Development of a Design Support Tool for Switching Power Supplies

Yuji Fukaishi*

Abstract The design calculation of switching power supplies requires knowledge of the IC used, transformer design, circuit design, and so on, and facilitating the design of power supplies is expected to have the effect of expanding opportunities for the adoption of such power supply ICs.

To increase such opportunities, we have developed “Sanken STR Pro”, a design support tool for power supply design using our ICs. Flyback converter power supply ICs, which are sold in large numbers, were selected as the target products for the tool, which is capable of automatic calculation, including peripheral circuits.

1. Introduction

In selecting a power supply IC, there are many details that need to be understood, such as the IC's supported power, pin functions, internal operation, and peripheral circuit configuration and constants. When designers who do not specialize in power supplies select a power supply IC from among power supply ICs made by multiple manufacturers, other factors besides QCD, such as the ease of prototyping and study, including the availability of adequate support, can also be considered.

Our lineup of power supply ICs includes those for LLC and PFC applications, which are used by a wide range of customers. We have developed an AC/DC converter design tool "Sanken STR Pro" using our power supply ICs for flyback converters, with the aim of expanding opportunities for the adoption of our power supply ICs.

2. Tool Philosophy

The number of configurable parameters has been minimized so that users can easily obtain calculation results. Figure 1 shows the Sanken STR Pro input screen.

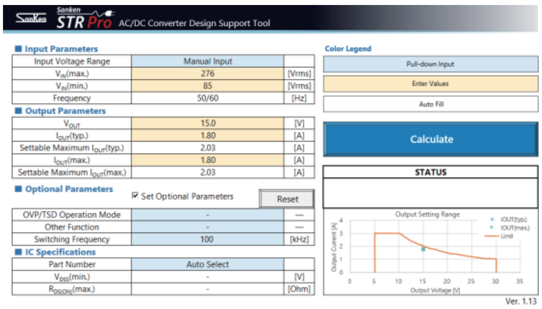


Figure 1: Sanken STR Pro Input Screen

Design results are obtained by selecting input/output specifications in the yellow cells and the desired power supply IC in the light blue cells on the input screen.

As a result of the design, the circuit diagram, bill of materials, and transformer specifications necessary for board design are output so that the fabrication of the actual machine can start immediately.

3. Internal Calculation Procedure

Design calculations within the tool are performed in the following order:

1: Transformer Calculation

2: IC Selection

3: Calculation of Peripheral Constants

In order to obtain practical results from the above calculations, knowledge gained from experience is required in addition to theoretical values, and that has conventionally been calculated and provided manually by FAEs. In addition to theoretical formulas, this tool incorporates the FAEs' accumulated knowledge and is automated using Excel and VBA, allowing users to obtain realistic results with simple operations.

The core of switching power supply design is the transformer design, and the first step is to calculate a transformer that meets the requirements based on the input/output specifications. The calculations are based on the following requirements:

- Can compatible power supply ICs be used? (IC temperature rise must be less than 50°C)

* Power Control Development Section, System Development Department
Power Device Development Division, Engineering Development Headquarters

- Make the transformer as small as possible (calculated sequentially from EI16)
- NI margin (magnetic flux saturation must not occur)
- Winding thickness (can it actually be wound?)

The flowchart is as shown in Figure 2.

There are also multiple variable elements, and the computation of the transformer specification is complex. Therefore, for the flyback voltage and assumed efficiency, a table was prepared for the input/output conditions, and the parameters are selected.

For transformer calculations, assume the number of secondary-side windings N_s and primary-side windings Np, and the required wire diameter according to the output specifications. Under these conditions, the gap L_g shall be gradually increased from 0mm and repeated until all judgments are satisfied.

