Development of Non-Isolated Converter Power Supply IC STR5M400 Series

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Abstract

In recent years, power supply ICs used in small home appliances such as ceiling fans, coffee makers, dehumidifiers/humidifiers, and vacuum cleaners have required surface-mount miniaturization, elimination of photocouplers through non-isolation, reduction of external components, and high efficiency across the entire load range. To meet these demands, we have developed the STR5M400 series, which is reported in this paper.

1. Introduction

For small-capacity power supplies of 5W or less used in small home appliances such as lighting equipment, ceiling fans, coffee makers, dehumidifiers/humidifiers, and vacuum cleaners, non-isolated buck converters are commonly used. These converters eliminate the need for isolation transformers and photocouplers, enabling compact, low-cost, and high-efficiency designs.

Market trends in this load range for power supply ICs include surface mounting for labor-saving, reduction of PCB area for miniaturization, and component selection tailored to load capacity for cost reduction.

In response to these trends, the STR5M400 series achieves both a reduction in component count and high efficiency across the full load range. Furthermore, to support a wide variety of applications, the series offers a rich lineup with variations in output voltage, operating frequency, and output power capacity.

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2. Product Overview

The STR5M400 series is a power supply IC that integrates a control chip and a high-voltage 700V power MOSFET in a surface-mount SOIC8 package. Compared to the existing mass-produced STR5A464S[1], the number of external components has been reduced by five.

In the power supply circuit diagram of STR5A464S shown in **Figure 1**, the feedback (FB) detection resistor (output voltage setting resistor) in section (a) and the diode and electrolytic capacitor in section (b) were required. In the STR5M400 series, these components are eliminated by combining the VCC and FB terminals into a single shared terminal, enabling a simplified power supply circuit diagram as shown in **Figure 2**.

For the capacitor in section (c) of **Figure 2**, we con-

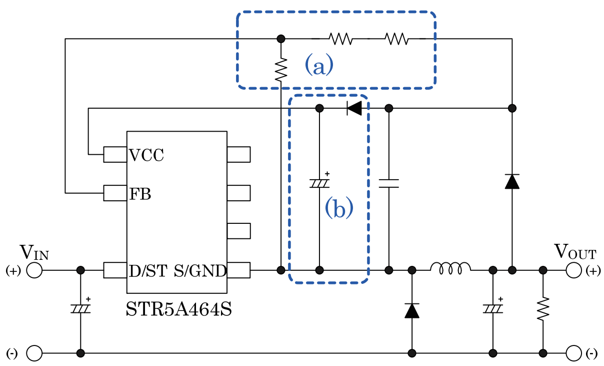


Figure 1. Power Supply Circuit Diagram of the Existing STR5A464S Mass-Produced Product

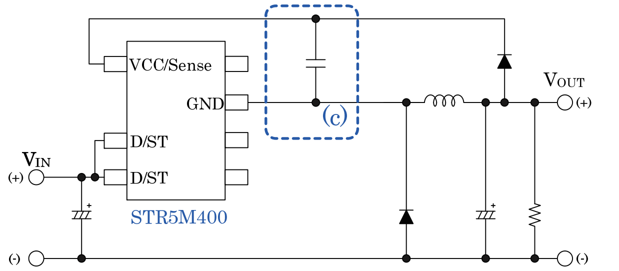


Figure 2. Power Supply Circuit Diagram of the STR5M400 Series

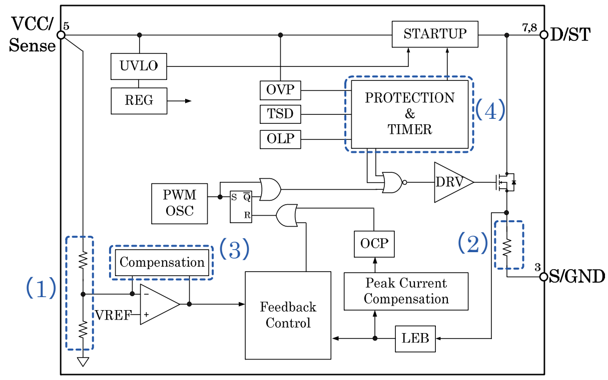


Figure 3. Block diagram

sidered applying it to the shared VCC/Sense terminal. In the existing STR5A464S, a capacitor of 10μF or more was used to ensure OLP (Overload Protection) delay time, but this resulted in degraded response performance, posing a challenge for low-capacitance designs.

To address this issue, we reviewed the internal circuitry and successfully ensured accurate delay time even with low-capacitance components, achieving both responsiveness and protection.

The STR5M400 series lineup, shown in Table 1, offers various combinations of output voltage, switching frequency, on-resistance, output current, and Green Mode support to accommodate diverse application needs.

