Secondary Battery as Source to Mobile Phone Battery

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Abstract—The charging of a mobile with direct DC supply at low cost is becoming an innovative technology. A new approach to recharge the mobile battery by direct DC supply without the conversion of AC to DC is reported. The approach applies a three terminal voltage regulator 78M05 IC to give a constant voltage 5V and current \(\approx 500\text{mA}\) from a 9V rechargeable battery connected parallel to the voltage regulator. It is observed that the voltage difference of the rechargeable battery drops when the mobile phone battery is charged and a voltage regulator is added in addition to regulate constant voltage finally. The analysis was also done by the AC power supply via the mobile charger. The charger is helpful for the charging of the mobile phone battery when there is no AC power supply. The entire setup can be reduced as an integrated chip along with the mobile phone charger, so the size of the charger remains same. Based on extensive simulation results using Matlab/ Simulink and experimental results, it has been established that the performance of the controller both in transient as well as in steady state is quite satisfactory.

Index Terms—rechargeable battery; 78M05 IC; simulink; Lithium ion battery LIB; voltage regulator; uninterruptible power supply; Universal Serial Bus (USB).

1. INTRODUCTION

Mobile phone are lifesavers as they help in emergencies. Mobile phones are a comfortable way of communication over a long distance. Along with the obvious convenience and quick access to help in emergencies big and small, mobile phones can be both economical and essential for travelers trying to stay connected. To stay connected, the mobile phone battery should contain more charge or it should be regularly charged through an AC power source via mobile charger [1].

A battery is a combination of cells. The cells in a battery may be connected in series or in parallel. Primary cells cannot be recharged, that is, the conversion of chemical energy to electrical energy is irreversible and the cell cannot be used once the chemicals are exhausted. Examples of primary cells include the Leclanche cell and the mercury cell. Secondary cells [2] (Rechargeable) can be recharged after use, that is, the conversion of chemical energy to electrical energy is reversible and the cell may be used many times. Examples of secondary cells include the lead-acid cell and the alkaline cell. Practical applications of such cells include car batteries, telephone circuits and for traction purposes such as milk delivery vans and fork lift trucks.

Lithium-ion (Li-ion) batteries [3] are comprised of cells that employ lithium intercalation compounds as the positive and negative materials. As a battery is cycled, lithium ions exchange between the positive and negative electrodes. They are also referred to as rocking chair batteries as the lithium ions “rock” back and forth between the positive and negative electrodes as the cell is charged and discharged. The
positive electrode material is typically a metal oxide with a layered structure, such as lithium cobalt oxide (LiCoO2), or a material with a tunneled structure, such as lithium manganese oxide (LiMn2O4), on a current collector of aluminum foil. The negative electrode material is typically a graphitic carbon, also a layered material, on a copper current collector. In the charge/discharge process, lithium ions are inserted or extracted from interstitial space between atomic layers within the active materials. The designs of the batteries are of different types, round, prismatic, polymer. Generally, prismatic batteries are used in mobile phone.

The battery of a mobile phone is rated at 3.7V, from 1000mAh to 1300mAh (3.7mWh - 4.8mWh). Generally the mobile phone battery is charged by converting the AC supply to DC constant voltage 4.8 V–5.2V and current 300-500 mA. Another alternative maybe the use of Universal Bus Serial female that can provide 5V DC and 100 mA currents to slow the charging for mobile phone battery which is considered sufficient for its operations.