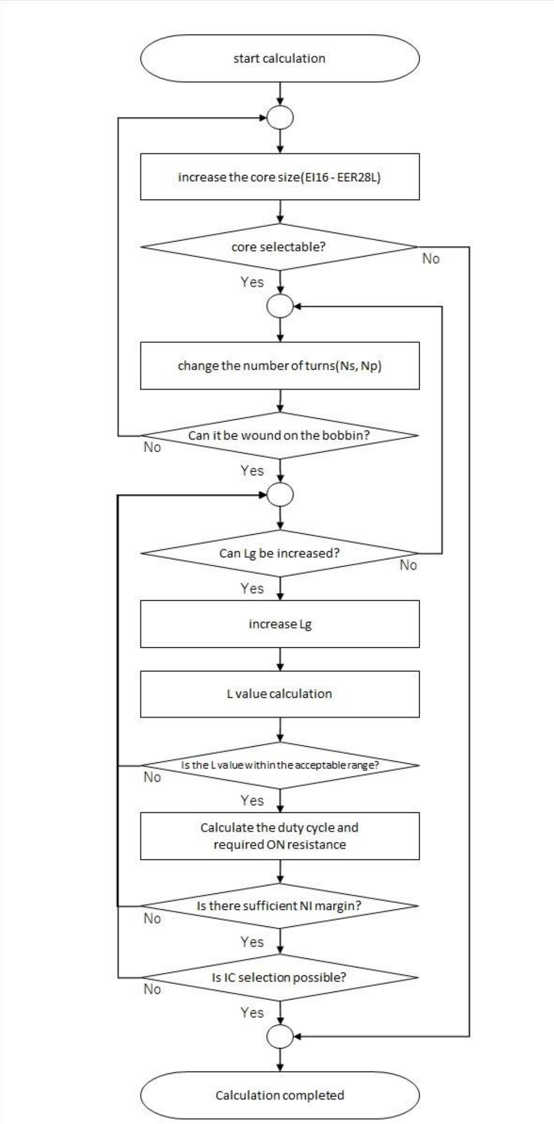


Figure 2: Transformer Calculation Decision Flowchart

The relationship between L_g, transformer inductance L, and NI margin (allowable primary side current) is shown in Figure 3. When L_g is small, the inductance L of the transformer is large, and the NI margin (allowable primary side current in Figure 3) is small. The calculation is completed if the inductance is greater than the criterion judgment value because the maximum inductance is reached under the calculation conditions at L_g, where the NI margin becomes the required value.

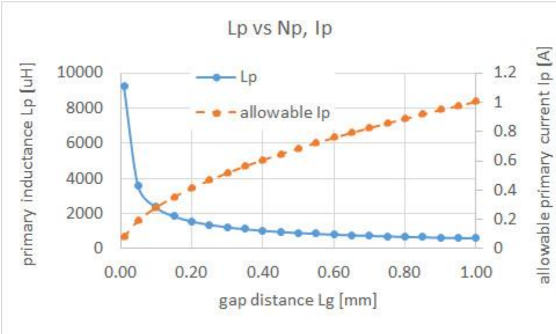


Figure 3: Relationship Between L_g and Inductance (e.g. EI16, N_p=100T)

For prototyping and mass production of transformers, it is necessary to consider the availability of components such as cores and bobbins. For that reason, this time we have received information on cores and bobbins that can be supplied via Sanshin Electric(1), and calculations have been made based on these drawings. Since the design is based on the bobbins that can be supplied, feasible design results can be obtained, and transformer prototype requests can be made based on the results.

Manual calculation methods require a certain amount of guesswork and may require too many calculation work-hours to adjust to the optimum value. The calculations in this tool are performed on a brute force basis for combinations of N_s and L_g, the number of secondary-side windings, to determine whether a smaller core will satisfy the required inductance. Therefore, it is possible to obtain results that are optimal within specified conditions, which would be too time-consuming and difficult to achieve with manual calculations.

In AC-DC power supply design, AC line noise suppression is also a difficult item to design for. The tool uses accumulated noise data from actual equipment to select a noise filter that matches the power specifications of the power supply. This enables the selection of appropriate noise filters, and is expected to reduce the working hours required by the user for noise countermeasures.

In addition, our power supply IC for flyback converters has a "green mode" that reduces the oscillation frequency according to the load. As shown in Figure 4, the oscillation frequency varies depending on the "green mode," making the calculation more complicated than for a fixed-frequency PWM. The tool finds the oscillation frequency corresponding to the load region to be calculated, and selects a more suitable IC.

