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Repurposing ATX Power Supply for Battery Charging Applications

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Abstract

ICT equipment is usually replaced at regular intervals, usually before the equipment has failed, opening up the opportunity of providing a second-life through repurposing. In this paper we investigate the technical feasibility of repurposing the standard ATX power supply found in many desktop computers into a 12V battery charger. We provide an overview of the ATX power supply before describing how the power supply may be modified into a battery charger alongside experimental results.

1 Introduction

Computer equipment is often made redundant before unit failure, due to the rate at which computer hardware and software advances. Indeed many organisations (commercial and government) have an ICT replacement policy, and it was reported in [1] that PCs are made redundant every four years and laptops every two years, as result of being out of date and the reduction in their performance. In [2] and [3] the life span of an Advanced Technology Extended computer power supply unit (ATX PSU) is expected to be around 100,000 hours (11 years) depend on the operation conditions, which means the ATX PSU in the majority of PCs is made redundant at least 5 years before the end of its life span.

In 2015 it was estimated that worldwide sales of devices (PCs, ultra-mobiles, mobile phones and tablets) will be in the order of 2.5 billion units [4], with approximately 3m desktop PCs being sold in the UK alone [5]. In 2014 it was estimated that 500,000 tonnes of waste electrical and electronic equipment was collected from the UK business sector [6], with IT and telecommunications equipment being the largest contributor accounting for some 126,000 tonnes [7]. Consequently, significant scope exists to improve the UK's recycling/reuse in this area while creating an opportunity for a new industry to operate alongside the current reuse and recycling practices [8].

Repurposing equipment does not remove the need to recycle but it does provide a way of extending the useful life of a system. A number of charitable organisations such as Computer Aid International and Aspire-Sheffield have been created with the purpose of reusing ICT equipment in third-world countries. Indeed, to date Computer Aid International has provided a second-life to over 230,000 PCs. More recently IBM with their "UrJar" project have been looking into the prospect of reusing old laptop batteries to provide power for lighting in off-grid areas [9].

Since ATX PSUs contain the same basic components (MOSFET, diodes, transformer, inductor and capacitor) as found in most battery chargers it should be relatively straightforward to modify them given the correct infrastructure. For the ATX PSUs investigated in this work, it was found that regardless of the manufacturer, all the power supplies have a common design containing power transformer (with multiple secondary to produce a range of voltages) driven by a half-bridge or forward power converter. In [10-12] we exploited this level standardisation to repurpose ATX PSUs into PV powered mobile-phone battery chargers where the charge control is already built into the mobile phone.

While a large amount of literature exists on the design of battery chargers, no substantial research has been carried out on the reuse of existing computer power supply as battery chargers. This paper will demonstrate the technical feasibility of repurposing waste computer power supplies into 12V lead-acid battery chargers suitable for deployment in developing nations where access to battery charging facilities is sometimes limited but 12V batteries are more readily available.

2 Review of ATX (advanced technology extended) power supply unit

The ATX power supply is designed to interface the voltage between the utility AC mains and the load required by the different computer components. A typical ATX power supply converts the mains power through two stages, an AC-DC and then DC-DC to provide the multiple DC outputs [13]. For older PSUs the AC-DC conversion stage is simply a rectifier (with input filter) and the PSU operates without power factor correction (PFC), Fig. 1a. The more recent PSUs feature active PFC circuitry (Fig. 1b) necessary to meet EN61000-3-2 regulations introduced in 2000 [14]. In addition the older non-PFC PSUs possess a manual changeover switch to allow the user to select either 110V or 230V operation using a built-in voltage doubler rectifier. The DC-DC stage converts the DC link voltage into the required standard voltages. This paper will focus on the newer APFC as they are now more widely available.

