SII Seiko Instruments Inc.

Application Note No.101

Frequency 300 kHz Step-Down Switching Regulator Controllers S-8520/8521 Series

Product Overview

The S-8520/8521 series consists of CMOS step-down switching regulator controllers of PWM control (S-8520 series) and PWM/PFM switchable control (S-8521 series). These devices contains a reference voltage source, oscillation circuit, error amplifier and other components. These controllers are available in three types having oscillation frequencies of 60, 180 or 300 kHz. This report focuses on the 300 kHz type, providing an introduction to important points in terms of features and design from the viewpoint of compact size and light weight of the systems in which it is used.

Development Background

Dramatic reductions have recently been made in the size and weight of portable devices. In the case of battery-powered products in particular, increased efficiency of the power supply circuit has become an important aspect to ensure long-term portable use. As a result, the number of cases in which switching regulators are used is increasing.

In the case of using switching regulators in portable devices, component size is an issue that frequently causes problems for the designer in terms of attempting to reduce size. In the case of attempting to reduced component mounting height in particular, there are many cases in which coil height presents a difficult problem. Recently, the development of thin coils has proceeded actively, and numerous products have been released offering a mounting height of less than 3 mm. Due to limitations on the physical size of thin coils, however, there are many that have an inductance value on the order of several to 20 µH. In order to use such a coil, it is essential to raise the switching frequency. In addition to lowering the inductance value of the coil by increasing the switching frequency, since the peak current during switching operation decreases, it becomes possible to use smaller coils having a lower mounting height.

Amidst this background, we have developed the S-8520/8521 series of high-frequency 300 kHz step-down switching regulator controllers based on the development concepts described below.

- Accommodation of compact (thin) coils by using an oscillation frequency of 300 kHz.
- Low current consumption because of CMOS process and high conversion efficiency (90% or more). (S-8521 holds high efficiency even when output current is 1mA or less.)
- Space-savings through the use of an ultra-compact package (mounting surface area: 2.8 mm x 2.9 mm) and few externally connected components.

Features

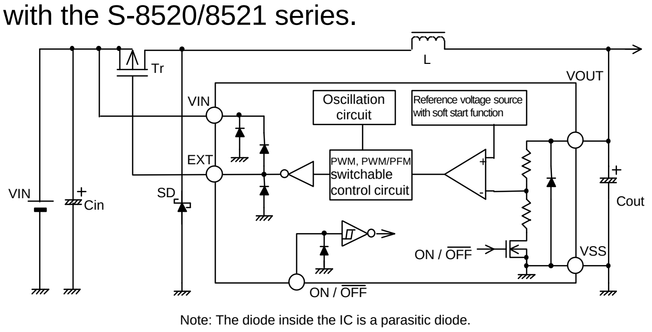
The features of the S-8520/8521 series are shown in Table 1.

- Low current consumption :
  During operation: 100 µA max.
  During power off : 0.5 µA max.
- Input voltage range : 2.5-16 V
- Output voltage range :
  Set in 0.1 V steps from 1.5 to 6.0 V
- Duty cycle : 0-100% (PWM control: S-8520)
  25-100% (PWM/PFM switchable control: S-8521)
- Externally connected components : Switching transistor, coil, diode, capacitor only
- Built-in soft start function
- With power off function
- SOT-23-5 package

Table 1

The major features of the S-8520/8521 are low current consumption by taking advantage of the CMOS process, and the use of the SOT-23-5 package, the smallest package in the world for a step-down switching regulator controller. In addition, the externally connected components that compose the step-down switching regulator consist only of a P ch power MOSFET or PNP transistor, coil, capacitor and diode, enabling the power supply unit of portable devices to be designed while saving on space.

Fig. 1 shows a block diagram illustrating configuration of a step-down switching regulator with the S-8520/8521 series.



Note: The diode inside the IC is a parasitic diode.

Fig. 1

Important Design Aspects

When designing a step-down switching regulator using members of the S-8520/8521 series, the most important factor is the selection of externally connected components. The coil and switching transistor in particular have a significant effect on the maximum output current value and efficiency. Therefore, the following provides a description of important points that should be considered when selecting the coil and switching transistor.

1. Coil Selection

Important parameters when selecting a coil include inductance value, maximum allowable current and direct current resistance value. The inductance value and direct current resistance value have a particularly large effect on efficiency.

The lower the direct current resistance value, the more advantageous it is for efficiency. Since there is a tradeoff between efficiency and coil size, there are many cases in which the coil is selected while placing priority on component size in portable devices and other applications.