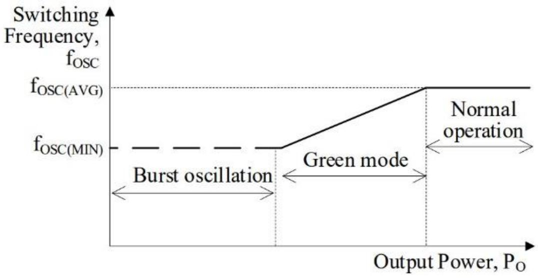
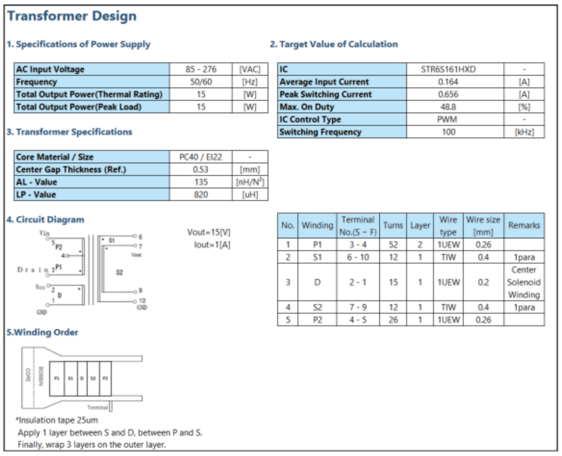


Figure 4: Green Mode Schematic

4. Results Obtained

The following can be obtained from the calculations:

1. Transformer Specifications (Figure 5)
2. Circuit Diagram (Figure 6)
3. Bill of Materials (Figure 7)



Transformer Design

1. Specifications of Power Supply

AC Input Voltage	85 - 276	[VAC]
Frequency	50/60	[Hz]
Total Output Power(Thermal Rating)	15	[W]
Total Output Power(Peak Load)	15	[W]

2. Target Value of Calculation

IC	STR6S161HXD	-
Average Input Current	0.164	[A]
Peak Switching Current	0.656	[A]
Max. On Duty	48.8	[%]
IC Control Type	PWM	-
Switching Frequency	100	[kHz]

3. Transformer Specifications

Core Material / Size	PC40 / EI22	-
Center Gap Thickness (Ref.)	0.53	[mm]
AL - Value	135	[nH/N²]
LP - Value	820	[uH]

4. Circuit Diagram

Vout=15[V]
Iout=1[A]

No.	Winding	Terminal No.(S – F)	Turns	Layer	Wire type	Wire size [mm]	Remarks
1	P1	3 - 4	52	2	1UEW	0.26	
2	S1	6 - 10	12	1	TIW	0.4	1para
3	D	2 - 1	15	1	1UEW	0.2	Center Solenoid Winding
4	S2	7 - 9	12	1	TIW	0.4	1para
5	P2	4 - 5	26	1	1UEW	0.26	

5.Winding Order

*Insulation tape 25um
Apply 1 layer between S and D, between P and S.
Finally, wrap 3 layers on the outer layer.

Figure 5: Transformer Specifications

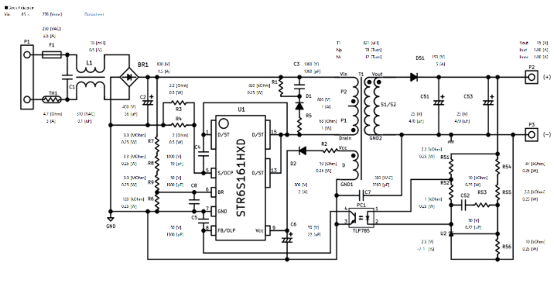


Figure 6: Circuit Diagram

■Bill of Material — Output Parameters, Vout:15[V], Iout_typ:1[A], Iout_max:1[A]