Table 1. STR5M400 series lineup

製品名	V_{OUT} [V]	f_S [kHz]	$R_{DS(ON)}$ Max. [Ω]	I_O [A]	GM
STR5M467H4	14.2	100	16	0.10	—
STR5M467H3	13.0	100	16	0.10	—
STR5M467M5	15.0	60	16	0.25	✓
STR5M422M5	15.0	60	3	0.40	✓
STR5M422M2	12.0	60	3	0.40	✓

Notes:
1. Including conceptual products
2. GM refers to Green Mode, a function that reduces the oscillation frequency under light-load conditions.

3. Product Features

Figure 3 shows the block diagram of the IC. The key features of this product are the integration of the following four functions:

(1) Feedback resistor
(2) Current sensing resistor
(3) Phase compensation circuit
(4) Overload protection (OLP) timer

3.1 Feedback Resistor

The feedback resistor corresponds to section (1) in Figure 3. By integrating the resistor into the IC, external components can be reduced, and users are relieved from the task of individually setting resistor values.

3.2 Current Sensing Resistor

The current sensing resistor corresponds to section (2) in Figure 3 and, as shown in Figure 4, utilizes interconnect resistance on the control chip. This wiring resistance is formed using aluminum alloy and typically exhibits a temperature characteristic of over 30% increase at a 100°C rise. Our proprietary technology compensates for this temperature characteristic.

The IC adopts a current-mode control method, detecting current information via the sensing resistor. Overcurrent conditions are also detected using this resistor. As with the feedback resistor, integrating this component reduces external parts and eliminates the need for user-side constant setting.

Notably, this IC is the first product to use our latest high-voltage process[2], which has been cost-optimized compared to our existing high-voltage process.

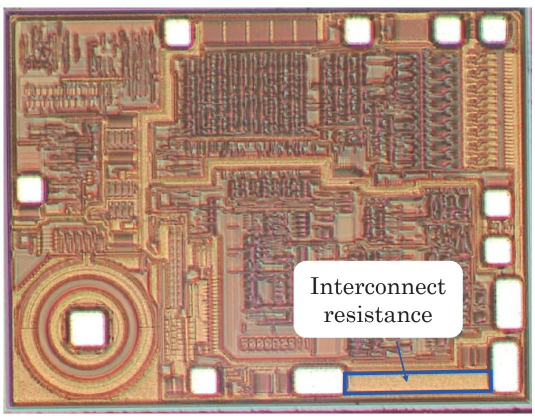


Figure 4. Photograph of the Control Chip

3.3 Phase Compensation

The IC includes a phase compensation circuit within the error amplifier section. This circuit supports output capacitors ranging from low to high capacitance (approximately 10μF to 470μF), including low-ESR ceramic capacitors. It also eliminates the need for users to set compensation constants individually.

3.4 OLP Timer

Figure 5 shows the timing waveform of VCC and the gate signal DRV of the Power MOSFET during OLP operation. The OLP time 1 and OLP time 2 are both controlled by internal timers, allowing the IC to maintain switching stop time without being affected by the VCC capacitor value, unlike the STR5A464S.

This ensures reliable suppression of IC temperature rise during abnormal conditions.

As shown in Figure 5, when VCC drops to VCC (Bias) during OLP time 1 or 2, the startup circuit activates bias assist to maintain VCC voltage. After OLP time 2 ends, bias assist stops, and when VCC falls below VCC (OFF), bias assist reactivates to raise VCC. This cycle results in intermittent switching operation.

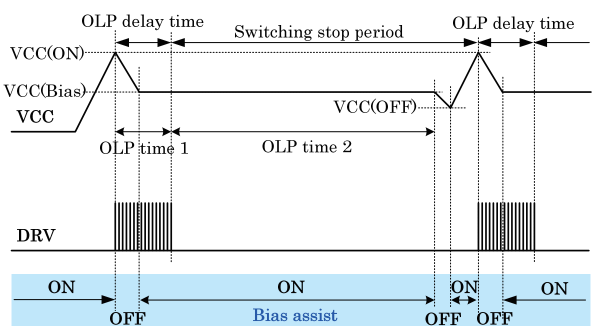


Figure 5. Timing waveform during OLP operation

Figure 6 shows the operating waveform under heavy-load conditions during OLP at AC 200 V. Due to this intermittent operation, the temperature during OLP at AC 265 V is maintained at 92.4°C, satisfying the requirement of being below 100°C (assuming Ta = 60°C).