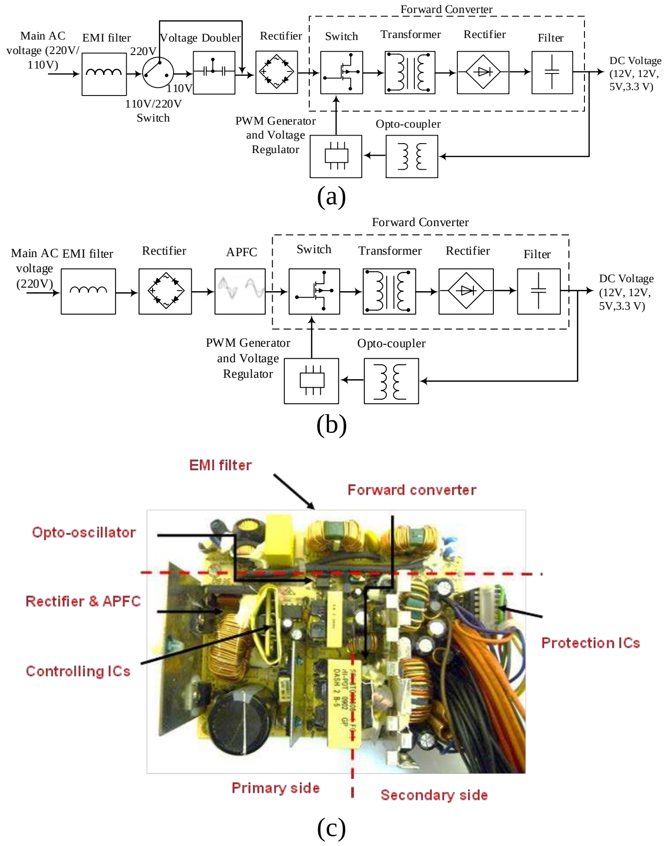

Figure 1: ATX PSU. (a) Older (non-PFC) design, (b) Newer design (APFC) (c) Picture of an APFC PSU

There are five main parts arranged in order from the input to the output side: EMI filter, rectifiers, active power factor corrector (APFC), half-bridge or forward power converter and standby power supply. Other components include filters, control and protection circuits. The ATX PSU produces a range of output voltages and every voltage is identified with a specific colour as shown in Fig. 1c: +12 V (yellow), -12 V (blue), +5 V (red) and +3.3 V (orange) [13]. The PSU consists of primary and secondary side, the primary side is easily recognised by large electrolytic capacitor located on the left hand side of Fig. 1c (n.b. two electrolytic capacitors can be found older non-PFC version). Most of the ATX PSU we encountered featured two or three transformers located between two large heatsinks. The large transformer is for the main forward converter and it is used to step down the DC voltage to the desired levels. The medium size transformer is used to generate the standby voltage (+5VSB) needed to initiate operation of the power supply. The smallest transformer is used for gate drive coupling. A brief overview of the main PSU modules now follows.

2.1 Active power factor corrector

DC voltage has traditionally been obtained by rectifying the mains and then smoothing with a bulk capacitor. One issue is that energy is only delivered wherever the mains voltage exceeds the bulk capacitor voltage; the resulting large current pulse causes high component stresses and a low power factor (PF) of ~0.5. Passive power factor correction circuits are able to improve the power factor to about 0.7, but this had become insufficient as regulations tighten. By 2007, Energy Star 4.0 specification requires computers to use power supplies that are 80% or greater in efficiency, with power factor of no less than 0.9 with most modern PSUs approaching unity

2.2 Forward converter

The forward converter is the essential part of an ATX power supply, converting the high DC voltage from the APFC circuit into the desired low DC voltages for the computer's motherboard, etc. A single rail forward converter consists of a minimum of two switches, S1 and S2, a transformer, T1, four diodes, D1-D4, and an LC low-pass filter, L1 and C1. For each additional voltage output, an extra pair of diodes and an LC filter is used, Fig. 2. Transformer T1 is designed such that the outputs are tightly coupled and so the +12 V and +5 V outputs can be regulated with just a single control variable. The +3.3 V output is usually regulated in one of three ways: 1) a post-regulator is added to the 5 V output is commonly found in cheaper PSUs; 2) in high-end PSU a magnetic amplifier (mag-amp) is often used that consisting of a saturable inductor which postpones the transformer secondary voltage develop across the diode D7 which affects the duration over which power is transferred; 3) in very rare cases (e.g. Enermax Galaxy 1000 W) a whole independent set of +3.3 V rectification and filtering circuitry is added.

