



## 25W OFF-LINE AUTORANGING BATTERY CHARGER WITH L5991A

by Domenico Arrigo

### INTRODUCTION

This note describes an off-line autoranging (85Vac-264Vac) battery charger designed to operate in three different functional modes:

- constant voltage
- constant current
- constant power

These requirements are typical of battery chargers for notebook computers.

The resulting output characteristic of the system is shown in fig 1.

The A-B portion of the V-I characteristic is a constant voltage mode. This situation happens when the battery pack is almost completely charged.  $V_o$  has to be set at the final value of the battery pack. From point B to C the charger operates in constant power mode, reducing the output voltage while increasing the output current.

The benefit of introducing the constant power mode is that the maximum output power is lower with respect to the power output at point E. This reduces the power managed by the primary circuitry and in consequence reduces the total dissipation power. This is a useful improvement considering that the complete system is packaged in a plastic case with a very limited capability of dissipating heat.

From point C to D the adapter works in constant current mode until the output voltage reaches 0V.

In practice it is difficult to have a constant current characteristic below an output voltage of 2-3V because the primary auxiliary supply voltage drops at the controller turn-off threshold (internally fixed at 7.6V typ.) and the V-I characteristic exhibit a foldback to zero.

If mandatory to operate in constant current mode till 0V, a secondary post-regulator or other tricky solutions on the windings, primary or secondary, are required.

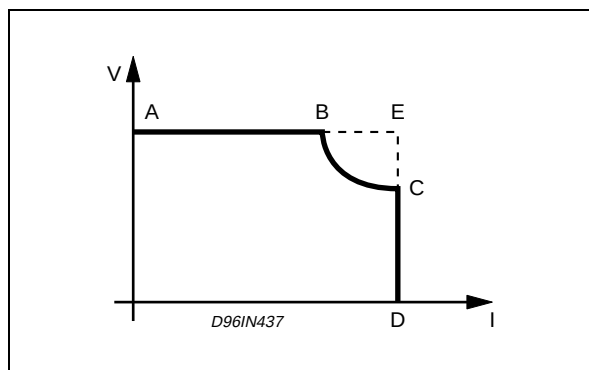
Fig 2 shows the V-I characteristic obtained with the circuit of Fig 3.

### ELECTRICAL SPECIFICATION:

|                               |                                    |
|-------------------------------|------------------------------------|
| Input voltage                 | 85Vac to 264Vac                    |
| Regulated output voltage      | 18V                                |
| Maximum output power          | 25W                                |
| Switching frequency           | 100kHz                             |
| Target efficiency @ full load | >80%                               |
| Topology                      | discontinuous current mode flyback |

Fig 3 shows the electrical circuit.

