

## Reducing the Total No-Load Power Consumption of Battery Chargers and Adapter Applications

### 1 Introduction

This paper describes how to reduce the power consumption, under no-load conditions, of battery chargers and adapters by using STMicroelectronics's TSM family of secondary-side devices. This family of devices provides accurate voltage and current regulation, while incurring very low consumption at no-load conditions. In fact, owing to these innovative, integrated devices, the total power consumption for the entire system at no-load conditions can be reduced down to nearly 100mW. With the arrival of new power consumption regulations, this capability is increasingly sought after.

The most innovative of ST's devices are the TSM101x family. These are highly integrated solutions for SMPS applications requiring CV and CC mode, integrating one voltage reference and two operational amplifiers. The voltage reference combined with one operational amplifier makes them ideal voltage controllers. The other operational amplifier, combined with the integrated voltage reference and a few external resistors, can be used as a current limiter.

These products family are designed for use in battery chargers with a constant voltage and a limited output current and in adapters. They can be used in every type of application requiring 0.5% and 1% voltage reference precision.

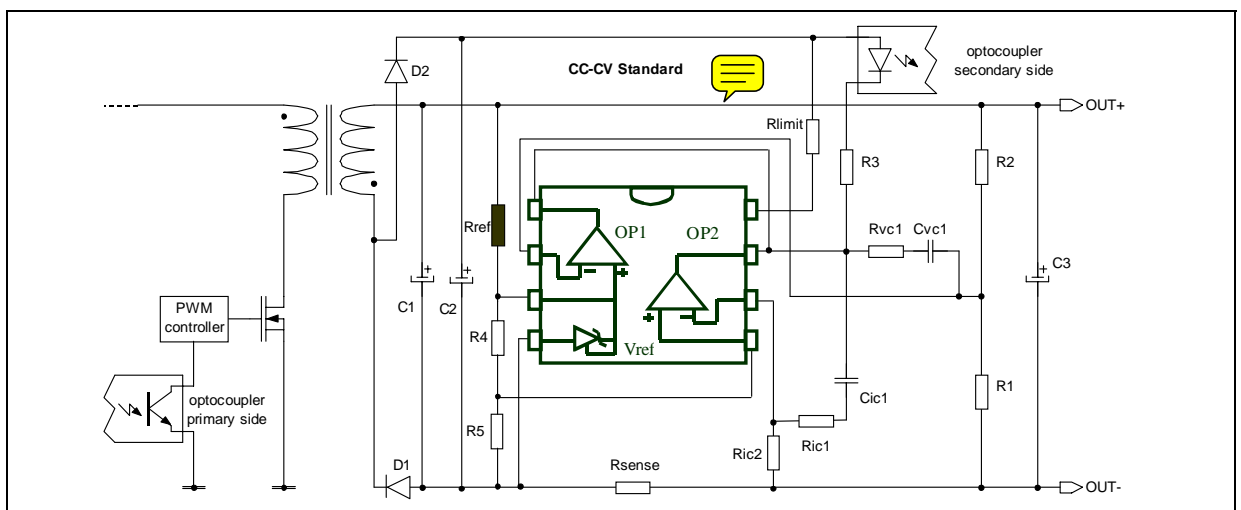
### 2 Power dissipation under no-load conditions

In a typical system for battery charger and adapter applications, different factors contribute to the total power dissipation under no-load conditions. However, in broad terms, the total power dissipation can be divided into the dissipation owing to the secondary-side ( $P_{out}$ ) and the power dissipation owing to the primary-side ( $P_{in}$ ).

#### Secondary-side power dissipation

This article deals with reducing the secondary-side power dissipation, so let us begin by considering a typical schematic of the secondary-side of an SMPS application, shown in [Figure 1](#).