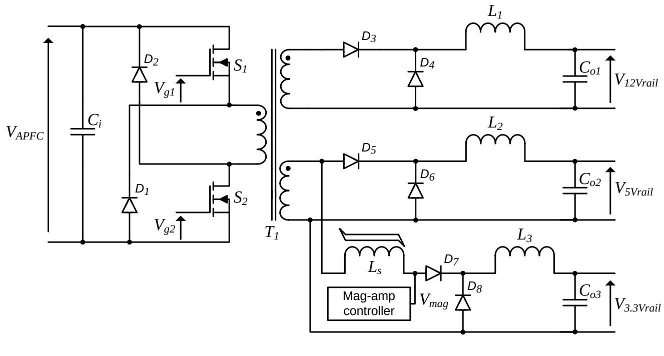

Figure 2: Typical forward converter found in ATX PSUs

2.3 Control and protection circuits

The APFC and forward converter stages within the ATX PSU are nowadays controlled by a dedicated IC. Early, non-PFC PSUs utilised a generic PWM such as the TL494 IC whereas nowadays the CM6800 (or similar) is commonplace. Figure 3 shows a typical schematic diagram for the CM6800 controller. The APFC is controlled via a current feedback loop where three signals, the instantaneous rectified line voltage V_{ac}, the long-term rms line voltage V_{rms} and the output voltage error V_{err}, are combined to form the current reference I_{ref} for PFC boost converter. The current loop adjusts the duty cycle of the boost converter such that the average inductor current follows the current reference. The forward converter output voltage is regulated via the opto-coupler using a compensation network based around a TL431 shunt regulator.

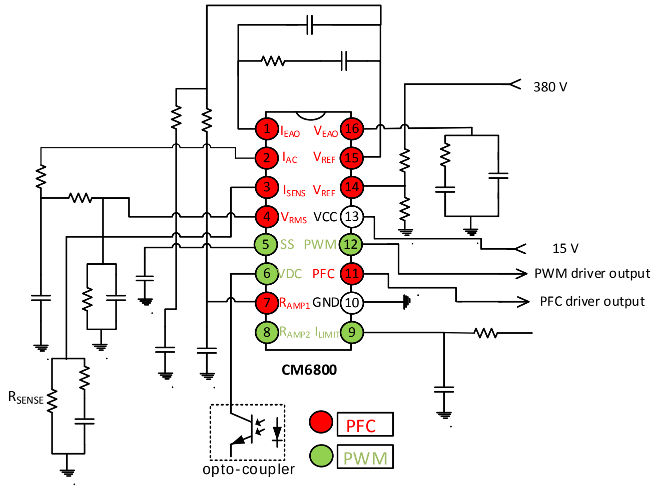

Figure 3: Typical CM6800 control IC circuit

The power supply and PC are protected using dedicated circuitry which shut down the power supply whenever the operating conditions are outside the tolerant. The most common IC in use is the PS223 and it mounted on the secondary side to monitor the PSU output voltage rails as shows in Fig. 4. With standards ATX12V and EPS12V, the PSU must provide: over voltage protection (OVP), over current protection and (OCP) short-circuited protection (SCP) [13]. Some manufactures have adopted to provide greater protection in the form of: under voltage protection (UVP), over temperature protection (OTP), over load protection (OLP), over power protection (OPP), no-load operation (NLO) and the power good signal (PG).