3.5 Oscillation Control

To improve power conversion efficiency under medium to light loads, the IC adopts Green Mode, as shown in Figure 7. The oscillation frequency is automatically controlled according to the load, minimizing unnecessary power

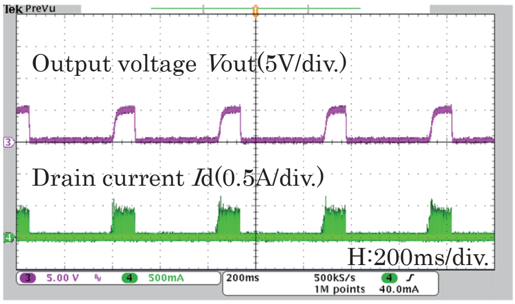


Figure 6. OLP operation

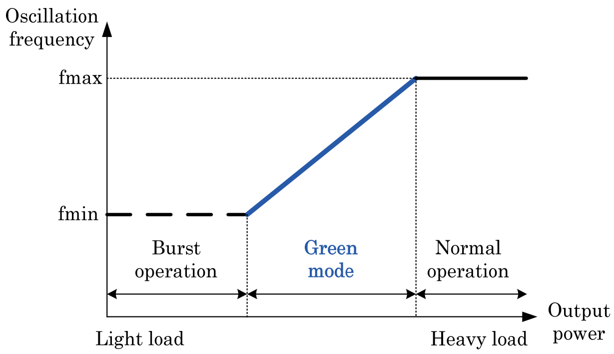
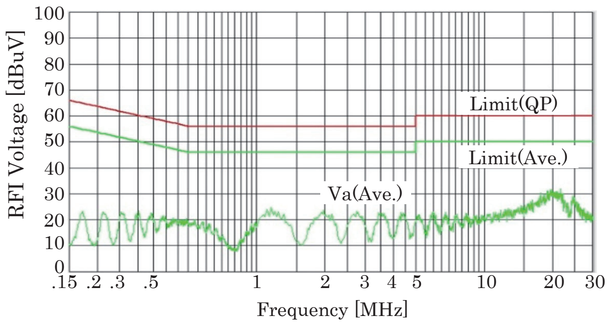


Figure 7. Operating Area of Green Mode

consumption and enabling high-efficiency power supply design across the full load range.

Additionally, the IC incorporates a random switching function that superimposes frequency variation on the average PWM oscillation frequency. This design ensures compliance with CISPR J14 standards for conducted emissions, even without noise suppression components such as input line filters, as shown in Figure 8.



Limit (QP): Upper limit of RFI voltage in Quasi-Peak measurement
Limit (Ave.): Upper limit of RFI voltage in Average measurement
Va (Ave.): Measured data

Figure 8. Conducted Emission Test (AC200V, in accordance with CISPR J14 Standard)

Under conditions of AC200V and V_{OUT} = 15V, the burst oscillation waveform at I_{OUT} = 3mA, Green Mode waveform at I_{OUT} = 25mA, and normal operation waveform at I_{OUT} = 200mA are shown in Figures 9, 10, and 11, respectively.

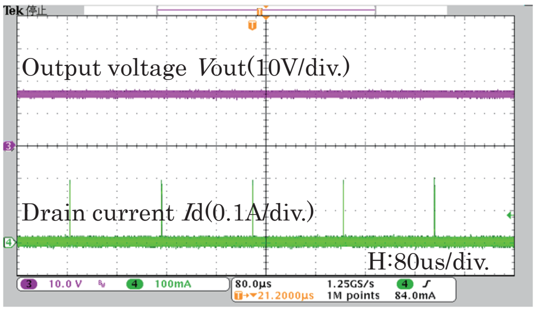


Figure 9. Burst Oscillation Mode

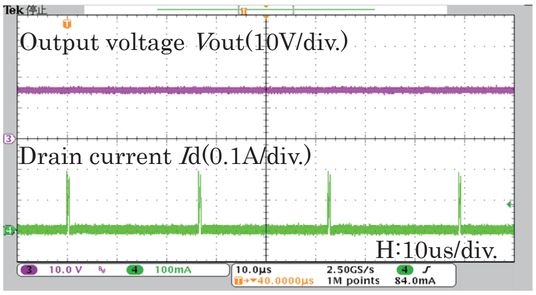


Figure 10. Green Mode

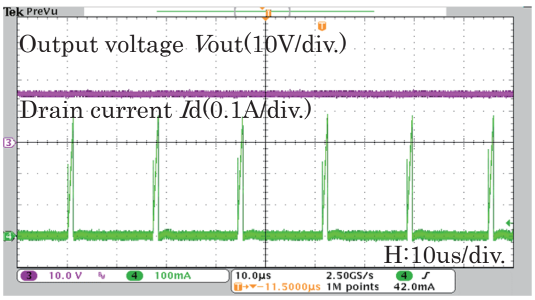


Figure 11. Normal Operation

4. Prototype Evaluation Results

Figure 12 shows the schematic of the power supply evaluation board using this IC, and Figure 13 shows the implementation photo. Table 2 shows the list of mounted components, demonstrating a 42% reduction in component count compared to the conventional product.

This section reports the results of power supply evaluation conducted using the evaluation board.

