC voltage, temperature sensor (Rt, NTC-47k), output ac current, output ac voltage (230V), a/b signals (over two low-side power transistor - Q5 and Q7), signals from two POT's (R22 and RT1) and etc. Better look at schematics of the inverter for signals connected to PIC MCU.

When starting the inverter for the first time (before connectin the voltage and current feedback signals to PIC MCU) you must fit (adjust) the polarity of the output signals (I and V) to the polarity of the direction signal A/B (LF, 50Hz signal) from PIC MCU. Signals must be exactly like this: positive output voltage (and high current - curr-h) must be at the same time when signal A/B =5V (log.1) and negative when A/B=0V (log.0).

If the voltage (and current) signals are contrariwise you must reverse only input or output pins of the power transformer. For contrariwise current signal you must reverse the pins (inpu or output) of the current transformer. And then you can connect this feedback signals to PIC MCU. b/a signal (pin2 - RA0/AN0) must include only a low levels of the separeted 'a' and 'b' signals (pin2 and pin1 - U10). If b/a signal include only a high-levels of signals 'a' and 'b', then you must change a connection places of this two signals to pin1 and pin2 of the U10 (a<->b and b<->a).

Input current is a DC and can be measured only with current sensing resistor (nonisolated) and Hall sensor (Isolated). This method is a prefarable only for input current measurement (for MPPT in Photovoltaic converters) and for input current protection. Output current of the inverters is a AC an can be measured with current sensing resistor, Hall sensor and Current transformer. This method is a preferable when implementing an output current control and regulation.

Current transformers secondary side has a two load resistors: R8=100 for high range and R18=1.5k for low range. They are in the feedbacks of two OPAMPs (U1A and U1C).

These two OP AMPs (U1A and U1C) forms two active current to voltage converters with two different current to voltage gain ratios.
For more info just look here:

http://en.wikibooks.org/wiki/Circuit_Idea/Op-amp_Inverting_Current-to-Voltage_Converter

4.5 Other components are :

TLP250 are working from 10-35V and if you supplying them directly from input DC voltage (before LM317) they can work in overall input voltage range (10.8-16Vdc).

"bootstrap"supply, components D6-C17 (for U3) and D7-C18 (for U3) in inverter schematics. And it is a specially designed only for high-side drivers. For more information see below link

http://www.intersil.com/data/fn/fn9087.pdf

D4 is for high voltage battery protection, and D5 is for reverse battery protection of the V_BAT analog input of PIC MCU (RA3).

4.6 UPS Conversion:

This requires additional circuits as:
1. Zero-cross detection for grid synchronization. (Figure 4.1)
2. Relay(s) for switching the load to grid or to UPS output. (Figure 4.2)
3. Battery charger - embedded in UPS or separated.