**Figure 1. V-I output characteristic**



**Figure 2. Practical V-I characteristics**

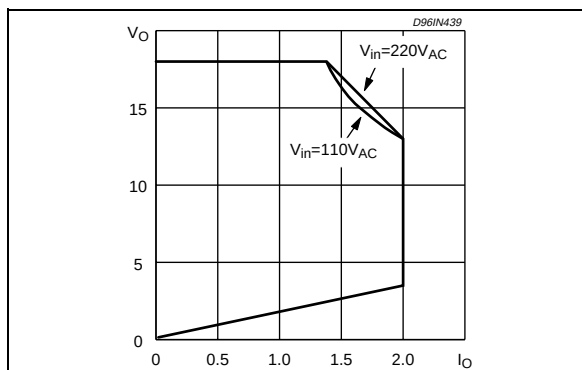
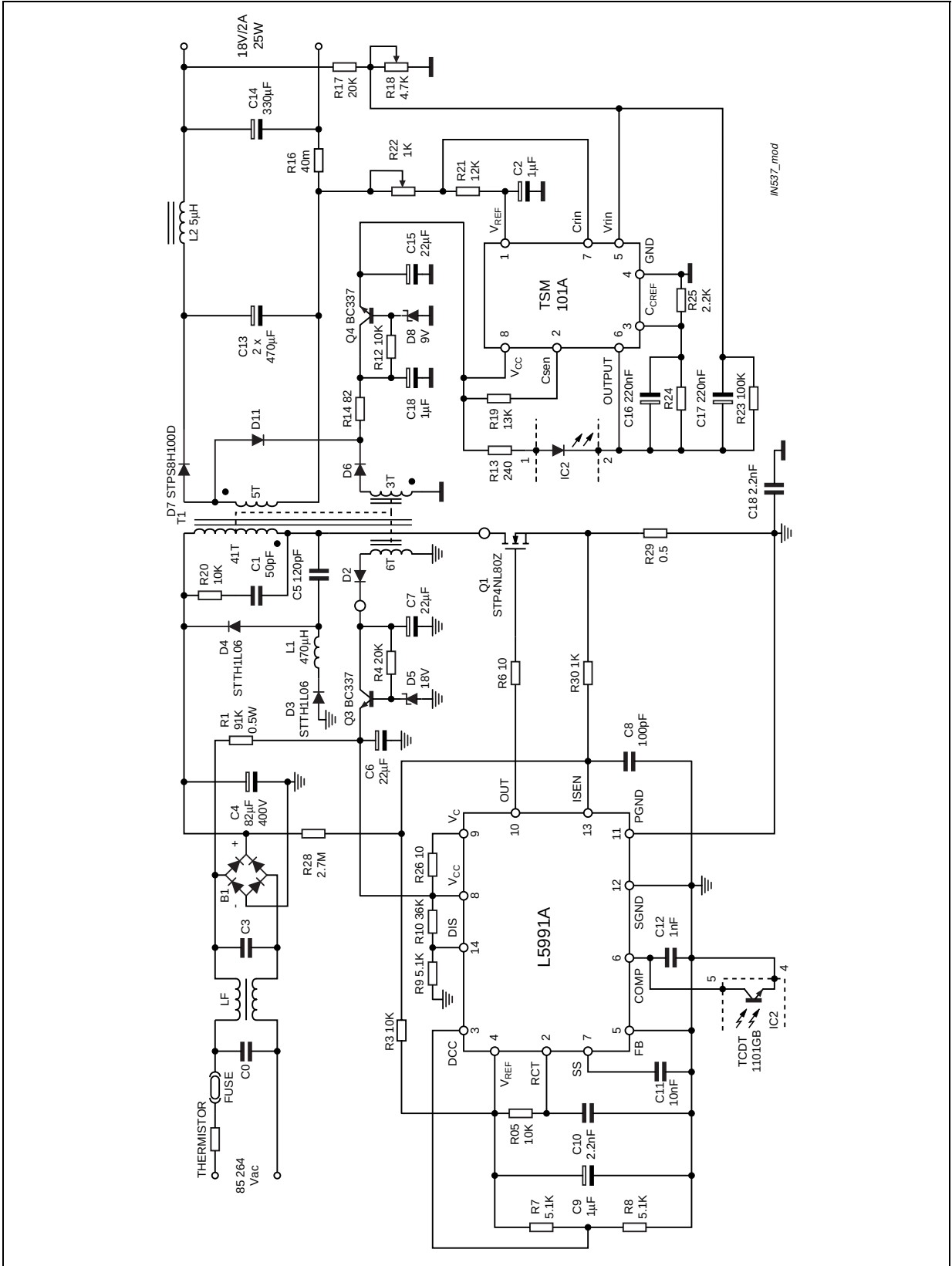


Figure 3. AC-DC converter electrical schematic



The realisation of the three different functional modes requires dedicated controls.

The voltage and current controls are located on the secondary side of the transformer, and the error signal is transferred to the primary controller via an optocoupler in order to have an isolated feedback.