2. PROPOSED SYSTEM FOR CHARGING MOBILE PHONE BATTERY USING RECHARGEABLE BATTERY

Introducing a rechargeable battery

A new approach to charge the mobile phone is by connecting a 9V rechargeable battery parallel to the voltage regulator, stepped down to 5V and current 500mA by the use of three terminal voltage regulator 78M05 [4] and again regulated to 4.7V. The three-terminal positive voltage regulator 78M05 employs built-in current limiting, thermal shutdown, and safe-operating area protection which make it virtually immune to damage from output overloads. With adequate heat sinking, the 78M05 can deliver in excess of 0.5A output current. Typical applications of 78M05 include local (on-card) regulators which can eliminate noise and degraded performance associated with single-point regulation. The parameters of 78M05 are input minimum voltage 6.5V, maximum input voltage 32V, output current in excess of 0.5A, output voltage is 5V, needs no external components, internal thermal overload protection, internal short circuit current-limiting, output transistor safe-area compensation. The 78M05 is available in TO-220, TO-39, and TO-252 D-PAK packages. The rechargeable battery used is 9V 250mAh Nickel Metal Hydride Ni-MH.

The schematic diagram of the mobile phone charger with rechargeable battery

The schematic diagram is shown in Fig.1. The AC Voltage is stepped down from 230V AC to 13.5Vrms by using step down transformer, is converted into DC by bridge rectifier and the output of the bridge rectifier may not be constant because the 230V AC varies.

![Fig. 1: Schematic diagram of proposed system](image-url)
The DC output from the bridge rectifier is varied from 9.5V to 12.5V. A 9 V rechargeable battery connected in parallel to the voltage regulator can be charged through this voltage. The low load current is better to increase the efficiency of the battery, so a circuit was designed to provide 4.7V regulated voltages and enough power to trickle charge the cell phone. So the voltage is regulated to 4.7V by using voltage regulator in two steps as shown in Fig. 2.

- In connection 1, the voltage can be stepped down to 5V and 500mA using a 78M05. Capacitors C₁ and C₂ are connected to regulate a fixed output. The output voltage can be increased by varying the resistors R₁ and R₂. Where Vₓₓ is the voltage across R₁ and V₀ is the output voltage.

\[ IR₁ ≥ 5I₀ \]
\[ V₀ = Vₓₓ \left( 1 + \frac{R₂}{R₁} \right) + I₀R₂ \]

- In connection 2, the transistor T₁ is used for the controlled output. The entire power NPN transistor as the average CL100, BD139, TIP122 can be used. Zener diode controls the output voltage, and diode protects the polarity of the output. Connect the positive end and the negative end properly to the USB female. If the polarity is incorrect, it will destroy the mobile phone battery.

When the AC power supply is turned on, both the secondary battery and the mobile phone battery will be charged simultaneously. The mobile phone battery will be charged via the DC-DC voltage regulator output and the rechargeable battery will be charged by the DC supply from the Bridge rectifier output voltage. If the AC power supply is suddenly interrupted the mobile phone battery will be charged by the secondary battery via DC-DC voltage regulator output voltage. The secondary battery voltage is to be maintained greater than 6.5V (the minimum input voltage required for the 78M05 IC to step down to 5.02V), for the charging to continue or else the charging stops. So a 9V rechargeable battery is used, for the system to run efficiently. When the charging is done through rechargeable battery, there will be a decrease in the voltage of the rechargeable battery. If the voltage is less than 6.5V it stops charging and will be shown as a bad contact of charger.

The analysis of the circuit shown in Fig.2 was done by both matlab/simulink and experimentally. The results obtained from the experimental study were quite satisfactory as with the Matlab/Simulink results. The results based on simulink are discussed in Section 3 and the results based on experiment are discussed in Section 4.
3. RESULTS AND DISCUSSIONS

**Simulation Results**

The decision to switching on the control action is carried out by comparing the upper limit of the state of charge (SOC) of the battery and the present status of SOC. When the SOC becomes higher than its limit, the controller will increase the duty cycle as a function of over voltage in the DC bus voltage. Moreover, when SOC of secondary battery is below 0.2, the discharging path of the secondary battery is automatically disconnected from the charger circuit through switch. In this paper a generic battery model presented in [5] is implemented. The model uses only the battery SOC as a state variable in order to avoid the algebraic loop problem and can accurately represent four types of battery chemistries including Ni-MH. Considering lifetime of the secondary battery, the SOC should reach up to some limit and when the SOC is reached maximum limit then secondary battery is disconnected from the AC power supply (disconnected charging path), then battery stops charging and makes its power to zero.