Next, with respect to the inductance value, as the inductance value becomes smaller, the peak current of the coil increases, and the output current value reaches a maximum at a certain inductance value. Moreover, as the inductance value decreases, the switching transistor loses the capacity to drive current resulting in a decrease in the maximum output current value.

Conversely, since the peak current becomes smaller when the inductance value is increased, the loss of the switching transistor decreases, and efficiency reaches a maximum at a certain inductance value. Moreover, as the inductance value increases, loss due to the series resistance of the coil increases resulting in poorer efficiency.

The optimum inductance value changes depending on what output current value in which efficiency is to be emphasized. In the case of the S-8520/8521 series (300 kHz type), since an inductance value of around 22 μH results in the most suitably balanced characteristics, select the optimum inductance value in the vicinity of this value.

When selecting a coil, it is also necessary to pay attention to the allowable current value. Application of a current in excess of this allowable current to the coil causes magnetic saturation of the coil resulting in a significant decrease in efficiency.

Consequently, it is necessary to select an inductance value so that the peak current does not exceed the allowable current of the coil. Caution is required particularly with respect to thin coils since there are some types that are susceptible to magnetic saturation. The peak current is indicated with equation 1 in the continuous mode.

$$Ipk = Iout + \frac{(Vout + VF) \times (Vin - Vout)}{2 \times Fosc \times L \times (Vin + VF)}$$

....(Equation 1)

Ipk : Peak current
Fosc : Oscillation frequency
L : Coil inductance value
VF :Diode forward voltage

2. Switching Transistor Selection

The EXT pin on members of the S-8520/8521 series allows direct driving of a P ch power MOSFET having a gate capacitance of about 1000 pF. In the case of using a P ch power MOSFET, since switching speed is greater than a PNP bipolar transistor and there is no power loss caused by base current, efficiency can be increased by roughly 2-3%.

Important parameters when selecting a P ch power MOSFET include the threshold voltage, gate-source breakdown voltage, drain-source breakdown voltage, total gate capacitance, on resistance and current rating. Total gate capacitance and on resistance in particular have an effect on efficiency.

The power loss due to charging and discharging the gate capacitance by the switching operation increases as total gate capacitance increases or as input voltage increases, thereby having an effect on efficiency in regions of low load current. Especially as the oscillation frequency increases, since the proportion of power loss due to charging and discharging of gate capacitance becomes larger, the total gate capacitance of the MOSFET is an important parameter.

Conversely, in regions of large load current, power loss caused by the on resistance of the MOSFET has an effect on efficiency. Since there is typically a tradeoff between total gate capacitance and on resistance, it is important to select a MOSFET according to what load current range in which efficiency is to be emphasized in the actual application.

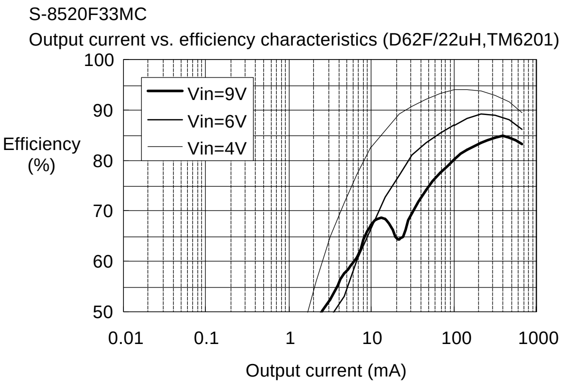
Applications

The following provides an introduction to several examples of efficiency characteristics of actual applications. Furthermore, those externally connected components used to acquire data are listed in Table 2.