**Figure1: Typical application using CC-CV Standard in SMPS**

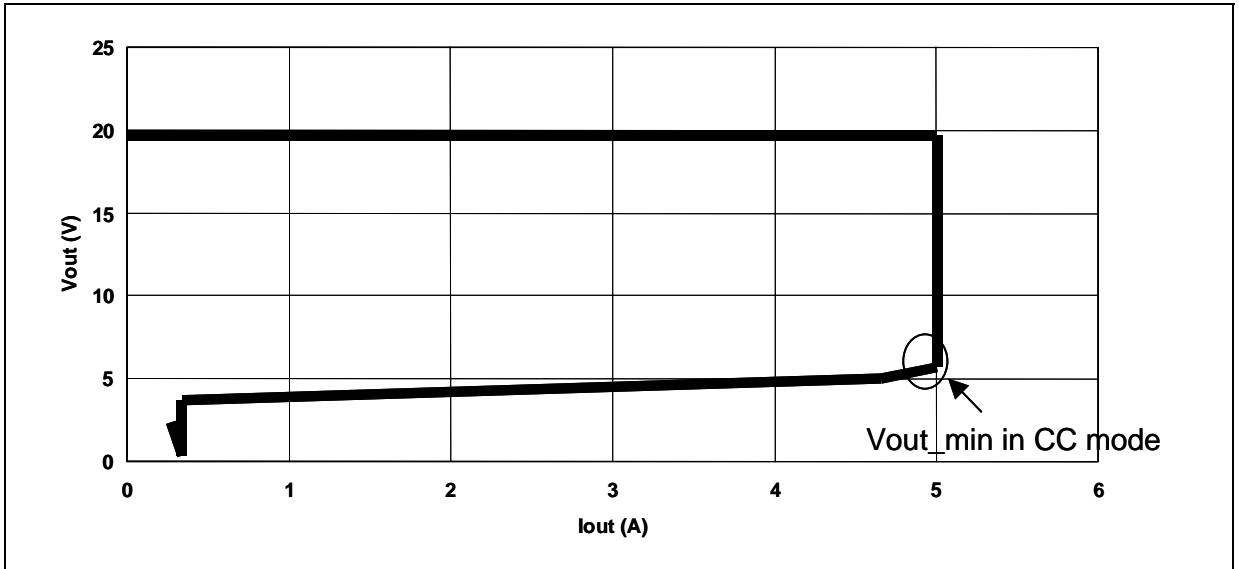


The CC-CV (Constant Current - Constant Voltage) standard is a monolithic IC that includes one independent op-amp and another op-amp for which the non-inverting input is wired to a 2.5V fixed voltage reference. A good example of such a secondary-side device is ST's TSM103W.

Normally the CC-CV voltage reference is "shunted", meaning that the internal current generator requires an external power supply in order to polarize and fix the voltage reference at 2.5V ( $V_{ref} = 2.5V$ ).

If we assume that  $V_{out}$  is connected to a discharge battery, the resulting characteristic curve,  $V_{out}-I_{out}$ , is shown in [Figure 2](#).

**Figure2: Characteristic  $V_{out} - I_{out}$  for adapter application**



In [Figure 2](#), we can see that the load charges gradually, by increasing the current and the voltage in order to reach a minimal voltage drop. This gradual increase guarantees a limited and stable current. Following this, the voltage value increases (while the current stays constant) up to the constant voltage value.

A typical adapter application will have  $V_{out\_max} = 20V$  (at no-load conditions) and  $V_{out\_min} = 5V$  (which is the minimal voltage necessary to have a constant current).

In order to have  $V_{out\_min} = 5V$ ,  $V_{cc\_min} = 5V$ . If the minimum current value to bias  $V_{ref}$  is 1mA, this means that:

$$I_{ref} = 1mA$$

$$R_{ref} = \frac{V_{outmin} - V_{ref}}{I_{ref}} = \frac{5V - 2.5V}{1mA} = 2.5k\Omega$$

Therefore, in order to have  $V_{out\_min} = 5V$ , we must fix  $R_{ref} = 2.5k\Omega$ .

Now that we have fixed the value of  $R_{ref}$ , let's consider a no-load condition where  $V_{out\_max} = 20V$ . It follows that:

$$I_{ref} = \frac{V_{out} - V_{ref}}{R_{ref}} = \frac{20 - 2.5}{2.5} = 7mA$$

The total value of the secondary-side power dissipation is calculated using:

$$P_{out} = V_{out} \cdot I_{tot}$$

Equation 1

where

$$I_{tot} = I_{cc} + I_{ref} + I_{opto}$$

Equation 2

and  $I_{opto}$  is the current needed to drive an optocoupler — typically about 1.5mA.