Simulation of proposed system is incorporated using Matlab/Simulink. Simulation is carried out by considering different possible power supply either by the secondary battery or the AC power supply.

The transient response of 9V battery is shown in Fig.3 while charging through AC power supply. The battery voltage is reached to steady state at around 0.2 sec (200 ms). The transient response (transient period) is satisfactory when the secondary battery is charged with AC power supply. Once the secondary battery maintains a voltage greater than 6.5V then it can charge the mobile phone battery only if it is not connected to AC power supply. Simulation results were carried out up to 20 sec. From 10 to 15 sec, the charger circuit gets disconnected from main supply, so mobile battery starts charging from secondary battery. For this condition one simple switch is connected in between bridge rectifier and dc-dc voltage regulator. From 10 to 15 sec the supply current from the AC power supply is zero. The response of supply current and transformer secondary voltage is shown in Fig.4.

![Graph](image)

Fig. 3: Voltage response of secondary battery

Figure.5 shows the response of voltages. The response of input voltage to mobile phone battery is shown in Fig.5 (a). The main supply is disconnected from 10 to 15 sec., during this time period the mobile phone battery charges from secondary battery. The input DC voltage to mobile phone battery is regulated by proposed system in entire time period. From Fig.5 (a), the DC voltage is constant, it is the input voltage to mobile phone battery and the constant input voltage will increase the life time of the mobile phone battery. The voltage response of secondary battery in both charging and discharging is shown in Fig.5 (b). From 10 to 15 sec., the secondary battery discharges the power for charging purpose.
The corresponding current waveforms are shown in Fig. 6. Fig. 6 (a) shows the response of mobile phone battery current. This current is positive because the battery is always charged from either the main power supply or secondary battery. The current wave form of secondary battery is shown in Fig. 6 (b). Up to 10 sec., the current is negative, it represents the charging and positive current represents the discharging of secondary battery. From 10 to 15 sec., the current is positive so the secondary battery starts to discharge the power and by using this power the mobile phone battery gets charge because in this time period the charging system is disconnected from the AC power supply. After 15 sec., again the current of secondary battery becomes negative because the AC power supply is connected to secondary battery as well as mobile phone battery and starts to charge from the main power source (after 15 sec., it is shown in Fig. 6(b)).

Fig. 4: Response of (a) Current (b) Voltage
Fig. 5: Voltage Response of (a) mobile battery (b) Secondary battery

Fig. 6: Current Response of (a) mobile battery (b) Secondary battery
The charging and discharging of the batteries are represented by using SOC. During charging period the SOC will increase and SOC will decrease during discharging period. Fig.7 (a) represents the SOC response of phone battery, this will always increase because the battery charge from secondary battery as it gets disconnected from the AC power supply. Fig.7 (b) shows the response of SOC of secondary battery, it increase while charging and decrease while discharging. From 10 to 15 sec., the SOC of secondary battery is decreasing, because the battery starts to discharge the power due to uninterrupted power supply from AC power supply. Remaining time the SOC of secondary battery is increasing which means that the battery gets charge from main power supply.
4. EXPERIMENTAL RESULTS

TABLE I. ELECTRIC COMPONENTS

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitor</td>
<td>1</td>
<td>0.22µf</td>
</tr>
<tr>
<td>Capacitor</td>
<td>1</td>
<td>0.1 µf</td>
</tr>
<tr>
<td>Capacitor</td>
<td>1</td>
<td>470 µf 25V</td>
</tr>
<tr>
<td>Variable Resistors</td>
<td>2</td>
<td>0-20kΩ</td>
</tr>
<tr>
<td>Resistor</td>
<td>1</td>
<td>560Ω</td>
</tr>
<tr>
<td>Diode</td>
<td>5</td>
<td>IN4007</td>
</tr>
<tr>
<td>Zener Diode</td>
<td>1</td>
<td>4.7V, 400mW</td>
</tr>
<tr>
<td>Transistor</td>
<td>1</td>
<td>CL100</td>
</tr>
<tr>
<td>Step Down Transformer</td>
<td>1</td>
<td>230/13.5V</td>
</tr>
<tr>
<td>Secondary Battery</td>
<td>1</td>
<td>9V, 230mAh</td>
</tr>
</tbody>
</table>

The electric components used in the experiment are listed in Tab.1. The experiment was done in three ways to charge the mobile phone battery. The pop up shown in the mobile phone is charger connected.