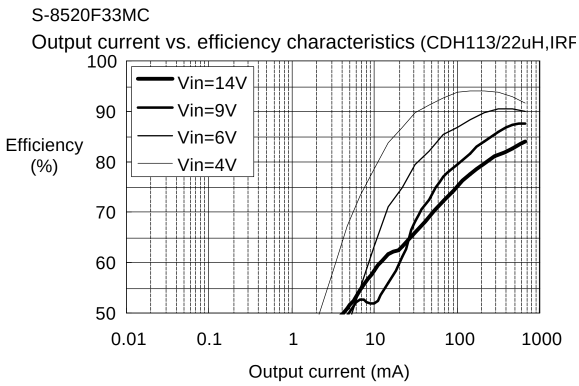
Component	Product name	Manufacturer	L value	Direct current resistance	Max. allowable current	Diameter	Height
Coil	CDH113	Sumida Electric	22uH	0.09 Ω	1.44A	11.0mm	3.7mm
	D62F	Toko	↑	0.25 Ω	0.70A	6.0mm	2.7mm
Diode	MA720	Matsushita Electronics	Forward current 500 mA (at VF = 0.55 V)				
	MA737	↑	Forward current 1.5 A (at VF = 0.5 V)				
Capacitor	P93	Nichicon					
	TE	Matsushita Electronics					
Pch MOSFET	TM6201	Toyoda Automatic Loom Works	VGS 12V max. , ID -2A max. , Vth -0.7V min. , Ciss 320pF typ. Ron 0.25 Ω max.(Vgs=-4.5V) ,SOT-89-3 PKG				
	IRF7606	International Rectifier	VGS 20V max. , ID -2.4A max. , Vth -1V min. Ciss 470pF typ. Ron 0.15 Ω max.(Vgs=-4.5V) ,Micro 8 PKG				

The characteristics values in the above table were excerpted from the October 1998 catalog. Please inquire to the respective component manufacturer for further details on their characteristics.

Table 2



Graph 1



Graph 2

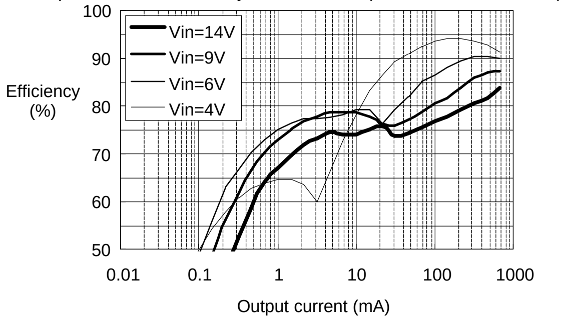
Graph 1 illustrates an application in which the output voltage is 3.3 V at an input voltage of 10 V or less, and the load current is roughly 500 mA. This is an example of attempting to combine the smallest externally connected components possible. The Toko D62F coil (22 μH) having a diameter of 6.0 mm and height of 2.7 mm was used for the coil, while the Toyoda Automatic Loom Works TM6201 in an SOT-89-3 package is used for the switching transistor.

With this configuration, it is possible to obtain a maximum efficiency of 94% in the case of an input voltage of 4 V.

Graph 2 indicates an application in which the output voltage is 3.3 V at an input voltage of 16 V or less, and the load current is about 1 A. The Sumida Electric CDH113 coil (22 μH) having a diameter of 11.0 mm and height of 3.7 mm was selected for the coil based on the relationship with maximum allowable current value. In addition, the International Rectifier IRF7606 was used for the switching transistor in consideration of the relationship with withstand voltage.

In comparison with the characteristics of Graph 1, since the direct current resistance of the coil and the on resistance of the switching transistor are lower, efficiency is good in regions of high output current (approximately 200 mA or more). Conversely, due to the increase in the gate capacitance of the switching transistor, efficiency is poor in regions of low output current (approximately 10 mA or less).

Graph 3 illustrates an example of characteristics in the case of using the S-8521 of PWM/PFM switchable control. The externally connected components are the same as in Graph 2, and the Sumida Electric CDH113 coil (22 μH) and International Rectifier IRF7606 switching transistor are used.



Graph 3

The S-8521 is PWM/PFM switchable control and normally operates at from 25% to 100% of duty cycle in PWM control, and during light loads, automatically switches to PFM control at a duty cycle of 25%. The reason for the increase in efficiency in the vicinity of an output current of 10 mA is due to the S-8521 switching to PFM control. Use of the S-8521 employing PWM/PFM switchable control makes it possible to realize high efficiency over a wide range in applications in which the load current varies between device standby and operation.

Direction for the Future

The power supply circuits of portable devices are expected to become increasingly small and thin in the future.

Although the oscillation frequency of the member of the S-8520/8521 series introduced in this report is 300 kHz, in consideration of the increasingly reduced size and low ripple of externally connected components, higher oscillation frequencies will be necessary. However, this does not mean that oscillation frequency should be increased limitlessly in battery-powered portable devices. Since higher oscillation frequencies result in greater self-current consumption by the IC, this is somewhat disadvantageous in terms of efficiency.

We are planning on developing products offering even higher frequencies (e.g., 600 kHz to 1 MHz) in the future while taking advantage of the merit of CMOS, namely low current consumption.