Reference	Category	Rating	Manufacturer	Reference model number	Remarks
F1	Fuse	250[VAC]2.5[A]	-	-	Safety standard product
TH1	Thermister	4.7[Ohm]3[A]	-	-	-
C1	Film capacitor	310[VAC]0.1[uF]	-	-	X2-Safety Class
C2	Electrolytic capacitor	450[V]56[uF]	-	-	High ripple current product
C3	Chip Ceramic Capacitor	1000[V]1000[pF]	-	-	-
C4	Chip Ceramic Capacitor	1000[V]10[pF]	-	-	-
C5	Chip Ceramic Capacitor	50[V]1500[pF]	-	-	-
C6	Electrolytic capacitor	50[V]22[uF]	-	-	-
C7	Ceramic Capacitor	300[VAC]2200[pF]	-	-	X1Y1 Class
C8	Chip Ceramic capacitor	50[V]1000[pF]	-	-	-
C51	Electrolytic capacitor	25[V]470[uF]	-	-	Low impedance product
C52	Chip Ceramic Capacitor	50[V]0.22[uF]	-	-	-
C53	Electrolytic capacitor	25[V]470[uF]	-	-	Low impedance product
BR1	Bridge Diode	800[V]1.5[A]	-	-	-
D1	Snubber Diode	800[V]1[A]	Sanken	SARS05	-
D51	Schottky Diode	150[V]5[A]	Sanken	SJPE-T15	Need Heatsink
D2	Fast Recovery Diode	300[V]2[A]	Sanken	SJPX-H3	-
L1	Line Filter	18[mH]0.5[A]	-	-	-
T1	Transformer	EI22	-	-	-
R1	Chip Resistor	820[kOhm]0.25[W]	-	-	Maximum rated voltage above 200V
R2	Chip Resistor	10[Ohm]0.25[W]	-	-	-
R3	Chip Resistor	2.2[Ohm]0.5[W]+/-5[%]	-	-	-
R4	Chip Resistor	2[Ohm]0.5[W]+/-5[%]	-	-	-
R5	Metal Oxide Film Resistor	68[Ohm]1[W]	-	-	-
R6	Chip Resistor	120[kOhm]0.25[W]+/-1[%]	-	-	Theoretical value: 128.9[kOhm] (e.g. 200[kOhm] // 360[kOhm])
R7	Chip Resistor	3.3[MOhm]0.25[W]+/-1[%]	-	-	Maximum rated voltage above 150V
R8	Chip Resistor	3.3[MOhm]0.25[W]+/-1[%]	-	-	Maximum rated voltage above 150V
R9	Chip Resistor	3.3[MOhm]0.25[W]+/-1[%]	-	-	Maximum rated voltage above 150V
R51	Chip Resistor	2.2[kOhm]0.25[W]	-	-	-
R52	Chip Resistor	1[kOhm]0.25[W]	-	-	-
R53	Chip Resistor	10[kOhm]0.25[W]	-	-	-
R54	Chip Resistor	47[kOhm]0.25[W]+/-1[%]	-	-	-
R55	Chip Resistor	3.3[kOhm]0.25[W]+/-1[%]	-	-	-
R56	Chip Resistor	10[kOhm]0.25[W]+/-1[%]	-		-
U1	Off-line PWM controller IC	700[V]3.95[Ohm]max	Sanken	STR6S161HXD	
U2	Shunt Regulator	2.495[V]+/-1[%]	Texas Instruments	TL431	-
PC1	Optocoupler	P=10.16[mm]	Toshiba	TLP785	-
P1	Connector	250[V]7[A] P=7.92[mm]	JST	B2P3-VH	-

Figure 7: Bill of Materials

- The transformer specification results, which cover all parameters necessary for transformer prototyping, can be output to be submitted directly to the transformer manufacturer for prompt prototyping.
- The circuit diagram conforms to our evaluation board, making it easy to fabricate a board.
- The bill of materials includes ratings to support parts selection.

5. Validity of Results

As an AC/DC converter design tool, it is important to obtain results that can be applied to actual equipment. If the results are not practical, the main objective of improving design efficiency cannot be achieved.