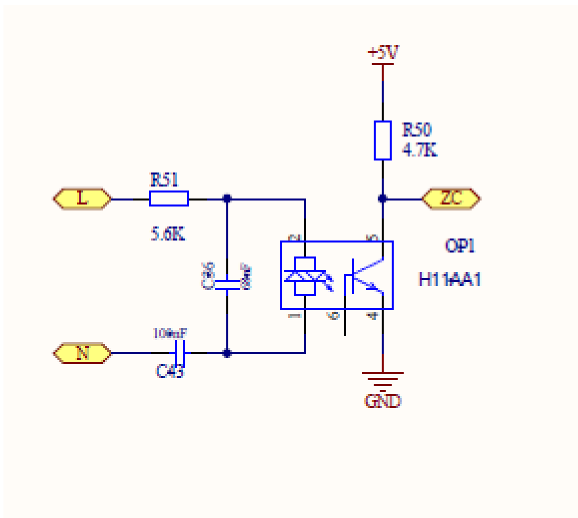


Figure 4.1

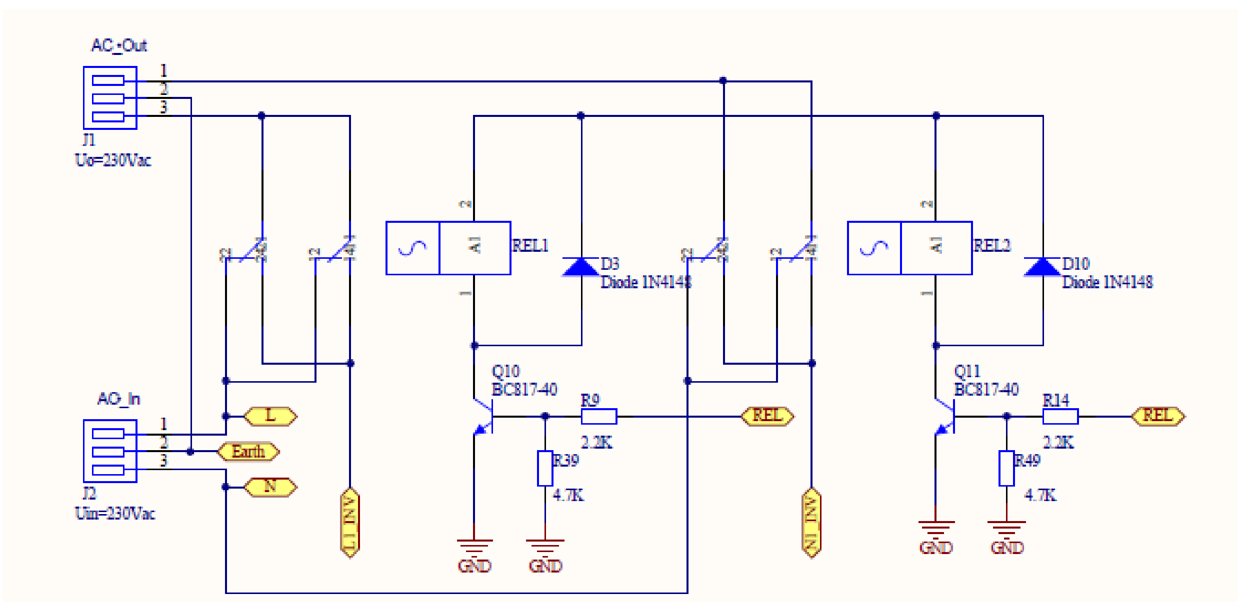


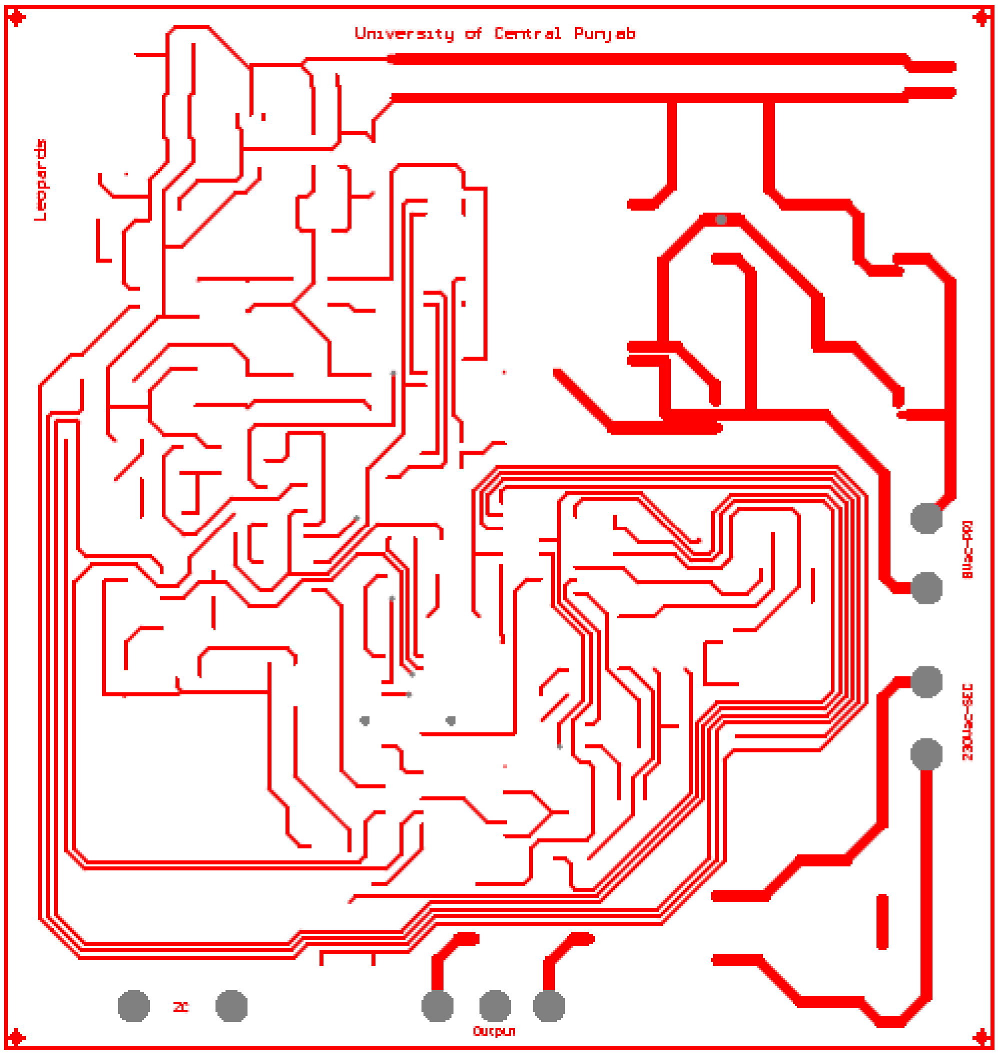
Figure 4.2

4.7 PCB and Assembly:

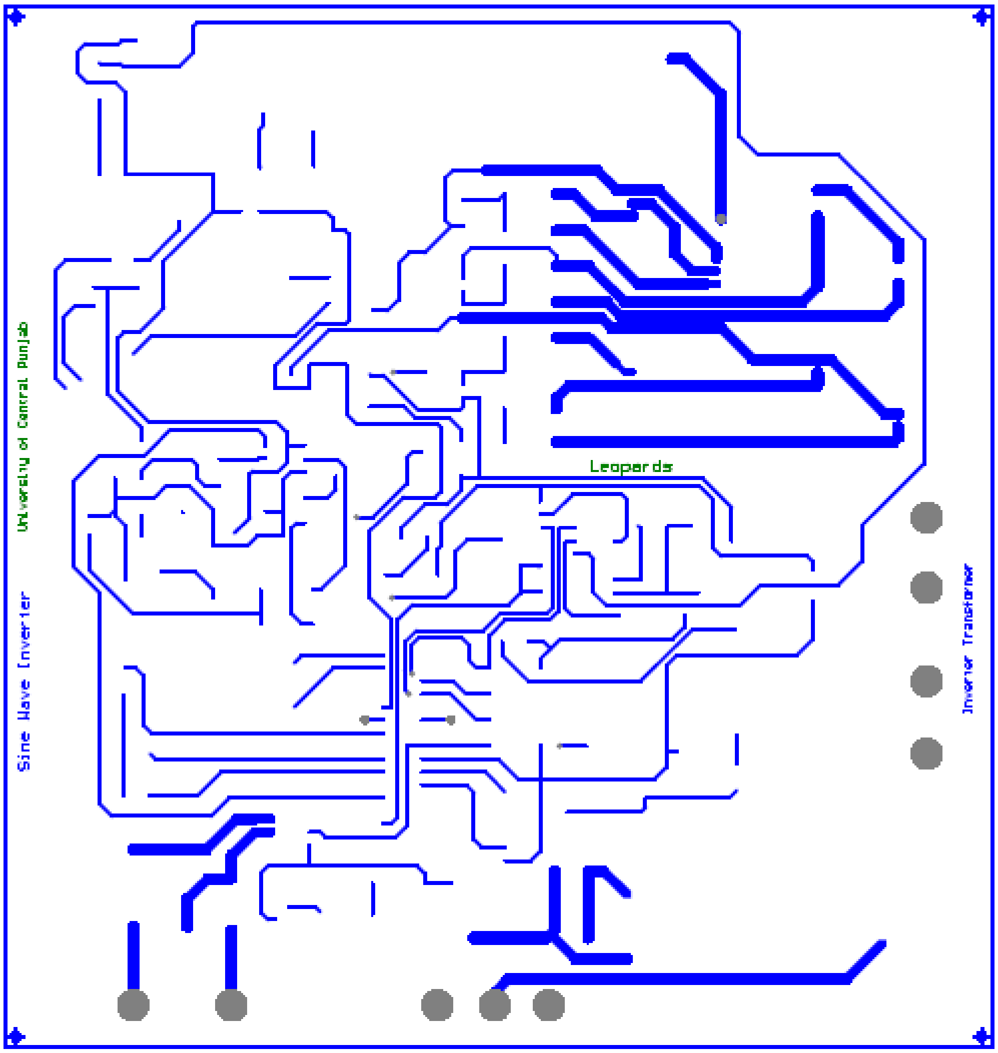
1) PCB
    i) Top Layer
    ii) Bottom Layer
    iii) Top Overlay
2) Assembly
    i) Top Assembly
    ii) Bottom Assembly