This means that for a typical system at no-load conditions where  $V_{out} = 20V$ ,  $I_{ref} = 7mA$ ,  $I_{cc} = 1.5mA$  and  $I_{opto} = 1.5mA$ , giving a secondary-side power dissipation ( $P_{out}$ ) equal to:

$$P_{out} = (V_{out} \cdot I_{tot}) = (V_{out} \cdot (I_{ref} + I_{cc} + I_{opto})) = (20V \cdot (7mA + 1.5mA + 1.5mA)) = (20V \cdot 10mA) = 200mW$$

Equation 3

### Primary-side power dissipation

Now to turn our attention to the primary side of a typical adapter application. The primary side of an SMPS application consists of a number of functional blocks (such as the PFC and PWM), each contributing to the overall power consumption of the device. But in general, the overall power dissipation owing to primary side functions can be assumed to be about 80mW under no-load conditions (for battery chargers and adapters in the range 5W).

The key factor concerning the overall power consumption on the primary-side is its **efficiency rating**, which is at best about 50%. This means that to transfer 1mW of power to the secondary side, 2mW of power are generated in the primary side.

Returning to our calculation in [Equation 3](#) above, this means that if we require 200mW of power on the secondary-side in no-load conditions, 400mW will be generated on the primary side, and an additional 80mW will be necessary to drive the primary-side functions.

This relationship means that for any given reduction in no-load power dissipation on the secondary side, the beneficial effect will be twice as great on the primary side.