4.1 Power Supply Characteristics

Figure 14 shows the efficiency characteristics, and

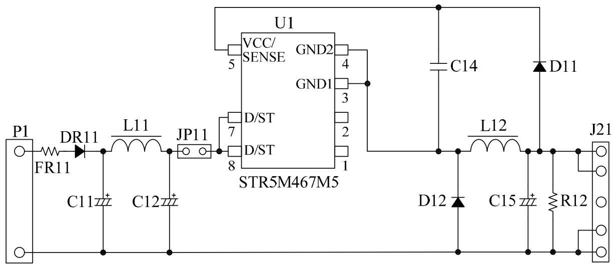
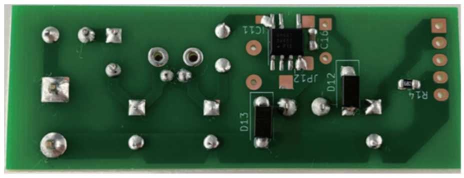


Figure 12. Power Board Schematic

(a) Front



(b) Back

Figure 13. Power Evaluation Board

Table 2. List of Mounted Components

Symbol	Part name	Rating	Proposed product	Conventional product
C12	Electrolytic capacitor	105 °C, 400 V, 8.2 μF	✓	✓
C14	Ceramic capacitor	50 V, 0.47 μF	✓	✓
C15	Electrolytic capacitor	105 °C, 25 V	✓ (220μF)	✓ (470μF)
C16	Electrolytic capacitor	105 °C, 50 V, 10 μF	—	✓
D11	Fast recovery diode	500 V, 1 A (SJPD-D5)	✓	✓
D12	Fast recovery diode	500 V, 1 A (SJPD-D5)	✓	✓
D13	Schottky Barrier Diode	60 V/1 A (SJPD-D6)	—	✓
L12	Inductor	470 μH, 0.6 A	✓	✓
R1	Chip resistor	6.8 kΩ, 1/8 W, 1608	—	✓
R2	Chip resistor	33 kΩ, 1/8 W, 1608	—	✓
R3	Chip resistor	1.3 kΩ, 1/8 W, 1608	—	✓
R12	Chip resistor	6.8 kΩ, 1/8 W, 1608	✓	✓
U1	PWM offline converter IC		STR 5M467	STR 5A464S

Figure 15 shows the load regulation characteristics. The evaluation confirmed that high efficiency is maintained across a wide output current range under input conditions of AC100V and AC230V.

5. Conclusion

We have developed the STR5M400 series as the first

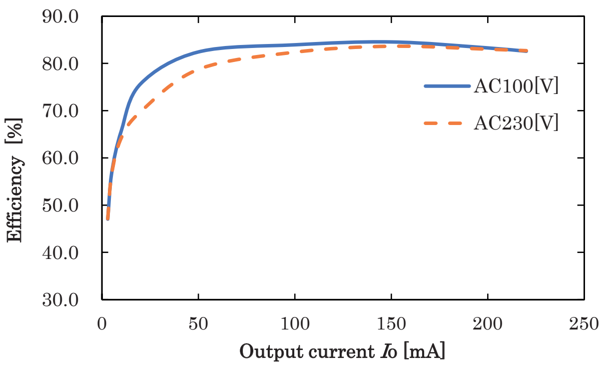


Figure 14. Efficiency Characteristics

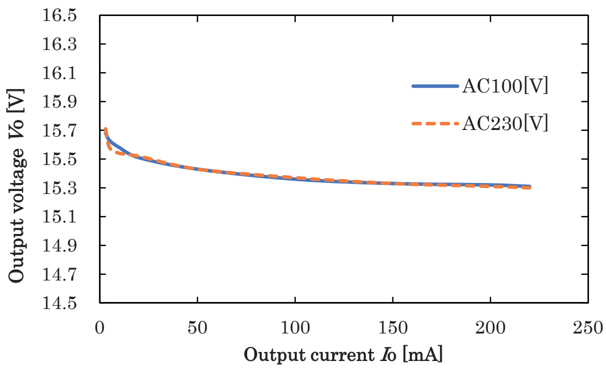


Figure 15. Load Regulation Characteristics

product using our latest high-voltage process for power supply ICs.

By adopting Green Mode, the IC achieves high efficiency under light load conditions. Additionally, it is the first in our lineup to use chip wiring resistance as a current sensing resistor, and by integrating the FB detection resistor into the IC, we have realized both miniaturization and cost reduction of the power supply.

Looking ahead, we plan to expand into new markets by developing products with higher capacity and efficiency, including GaN-based power MOSFETs and dual-output configurations.

References

1. Tadamasa, Terasawa, Kawamata: Sanken Technical Report, vol.46, p29–32 (Nov. 2014)
2. Aoki: Sanken Technical Report, vol.55, p22–25 (Nov. 2023)