Design and Development of Terminals of Hand-Held GPS using LinSeed Chip

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Abstract

*The increasing demand of portable and consumer oriented application has given rise to the new era of low power and short form factor embedded devices. Geographic information system (GIS) is rapidly growing technological field that incorporates graphical features with tabular geographical data in order to address real world problems. Some of the popular GIS applications are navigation, telematics, asset survey etc. These applications rely on **G**lobal **P**ositioning **S**ystem commonly referred to as GPS. This paper deals with the design and development of a hand held GPS device. It is based on the LinSeed Soft Chip from EILABS. The hardware design document has been prepared according to the requirement specifications. Based on requirement specification and design document functional block diagram has been developed for the hand held GPS. Schematics of the hand held terminals are drawn in ORCAD. After developing the schematic the PCB design has been carried out using CADSTAR tool. Linseed chip is a cost effective chip, which provides the features of ARM-9 architecture running on Linux embedded into it. The scope of this paper covers requirement gathering to testing of the final PCB assembly. This paper has achieved a very small form factor of 115mmx60mm for USB powered GPS hand held, with built-in Li-Ion battery charger and support for executing the Linux OS.*

Key Words: Hand held GPS, LinSeed chip, ARM processor, Multilayer PCB design

Nomenclature

ADC -Analog to Digital Converter
ARM - Advance Risc Machine
BOM -Bill of Material
CC -Constant Current
CV -Constant Voltage
GIS -Geographic Information System
GPS -Global Positioning System
LCD -Liquid Crystal Display
PCB -Printed Circuit Board
PFI -Power Failure Input
PFO -Power failure output

1. INTRODUCTION

The ongoing migration of mobile lifestyle and the increasing capabilities of portable systems have paved the way to the hand held era. The GPS market has evolved from defense oriented applications to professional commercial applications such as surveying, marine fleet management and AIRCRAFT navigation systems [1]. The aim of this paper is to design the terminals of hand held GPS and to develop the customized PCB and develop a complete hardware product which can be used for survey purpose. The proposed design is based on LinSeed chip which is running on Linux and having ARM-9 processor [5]. The designed circuit should fulfill the requirements of the low power consumption and small form factor. It will be useful for storing the information (name, address) regarding the different routes and giving the shortest route information from a particular point.

2. HARDWARE REQUIREMENTS AND SPECIFICATIONS

2.1 Power requirements

The power requirements for the systems are as follows-

- System should run on a rechargeable battery
- AC power should be from the USB port for charging the battery to reduce the form factor and make the USB port more fruitful.
- There should be a power on reset circuitry to ensure that the system is switching on in a known and a stable state.
- Voltage regulators are required to supply **2 Display** different voltages.
- Power consumption of Linseed will be 3.3V and 1.8V.
- Power required for the graphical LCD will be 3.3V.

2.2 Module Requirements

- LCD should be a graphical LCD to show the maps on the screen
- It will be connected to the Linseed chip through the SPI port
- Black and white LCD can be used to reduce the cost
- It should be sun light readable display with back lighting (white light)

2.3 GPS Receiver Requirements

- It should support different protocols like NMEA, UBX, and RTCM.
- It should meet with small Form factor requirement.

- It should support active and passive antenna
- GPS receiver will connect to Linseed processor through the UART serial port

2.4 Antenna Requirements

- If active antenna is used then it should have low power consumption
- The Antenna should be embedded in the device
- The Antenna should be mounted on the PCB

2.5 Keypad Requirements

- Keypad should be an alphanumeric keypad to store the location name and address.
- It will be a matrix keypad of size 5x4. Tactile keys will be used with tactile feedback to user.
- A keypad scanner is needed for scanning purpose.
- The keypad scanner will be connected to the Linseed processor through GPIOs.