As a verification of this tool, a prototype board (DE0023 [2)(3)]) with an output of 15V/1.61A using STR 6 A153MVD was fabricated based on the output results. The results of the evaluation are shown below. (Figures 8 through 11, Table 1)

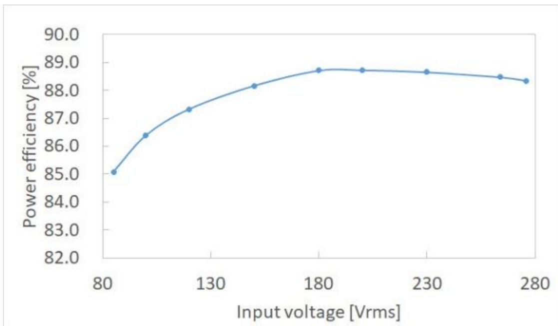


Figure 8: Input Voltage vs. Efficiency

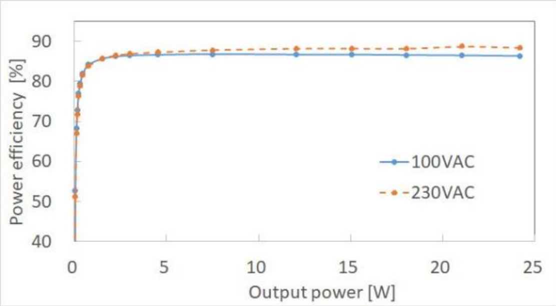


Figure 9: Output Power vs. Efficiency

The efficiency characteristics shown in Figures 8 and 9 confirm that the efficiency at rated load is at least 85%, which is sufficient performance.

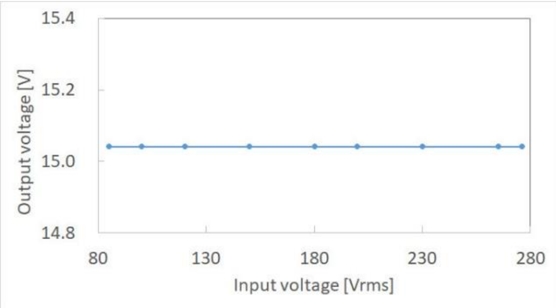


Figure 10: Line Regulation

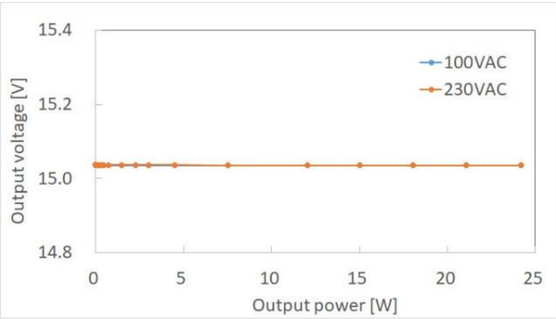


Figure 11: Load Regulation

The regulation characteristics shown in Figures 10 and 11 were also confirmed to be acceptable, with small changes in output voltage relative to input voltage and output load.

Table 1 shows the results for component temperature rise. The temperature rise of ICs and transformers was also confirmed to not exceed 100°C component temperature, compared to an ambient temperature of 50°C.

The above results confirm that the characteristics are not a problem in practical use.

Table 1: Component Temperatures

Ambient Temperature [°C]	Input Voltage [VAC]	Steady-state case temperature [°C]		
		PWM Controller IC (U1)	Secondary Rectifier Diode (D51)	Transformer (T1)
25	85	70.5	72	52.7
	276	59.8	72.4	52.7
50*	85	95.5	97	77.7
	276	84.8	97.4	77.7

*Case temperature converted from 25°C ambient temperature

6. Future Prospects

The Sanken STR Pro tool developed this time is freely available for download on our website, and has been downloaded by a wide range of people in Japan and abroad.

The current tool is for single output, but flyback converters are often used with multiple outputs, and we have received requests from users to support multiple outputs. Another point of concern for users is the temperature rise in the transformer.

Therefore, the addition of multiple outputs and transformer temperature estimation functions is under consideration for the next version.

7. Conclusion

We have developed an AC/DC converter design tool "Sanken STR Pro" that uses our STR Series of flyback converter power supply ICs. This success in simplifying the design of AC-DC power supplies required experience.

We will continue to add and update functions to make the tool even more useful.

Finally, we would like to thank everyone who helped us in the creation of the tool.

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