All figures as following

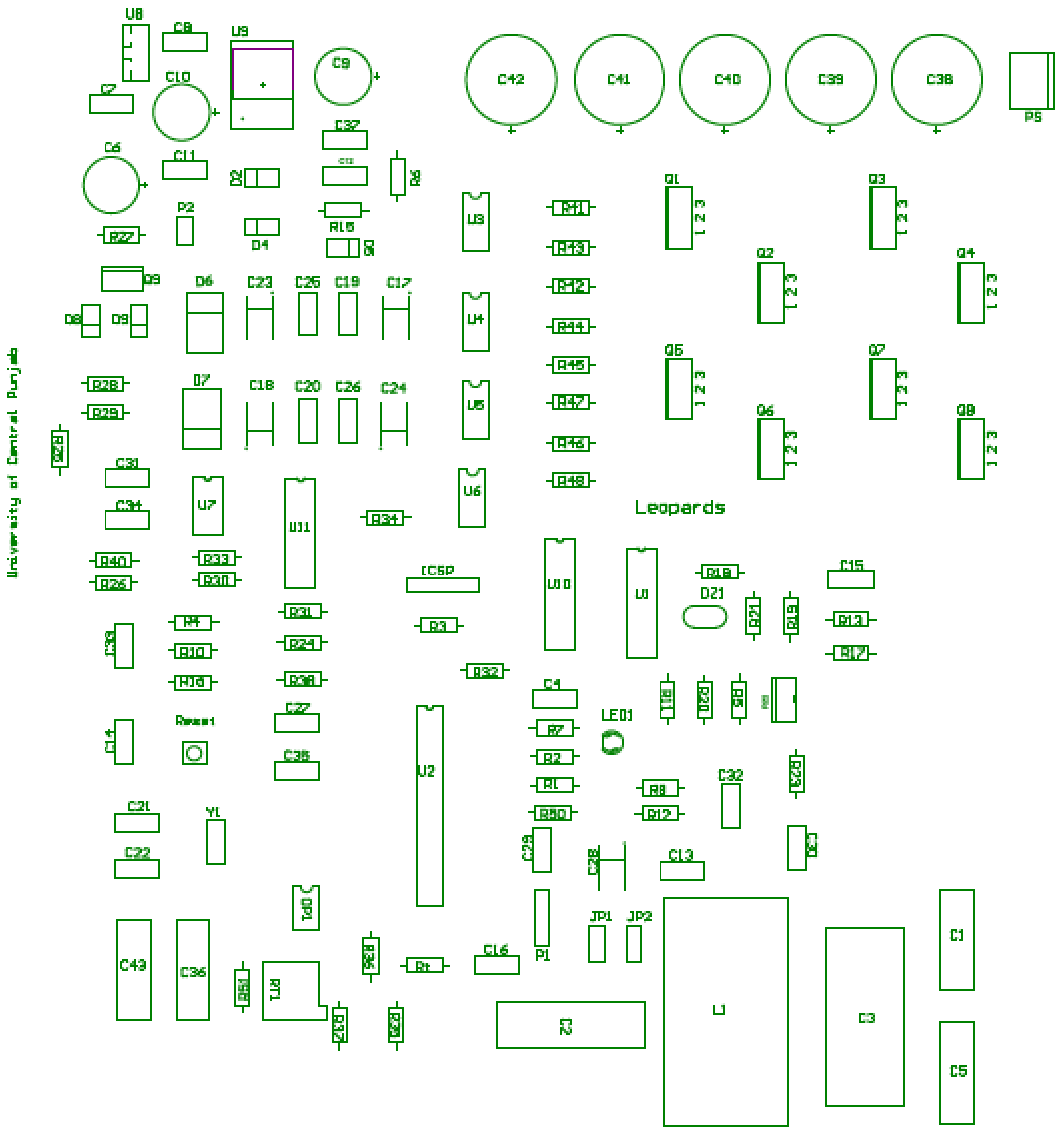
Top Layer:



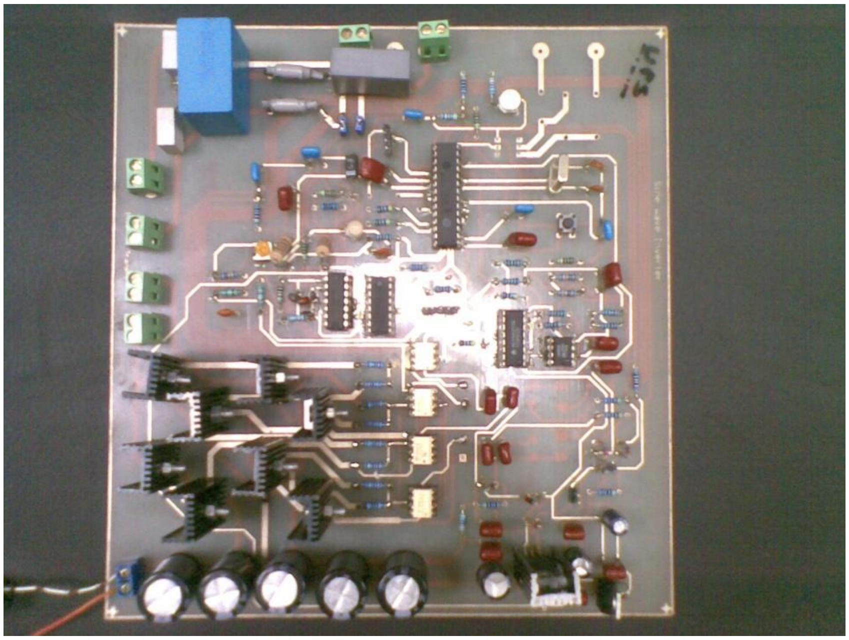
Bottom Layer:



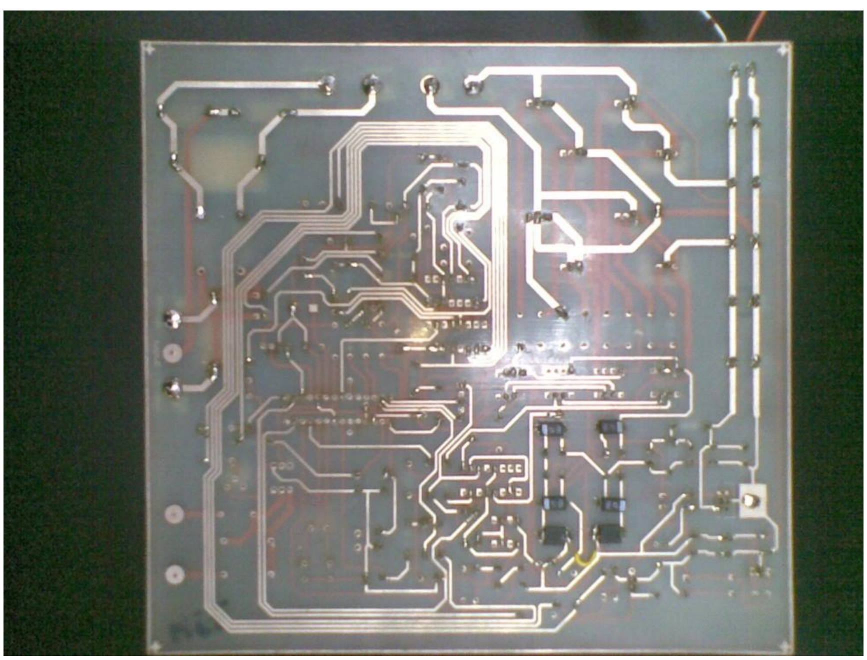
Top Overlay:



Top Assembly:



Bottom Assembly:



Recommendations:

For Proper working of Circuit following parameters must be ensured:

- V_OUT = 2.5V +/- max 1.5V (min 1V, max 4V, middle point 2.5V, sine wave)
- curr_h = 2.5V +/- max 1V (min 1.5V, max 3.5V, middle point 2.5V, sine wave)
- curr_l = 2.5 V +/- max 0.25V (middle point 2.5V, sine wave)
- volt = 4.45 - 4.82 Vdc
- Stdby = 0 - 5 Vdc
- b/a - depending on MOSFET Rds and output current magnitude, approx. 1 - 2V max.
- Active level of OE signal is low level (Log. "0").

  A/B direction signal is a square wave signal with frequency 50Hz and 50% duty cycle. For correct work of the inverter all feedback signals must be connected to the PIC MCU, with normal working levels.