3. FUNCTIONAL BLOCK DIAGRAM OF HANDHELD GPS DEVICE

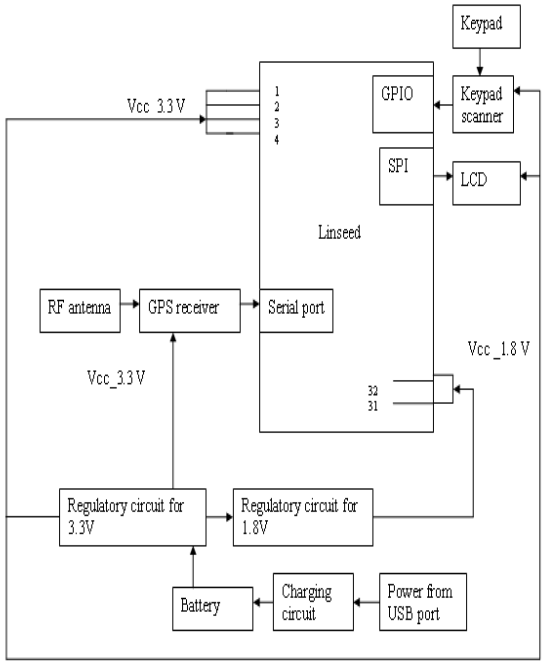


Fig. 1 Functional Block Diagram of GPS Handheld Device

A generic functional block diagram of the GPS handheld design using Linseed chip is shown in Fig.1.

4. SELECTED COMPONENTS

- TIM -4A GPS receiver
- SARENTAL GeoHelix Antenna
- LinSeed Chip (ARM-9 Processor)
- Voltage regulator (LM1117, TC1185)
- Linear charger (LTC1734**)**

4.1 Selection of GPS Antenna

The antenna is an important part of the GPS receiver system. The GPS receiver receives and translates the GPS signal from an electromagnetic wave into a RF signal that contains the amplitude and phase information of the GPS signal. Basically two types of antennas can be used for GPS applications namely patch antenna and helix antenna. Patch antennas are ideal for an application where the antenna is mounted on the flat surface. Patch antennas can show a very high gain especially if they are mounted on top of a large ground plane. Helix antennas can be designed for use with or without ground plane. If the application is a hand-held device then the antenna designed should be in such a way that natural user operation results in optimum antenna orientation. The helix antenna seems to be more appropriate in this respect. A quadrifilar antenna has been chosen here for the following reasons-

1) First the antenna has a better circular polarization making it effectively omni directional and making it more efficient.
2) Ground planes are excellent conductors of electronic noise which the antenna will channel into the receiver if the noise falls within the GPS band. Because the quadrifilar antenna does not use a ground plane it rejects this kind of noise providing more reliable signal to the receiver.

These properties make the quadrifilar antenna an excellent choice for portable devices [3,4].

4.2 Selection of GPS Receiver

Selection of the appropriate GPS receiver for a particular product is critical to its success. GPS receivers range from high end, high cost, high accuracy "geodetic quality" to low end, low cost, low accuracy "resource grade" or "recreational models".

The selection of TIM-4A is based on following factors.

- It shares the 25.4x25.4x3mm of form factor.
- It has got 35% reduced power consumption with its predecessor, which indicates extended battery life for portable and hand held consumer device.
- It supports passive and active antennas.
- It has antenna short and open circuit protection detection.
- It has 4Hz position update rate.
- It supports different protocols (NMEA, RTCM and UBX).

5. DESIGN OF POWER SUPPLY

The external power supply (5V) is connected to LTC1734, which is used to charge the battery. The

charging current, which is programmed here, is 500mA. TC1185 is a regulator for 3.3V, whose input is from the battery. For 1.8V, LM1117 voltage regulator has been used. Output from the regulator is going to LINSEED. ADM690 has been used for the reset and power failure indicator. The power failure indicator output is connected to the IRQ pin of LINSEED. Fig 2 shows the block diagram of power supply design.

6. SCHEMATICS OF THE HAND-HELD

6.1 Schematic of Power Supply

Fig 3 shows the schematic of the power supply.

6.2 Schematics of Keypad Scanner

Fig 4 shows the schematic of keypad design**.** For the keypad implementation there is a requirement of around 20 keys. This in turn implies that one needs nearly 9 GPIO lines for interfacing. These many GPIO lines are not available on the LINSEED.