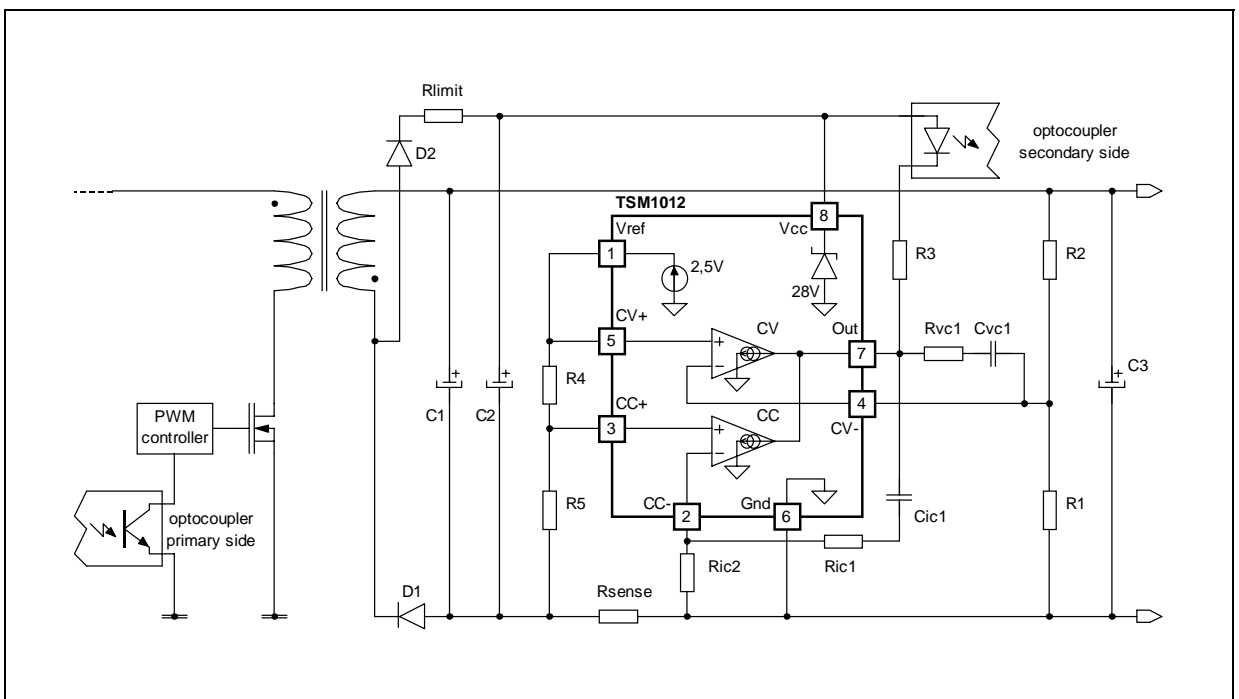
### 3 Optimizing your system

Typically, when one designs a battery charger or adapter application, a target power consumption is set for the application under no-load conditions. This target may be 500mW, or even 300mW, but until recently, it seemed impossible to reach a no-load total power consumption of as low as 100mW.

In this section, we will look at three example systems:

- A typical secondary side configuration, as seen in [Figure 1](#), and using a general-purpose secondary-side integrated circuit, such as ST's TSM103.
- An advanced secondary side circuit schematic (see [Figure 3](#)), using an integrated circuit such as ST's TSM1011 which includes a self-polarizing voltage reference. The inclusion of a self-polarizing voltage reference permits the elimination of the resistor  $R_{ref}$ , and by consequence, elimination of  $I_{ref}$ .
- An advanced secondary-side schematic (see [Figure 3](#)) using a very advanced integrated circuit, ST's TSM1012, which draws only 150 $\mu$ A under no-load conditions.

**Figure3: Advanced secondary-side schematic for battery-charger/adapter application**



In addition to considering the typical ([Figure 1](#)) and advanced ([Figure 3](#)) secondary side schematics, there are now on the market optocouplers that need as little as 0.5mA. As we will see below, using such an optocoupler can allow power consumption to drop very low indeed.

The following table summarizes the parameters for each of the above systems:

	System A “Typical Configuration”	System B “Optimized Configuration”	System C “Highly-Optimized Configuration”
<b>Secondary-side IC</b>	<b>TSM103</b>	<b>TSM1011</b>	<b>TSM1012</b>
$V_{ref}$	2.5V (externally polarized)	self-polarizing	self-polarizing
$R_{ref}$	2.5k $\Omega$	none	none
$I_{ref}$	7mA	none	none
$I_{cc}$	1.5mA	1mA	0.1mA
$I_{opto}$ (standard)	1mA	1mA	1mA
$I_{tot} = I_{ref} + I_{cc} + I_{opto}$	9.5mA	2mA	1.1mA
<b><math>V_{out}</math> under no-load condition</b>	20V	20V	20V
$P_{out}$	190mW	40mW	22mW
$P_{in}$	380mW	80mW	44mW
<b>Primaryfunction power dissipation</b>	<b>80mW</b>	<b>80mW</b>	<b>80mW</b>
<b>Total Power Consumption</b>	<b>460mW</b>	<b>160mW</b>	<b>124mW</b>
<b>Target consumption window</b>	<b>&lt;500mW</b>	<b>&lt;200mW</b>	<b>&lt;150mW</b>
<b>Using a low-power optocoupler:</b>			
$I_{opto}$ (low power)	0.5mA	0.5mA	0.5mA
$I_{tot}$	9mA	1.5mA	0.6
$P_{out}$	180mW	30mW	12mW
$P_{in}$	360mW	60mW	24mW
<b>Primaryfunction power dissipation</b>	<b>80mW</b>	<b>80mW</b>	<b>80mW</b>
<b>Total Power Consumption</b>	<b>440mW</b>	<b>140mW</b>	<b>104mW</b>
<b>Target consumption window</b>	<b>&lt;500mW</b>	<b>&lt;150mW</b>	<b>~100mW</b>

We can see from the above comparison that by using the TSM1012 and a low-consumption optocoupler, an economy of nearly 80% in power consumption can be obtained relative to the “typical” CC-CV secondary side solution. And most importantly, it is possible with this advanced system to descend to only 104mW in no-load conditions.

However, we can also see that only improving the optocoupler and retaining a standard secondary-side device (such as the TSM103) does not significantly improve the overall power consumption.