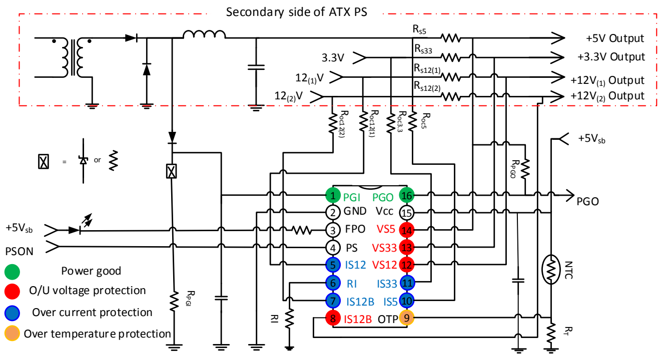

Figure 4: Typical PS223 ATX PSU protection circuit

3 Repurposing the ATX PSU

As mentioned in the previous section, the output voltage of the ATX power supply is regulated by a TL-431 shunt regulator opto-coupler circuit. Figure 5 shows the typical circuit found in CM6800 based PSUs that we examined. The TL-431 acts as both reference voltage generator and an error amplifier, with R4,5,6, and C1,2 forming a compensation network (usually PI or PID type). The current flow through the TL-431 (shunt current) is adjusted in a way to ensure the potential division of output voltage is equal to the TL-431 internal reference voltage (1.25V or 2.5V). The shunt current flows through the opto-coupler changing the bias point of the phototransistor and hence the control signal presented to the PWM controller inside the CM6800 IC.

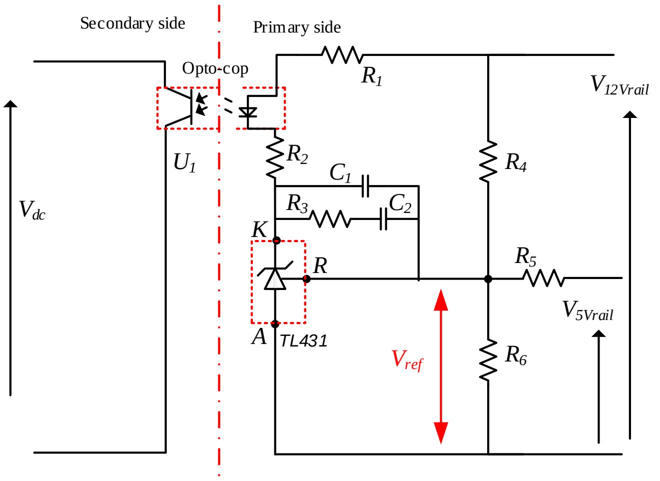

Figure 5: Typical TL431 opto-coupler feedback circuit found in ATX PSUs

The output voltage(s) of the PSU can be modified by adjusting the resistors in the voltage feedback network. In order to charge a 12V lead-acid battery the modified ATX PSU needs to provide an output voltage of at least 13.8 V. In this work we investigated two ways to achieve this.

3.1 Method 1

Prior to modifying the PSU the achievable variation in the +12V rail voltage was determined by replacing resistor R6 (Fig. 5) with a variable resistor Rvar = 3 kΩ. The experimental results presented in Fig. 6 clearly show the +12V rail is capable of providing over 15V.

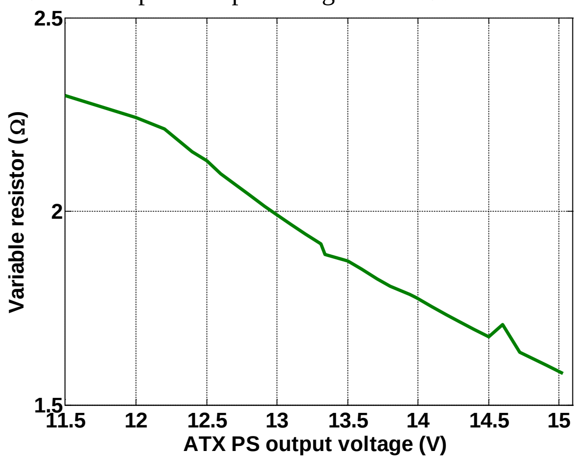

Figure 6: Variation in PSU output voltage

Having proven the PSU provides an adequate voltage range to charge a 12V battery, the available current over this operating range was investigated by setting the output voltage to specific values in the range 10 V – 13.8 V and varying the load. The results presented in Fig. 7 show the PSU is not capable of providing the maximum charge voltage under high-current conditions. Therefore, to charge a 12V lead-acid battery using the modification suggested above, a resistor is connected in series with the lead-acid battery to limit the charge current to 2A.