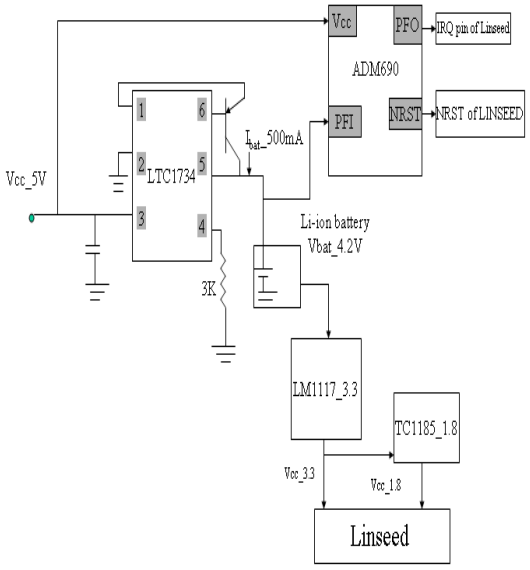


Fig. 2 Block Diagram of Power Supply

So to reduce the need of GPIO lines, an external circuitry has been added and this IC has been made to scan 32 keys with the use of only 5 GPIOs. All the column lines are at low level of logic and rows are driven high through with the 3.3V. When no keys are pressed, the row inputs are driven high by internal pull ups and the columns sequentially output a logic 0. When a key is being pressed, the connection will get established between the row and the corresponding column. The scanner scans, the row which goes low corresponding to the column. This initiates the key-bounce circuit timing and locks out the other inputs and scanner will take the data for that particular key.

For the extra rows, once the connection gets established between row and column, the data serves as an input to the NAND gate. If any key is pressed ,the output of the NAND gate will go high and stored in a D F/F (as shown in figure 4). The reason for storing this data is that software is not so fast compared to hardware changes. Therefore the available data should be stored till the software responds to hardware interrupts. When the data gets entered into the D F/F, the clock pulse goes high which sets the clock and the data available goes high generating the interrupt to the LINSEED. The output for this external row will come from the DF/F output.

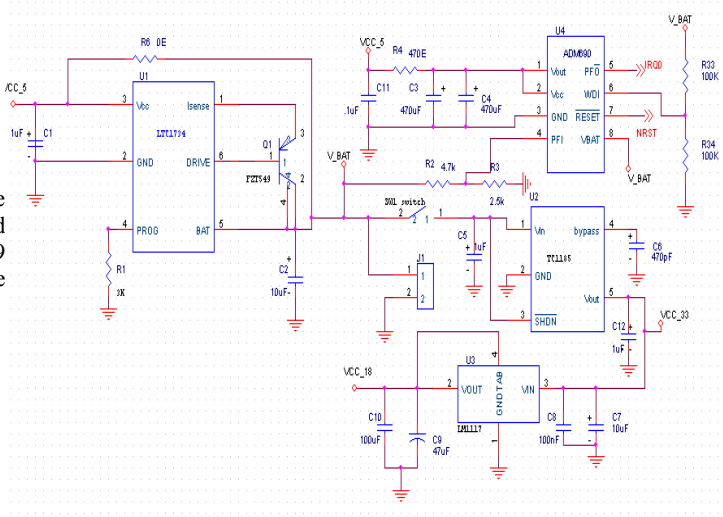


Fig. 3 Schematic of Power Supply [2]

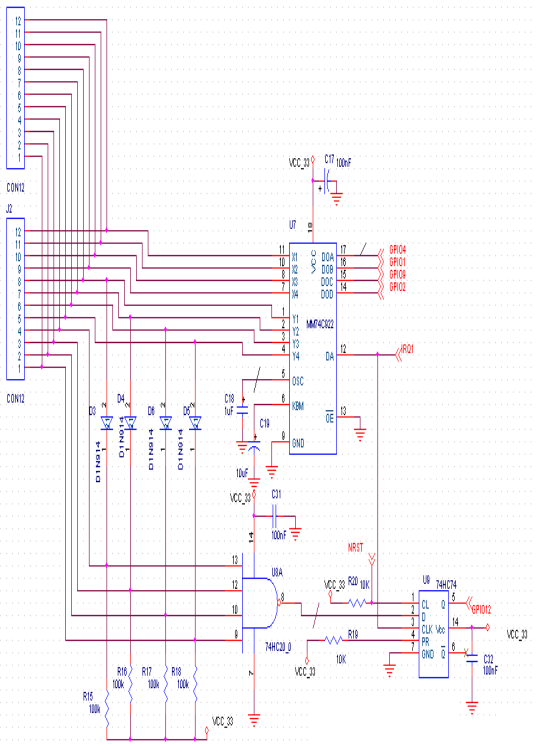


Fig. 4 Schematics of Keypad Scanner

6.3 Schematics of LinSeed

Figure 5 illustrates the schematics of LinSeed chip. This schematic describes all the pin configurations of the LinSeed.