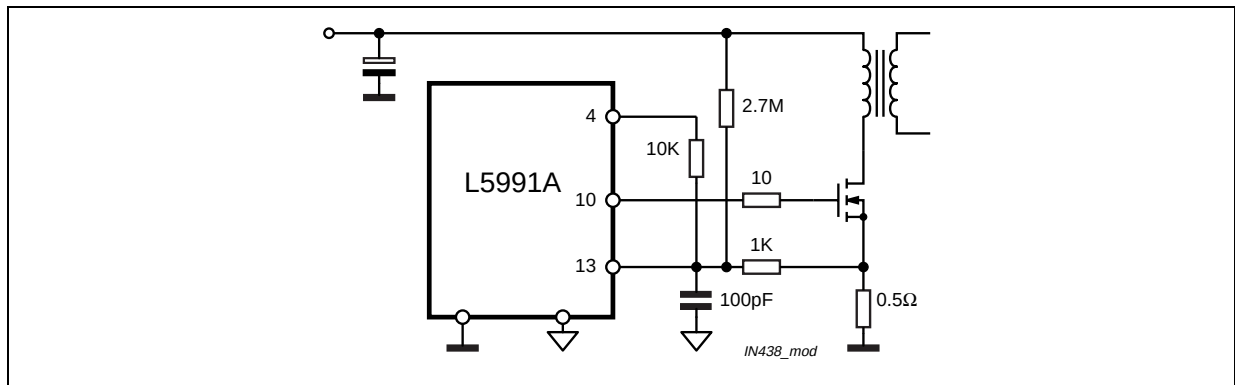
The TSM101A a dual op/amp, with an internal 1.24V reference is used. One op/amp is dedicated to the voltage mode control and the second one to the constant current control.

The two output are OR-ed and the common point drives the optocoupler.

The current signal is taken across the 40mOhm current sense resistor, R16, while the R18 potentiometer adjusts the output voltage.

The constant power characteristic is easy to achieve with discontinuous mode operation, since constant primary peak current means constant output power. The value is programmed by adding a proper offset voltage, defined by R3 value (fig 4), to the current sense ramp at pin 13.

**Figure 4. Schematic diagram for output constant power.**



The value of this resistor is related to the desired output power  $P_{out}$  by the below relationship:

$$R_3 = R_{30} \cdot \left[ \frac{4}{1 - \left( \sqrt{\frac{2}{L_1 \cdot f \cdot \eta}} \right) \cdot R_S \cdot \sqrt{P_{out}}} \right]$$

where  $L_1$  is the primary inductance,  $\eta$  is the expected efficiency,  $f$  is the switching frequency and  $R_S$  is the current sense resistance.

The L5991A introduces a delay,  $t_d$  @ 100ns, at turn-off, on the current loop, and due to this, the primary peak current value increases according to its slope.

The consequence is that the regulated output power is a function of the input voltage. R28 is introduced in order to compensate this error.

Its value can be calculated with the following formula:

$$R_{28} = \frac{(R_{30}/R_3) \cdot L_1}{t_d \cdot R_S}$$

A primary auxiliary winding is required to supply the IC after turn-on, and it has to be designed to generate a dc voltage within the limits of the IC supply voltage range. It should be loosely coupled with the secondary winding in order to minimise the reflected secondary-to-primary effects when the output voltage is going down towards short circuit.

A second auxiliary winding, on the secondary side transformer, forward coupled with the principal primary winding, has been added. When the system is in constant current mode, and the output voltage is reduced, this winding provides the supply voltage for the TSM101A.

The Table A summarises the efficiency performance of the complete system, and Table B shows the electrical system performance.

## AN1620 APPLICATION NOTE

**Table A. System efficiency.**

| Vin (Vac) | Iout = 1A |        | Iout = 2A, Pout = 36W |        | Iout = 1.8A, Pout = 25W |        |
|-----------|-----------|--------|-----------------------|--------|-------------------------|--------|
|           | Vout (V)  | $\eta$ | Vout (V)              | $\eta$ | Vout (V)                | $\eta$ |
| 85        | 17.97     | 83.9%  | 17.96                 | 82.2%  | 13.82                   | 82.6%  |
| 110       | 17.94     | 85.1%  | 17.96                 | 83.7%  | 13.86                   | 83.7%  |
| 220       | 17.89     | 84.4%  | 17.91                 | 83.5%  | 14.31                   | 83.8%  |
| 264       | 17.89     | 82.0%  | 17.89                 | 83.0%  | 14.41                   | 82.7%  |

**Table B. System performance (Pout limited to 25W)**

|                    |                                             |              |
|--------------------|---------------------------------------------|--------------|
| Line regulation    | Vin = 85 to 264 Vac, Iout = 1A              | 80mV         |
| Load regulation    | Iout = 0.5 to 1.8A, Vin = 85V<br>Vin = 264V | 10mV<br>10mV |
| Maximum efficiency | Vin = 180 Vac, Iout = 1.8A                  | 85.2%        |
| Output ripple      | Vin = 85 to 264 Vac, Iout = 1.8A            | < 200mV      |

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