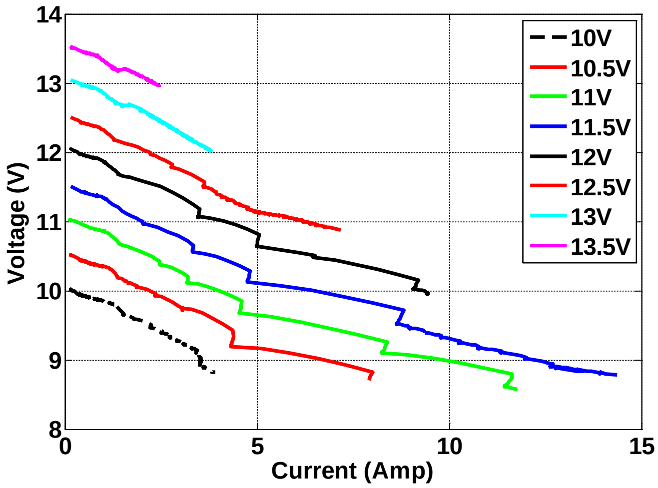

Figure 7: Voltage and current characteristics of the ATX PSU at different load conditions

The charging waveform of a 12V lead-acid battery is shown in Fig 8. The battery was initially discharged to a voltage of 11.4 V. Under charge the battery voltage increases, the current drawn decreases according to the charging characteristic of this battery. The battery achieved 93% of its capacity (43Ah) after 42 hours.

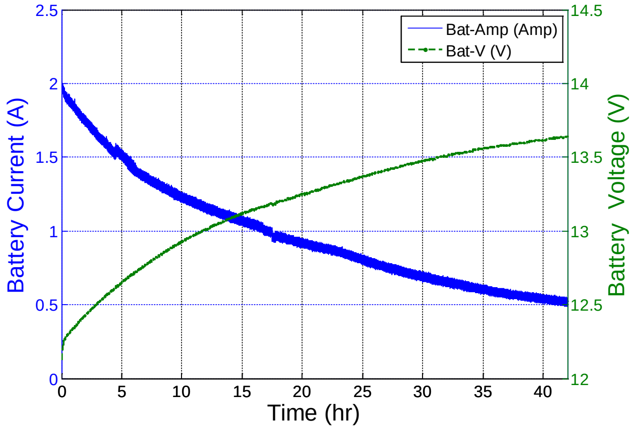

Figure 8: Charging characteristics for method 1

3.1 Method 2

Although method 1 successfully charged the battery, the 12V rail was not operated anywhere near its rating. In the second method R5 is removed so that only the +12V rail is regulated and over voltage protect circuit is disabled. Figure 9 shows the charge characteristics for method 2 where the battery was initially discharged to 11.4V and then charged using a maximum current of 14A. In this mode the battery reaches the float charge level within 3 hours.

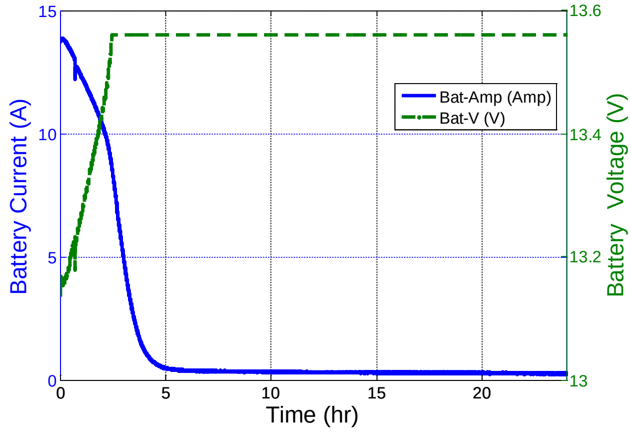

Figure 9: Charging characteristics for method 2

4 Conclusion

This paper has proven the technical feasibility of repurposing an ATX PSU into a 12V lead-acid battery charger. The methodology has been practically demonstrated on a 300W ATX PSU kindly removed from the WEEE stream and donated to us by Aspire-Sheffield. Using only minimal modifications the system has been shown to provide current limited constant voltage charging at up to 14 A suitable for VRLA batteries.

Acknowledgements

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