6.4 Schematic of GPS Receiver

The receiver chosen for the current design is a TIM-4A GPS receiver from u-blox company. It requires 3.3V power supply for its operation. There are 5 boot time configuration pins which become effective immediately after start-up power supply. For setting the baud rate to 19.2K all the boot mode configuration pins are connected to ground through a 0E resistor. Antenna signals to the GPS receiver pass through the RF_Pin. The antenna power supply is provided through the V_ANT pin. One LED has to be connected to the time pulse pin of the GPS receiver to show the status of the receiver. No battery back up is connected so the receiver. So whenever the power to the receiver is switched on, the receiver that turns on has no knowledge of its last position or time. Fig 6 shows the schematic of GPS receiver.

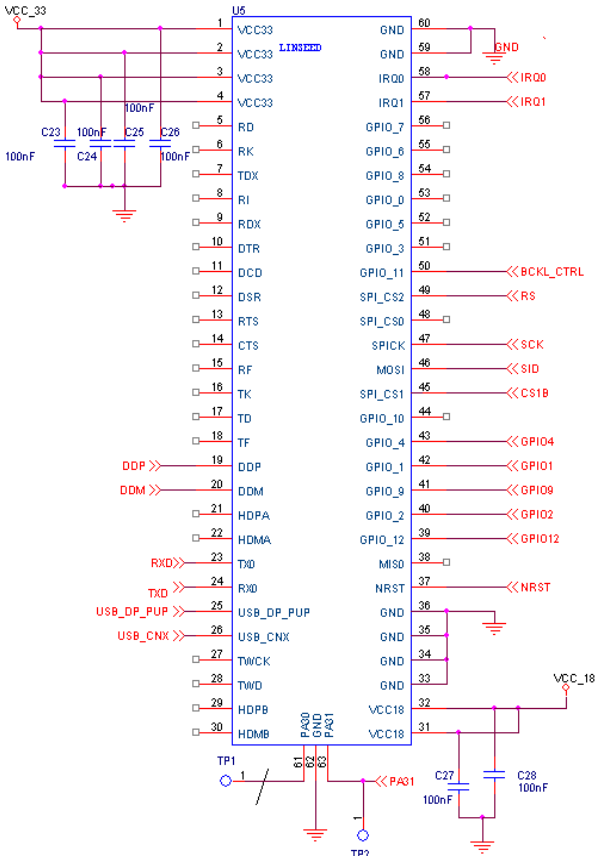


Fig. 5 Schematics of LinSeed [5]

6.5 Schematics of USB Device

Fig. 7 shows the schematic of the USB device. Here the power is drawn from the pin 1 of the USB connector. USB_CNX and USB_DP_PUP are emerging from the LINSEED. USB_CNX signal is used to detect whether the host is connected or not.

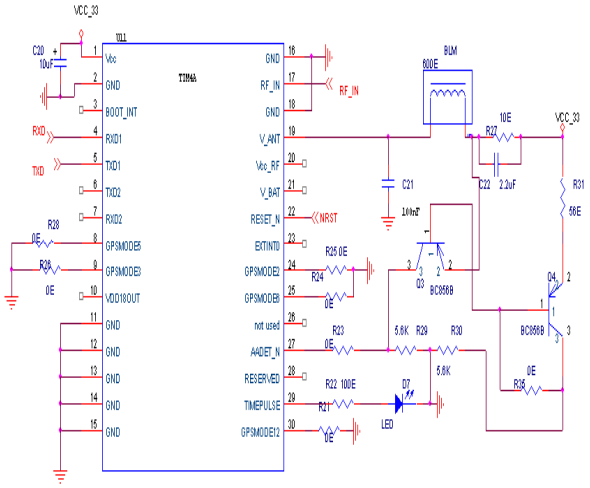


Fig. 6 GPS Receiver Schematic

USB_DP_PUP is enabling pull up on. A pull up resistor on the D- wire signals a low speed device, while a high speed device has a pull up on a D+wire.