1) Using the AC power supply as the primary source without connecting the connection2 of DC-DC voltage regulator.

Fig. 8: Experimental circuit without rechargeable battery and connection2

In this case the mobile phone battery is being charged through the AC power supply only with connection1 in voltage regulator. When the mobile phone battery is not connected, the voltage difference of the output is 5.02V across the connection1, the maximum current flow is 500mA and it can be increased by varying the resistors R1 and R2 shown in Fig.2. It is decreased to 4.35 (Fig.8) on connection with the mobile phone battery. After some time it is shown as a bad contact of charger. Increase in the output voltage by varying the resistor R1 and R2 also did not increase the voltage even after the connection of the mobile phone battery and it remained as 4.35V. The connection1 of DC-DC voltage regulator is shown in the Fig.2 and Fig.9.
2) **Using the DC power supply from the rechargeable battery as the primary source.**

The connection shown in the Fig.10 is when there is no AC power supply and the mobile phone battery is being charged by the rechargeable battery. In this case when the mobile phone battery is not connected the output voltage difference is 5.02V across the connection1, it can be increased by varying resistance $R_1$ and $R_2$ shown in Fig.2. It is decreased to 4.30V (Fig.10) on connection with the mobile phone battery. Increase in the output voltage by varying the resistor $R_1$ and $R_2$ also did not increase the voltage after the connection of the mobile phone battery and it remained same. After 1 min it is shown as a bad contact of charger.

In the above two cases there is a voltage drop after the connection with the mobile battery. In order to eliminate the voltage drop to 4.3V and to maintain the output voltage as 4.7V the connection2 as shown in Fig.2 and Fig.11 is added to the three terminal voltage regulators.
3) **Using the AC power supply when the rechargeable battery is connected parallel to the voltage regulator.**

The rechargeable battery is added parallel to the voltage regulator and the connection2 is also added to the three terminal voltage regulator as shown in Fig.12. In this case AC power supply is used to charge both the mobile phone battery and the rechargeable battery. When the mobile phone battery is not connected the voltage difference across the connection1 is 5.09V and the voltage across the connection2 is 4.8V. The voltage across the connection1 is increased by varying the resistance in order to achieve 5.3V across the connection2. Now when the mobile phone battery is connected to the system the voltage was dropped to 4.97V under transient state. At steady state the output voltage reached to 4.7V. There is no sign of bad contact of charger and the mobile phone battery is charged to 100%. It works when the AC supply is removed without the sign of charger removal. It is designed in such a way that the secondary battery and the AC source can be removed easily. So the mobile phone battery can be charged either by the AC power supply or Secondary battery depending on the availability.

![Fig. 12: Experimental circuit of proposed system](image)

**5. CONCLUSIONS**

The low load current is better to increase the efficiency of the secondary battery and mobile phone battery, so the circuit was designed to provide regulated voltages and enough power to trickle charge the secondary battery and mobile phone battery. The system can charge the mobile phone battery without the AC power supply with the help of Secondary battery. Mobile phones are both economical and essential for travelers trying to stay connected. To stay connected, the mobile phone can be charged with the help of Secondary battery. The results obtained from the experimental study were quite satisfactory with the results obtained from Matlab/Simulink. To increase the life time of 9V secondary battery or rechargeable battery the controller was designed on the basis of SOC. The proposed system can be reduced as an integrated chip, so that the size of the charger remains same.
6. REFERENCES


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