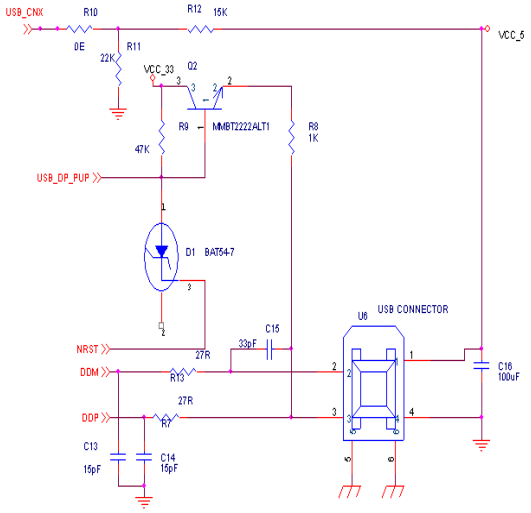


Fig. 7 USB Device Schematic

When the base of the transistor is high the transistor will be in off state. It sets the pull up on the DDM which indicates the connected device is low speed device. When the base of the transistor is at 0 level the transistor conducts and the emitter current flows through the resistor of 1 K. which charges the capacitor on the DDM and sets the pull up for the DDP, which indicates that the connected device is a high speed device. Reset is provided through the BAT54-7. Bat 54-7 is used for blocking the reverse current.

7. PCB DESIGN OF HAND-HELD

To reduce the form factor, 2 PCB boards have been designed. One for LCD and the other is for rest of the components. Both of the PCBs are of two layers.
While designing the PCB, there are certain general issues as well as some specific issues for this project, which have been taken into account.

7.1 Layout Considerations for RF Section

Signal loss of the antenna or the RF connection should be minimized as much as possible. When defining the layout including a GPS receiver, the placement of the antenna versus the receiver, grounding shielding jamming of other digital devices are the most important aspects to be considered very carefully. The placement of GPS receiver on the PCB is very important to achieve maximum GPS performance. The connection to the antenna has to be kept as short as possible to avoid jamming into the very sensitive RF section. RF critical circuit should be clearly separated from any other digital circuit on the system board. The antenna RF connection is on the PCB and connects the RF_IN pin with the antenna feed point or the signal pin of the connector. The whole layer stack below the RF connection is free of digital lines. This is because even a good solid ground plane provides only a limited isolation. The impedance of the antenna connection has to match the 50 ohm impedance of the receiver. To achieve an impedance of 50 ohms the width of the micro strip has to be chosen depending on the dielectric thickness H, the dielectric constant ε of the dielectric material of PCB.

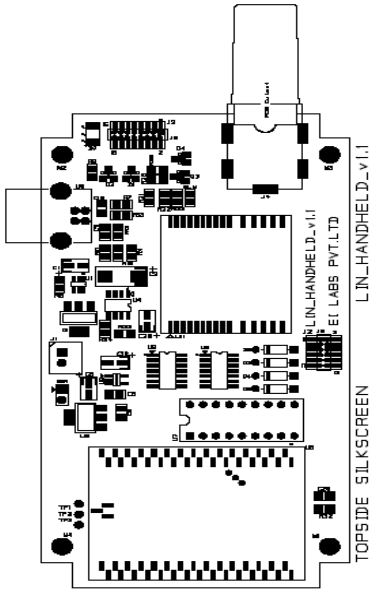


Fig. 8 Top Side Layout of Handheld GPS

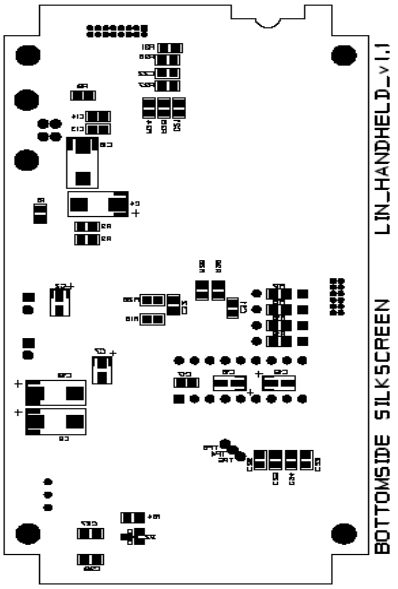


Fig. 9 Bottom Side Layout of Handheld GPS

The following need to be observed while designing the micro strip line-

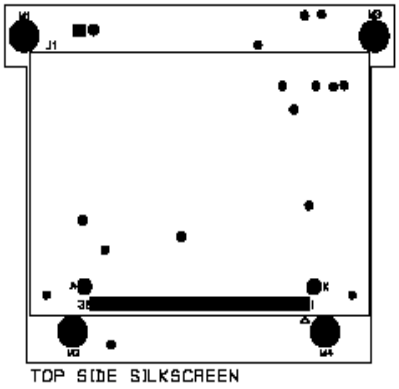
- The length of micro strip line has to be keep as short as possible.
- Distance between micro strip line and ground area has to be kept equal to the dielectric thickness.
- To reduce signal reflection, sharp angles in the routing of the micro strip line have been avoided. [6]

Figures 8 and 9 show the top side and bottom side component placement diagram.
Figure 10 shows the LCD screen shots for component placement and routing for the top side and bottom side.

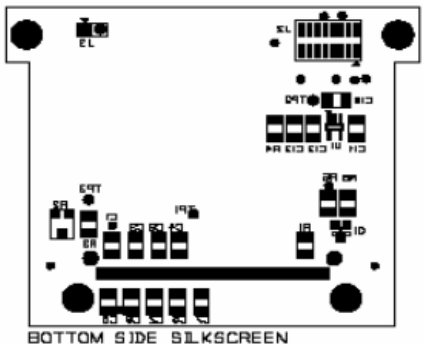
7.2 Routing Consideration for RF Section

- Routing the RF connection close to the digital section is avoided.
- Routing of the RF connection underneath the receiver is avoided
- The distance of the micro strip line to the ground plane on the bottom side of the receiver is avoided
- Vias have been used to connect the ground planes
- USB track impedance has maintained as 90 ohms without the use of external sense resistor
- Power track has to be thick because it carries more current
- Depending on the actual size of ground area additional vias should be placed in the outer region

Lots of viases have been used in this routing. Viases are used to create the electrical connection between one layer to another. This gives the ease of placing the components on the other side of the PCB and to reduce the size of the PCB.



(a)



(b)

Fig. 10 PCB Layout for LCD

When the charger circuit charges the battery, battery temperature rises first for some time and then it gradually decreases and becomes constant. The graph of variation in temperature with change in battery voltage is shown in Fig.11

It can be concluded from Fig 11 that when the ambient temperature was 28^0C. The battery temperature increases till 34^0C i.e. 6^0C to 7^0C above than the ambient temperature. The recommended temperature range for charging the Li- ion battery is between 0^0C to 50^0C. So care should be taken if the ambient temperature is 45^0C or above.

8. GPS HANDHELD PROTOTYPE

Figure 12 shows the prototype of developed handheld GPS.

9. LINSEED BOOTING

Figures 13 and 14 show the LinSeed booting. The Linseed has been tested by connecting the board to the gateway and the booting result has been shown using hyper terminal.

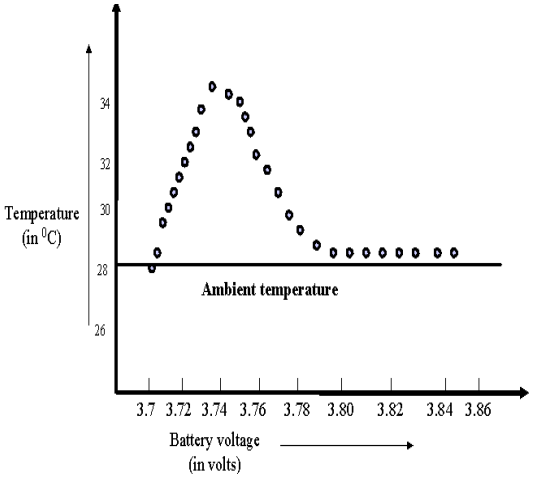


Fig. 11 Graph of Temperature Variation with Battery Voltage

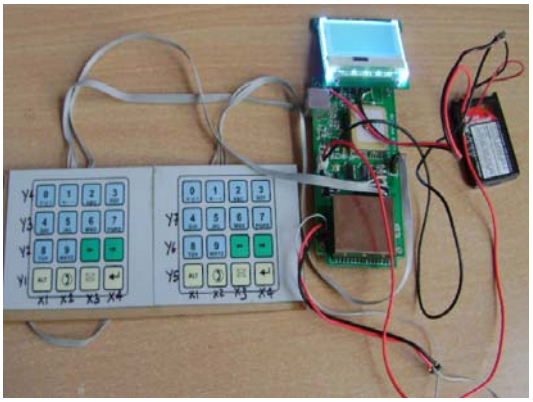


Fig. 12 Prototype of Handheld GPS

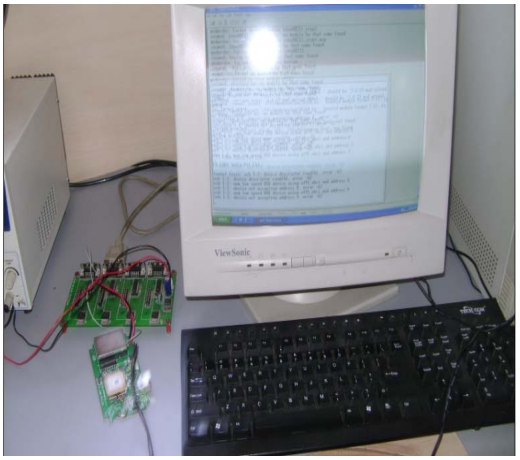


Fig. 13 Screen Shot of Linseed Booting

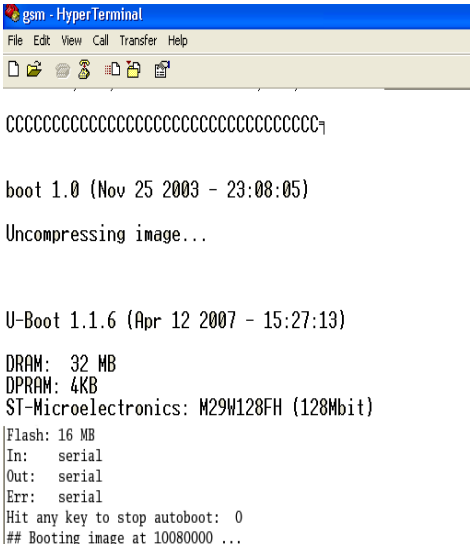


Fig. 14 LinSeed Booting

10. LCD TESTING

Figure 15 shows the LCD testing. 3.3V has been applied to the LCD and checked for its switch ON condition. Table 1 gives the key features of developed handheld GPS.

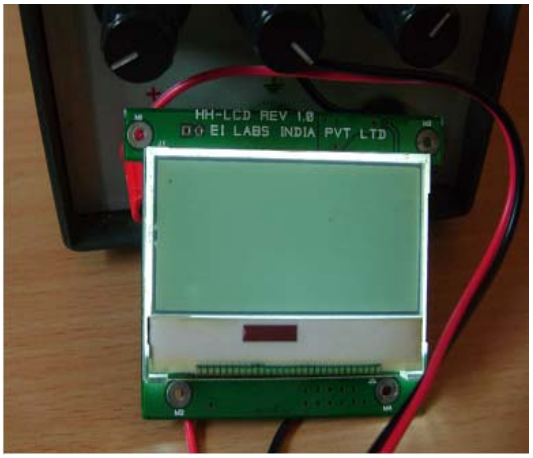


Fig. 15 LCD Testing

11. CONCLUSIONS

Hand held GPS receiver market is growing rapidly. Receivers are becoming powerful, cheap and smaller in size. Development of hand held devices incorporates the issues like finding the user requirements, selection of processor, cost, selection of battery, Power consumption. An attempt has been made to design and develop the low cost hand-held GPS terminals. The design presented serves the need of low cost and small form factor device. The component selected here according to the low profile package and small form factor. Linear charging methodology has been adopted here to charge the battery which gives the advantage of ease of use, size and cost reduced noise in contrast with the switch mode charging but it is associated with the power dissipation problem. Need of GPIO lines for interfacing between the keypad and processor have been reduced using the modified circuit for keypad scanner. The use of LINSEED gives a better environment to support the GPS application.

The paper has achieved a very small form factor of 115 mm x76mm for USB powered GPS hand-held, with built-in Li-Ion battery charger and support for executing the Linux OS.

Table 1 Key Features of Handheld

Form factor	115x76mm
Display	124x64, graphical with white backlight
Receiver	Form factor 25.4x25.4x3mm, with 35mA of supply current
Keypad	5x4 matrix keypad interface
Antenna	Geo Helix-S Sarental antenna
PC interface	USB
USB powered built in Li-ion battery charger and support for executing Linux-OS	

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