

Simulation-Based Evaluation of Temperature and PCB Thickness Effects on the Performance Efficiency of an RCC Smartphone Charger: ShPlus Model A1025 Charger as a Case Study

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ABSTRACT

Smartphone chargers are switched-mode power supply (SMPS) devices that convert alternating current (AC) into regulated direct current (DC). During operation, heat generated by component losses affects electrical performance, efficiency, and reliability. Thermal behaviour is influenced by printed circuit board (PCB) physical properties. However, the influence of FR-4 PCB thickness on charger performance under varying temperatures has received limited attention. This study therefore investigated the effect of temperature rise on a smartphone charger for various FR-4 PCB thicknesses. A virtual simulation approach was used to investigate the SHPLUS model A1025 charger, modelled as a Ringing Choke Converter (RCC). Nine PCB thicknesses (0.80 mm to 4.00 mm) were considered. Input voltage was varied from 100 V to 240 V AC, while temperature was increased from 35°C to 100°C. An AI-assisted computation was employed to simulate conventional thermal equations and generated performance data for conversion losses and efficiency. Simulation showed that conversion losses increased with temperature, while conversion efficiency decreased correspondingly. Thicker PCBs exhibited slightly higher thermal-related losses. The study concludes that temperature rise adversely affects electrical performance by increasing conversion losses and reducing efficiency. Although PCB thickness influences thermal behaviour, its effect is less significant than operating temperature in RCC chargers. The study recommends adopting optimized PCB design parameters and thermal-management techniques to improve efficiency and stability.

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INTRODUCTION

A smartphone charger is an electronic power conversion device designed to supply regulated direct current (DC) voltage required for charging smartphone batteries and powering internal circuits of mobile devices. Smartphone chargers contain different internal circuits that convert the high-voltage AC input from the mains into a stable low-voltage DC output suitable for safe device operation (Ikeri et al., 2024). The conversion process consists of several stages, including AC-DC rectifier, filter, and voltage regulator. Modern-day smartphone chargers adopt small-scale SMPS topology in order to achieve higher efficiency, reduced size, and lower heat dissipation compared to old-fashioned linear power supplies (Liu and Chang, 2005; Sayed et al., 2015; Yahaya et al., 2021).

Due to the multiple stages through which regulated DC power is achieved, smartphone chargers often experience internal temperature rise during operation due to power losses occurring in the circuit which include conduction losses, transformer losses, switching losses, and resistive losses (Górecki and Posobkiewicz, 2023; Papari et al., 2024; de Jong *et al.*, 2006). If this heat is not effectively dissipated, the temperature of the circuit increases, which can degrade component performance and shorten device lifespan. Effective thermal management is therefore a critical aspect of charger design, especially in modern compact chargers where space constraints limit conventional cooling techniques (Erickson and Maksimovic, 2020; Górecki and Posobkiewicz, 2023). Numerous studies have addressed power supply efficiency and thermal management through optimized

circuit topologies, such as high-efficiency flyback switching supplies (Jing et al., 2021). Recent AI modeling research by Alade and Adewole (2026) has revealed that an increase in the thickness of FR-4 PCB from 1.60 mm to 4.00 mm in heatsink-assisted DC-DC buck converter reduces conversion losses and improves efficiency. However, despite these advancements in specific topologies, coatings, and heatsink-assisted modules, relatively few studies have specifically examined how varying PCB thickness directly impacts the electrical performance within highly constrained, heatsink-free smartphone charger architectures. Addressing this gap, this study evaluated the temperature rise effects on the performance efficiency of a compact smartphone charger with SHPLUS Model A1025 charger as a case study for various FR-4 PCB thicknesses, using an AI-modelling approach.

This research contributed to the knowledge by showing that operating temperature and PCB thickness are two

essential factors that affect the design of compact chargers. It provides useful recommendations for engineers about the optimal PCB thickness for efficient and thermally stable operation, which can minimize the need for physical prototyping in the design process.

MATERIALS AND METHODS

The device to be considered as a case study is the SHPLUS A1025 Model smartphone charger, a 45W dual-port fast charger designed for modern mobile devices. The smartphone charger under investigation operates as a Switched Mode Power Supply (SMPS) based on a Ringing Choke Converter (RCC) topology. The internal architecture of the charger consists of several functional stages including, rectifier stage, switching and transformer stage and output regulation stage as shown in figure 1 (Kazimierczuk et al., 2023; Malysheva et al., 2020; Sedra et al., 2020; Busatto et al., 2022; Rashid, 2014).

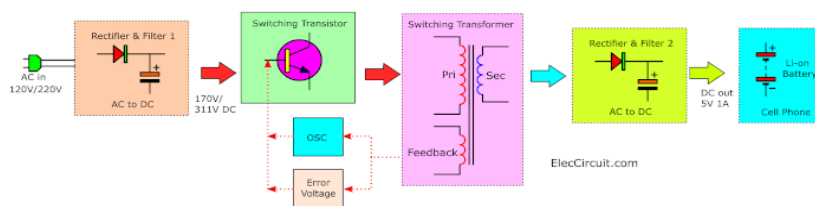


Figure 1: Block Diagram Illustrating the Major Power Conversion Stages in a Smartphone Charger

The tools and resources used in this study are presented in Table 1.

Table 1: System Tools and Resources

Tool	Resource	Description
Laptop Computer	Used for AI-simulation and data processing	
Simulation Environment	Used for electrical and thermal modeling	
Charger Specifications	SHPLUS Model A1025 technical data	

Virtual Experiment

This study adopts a virtual experiment methodology where AI-simulation is used to evaluate the effects of temperature rise on the performance of a smartphone charger for various FR-4 PCB thicknesses. SHPLUS Model A1025 charger is used as a case study.

The printed circuit board (PCB) thicknesses considered are 0.80 mm, 1.20 mm, 1.60 mm, 2.00 mm, 2.40 mm, 2.80 mm, 3.20 mm, 3.60 mm, and 4.00 mm for wider thickness range. Input voltages are varied from 100 VAC to 240 VAC in steps of 1 V, while the temperature rises from 35°C to 100°C in steps of 1°C. For each fixed PCB thickness and input voltage, the temperature is increased systematically across the specified range to determine the effect of temperature rise on charger performance. This procedure is repeated for all PCB thicknesses and input

voltage levels to ensure comprehensive evaluation. The study focuses on assessing key performance including conversion loss, conversion efficiency, thermal behavior and heat dissipation.

Equation Employed in Modeling

The thermal behavior of the charger is modeled based on heat transfer principles, where temperature rise is dependent on power dissipation and thermal resistance of the PCB. The following equations are employed for simulation (Erickson, 1997; Halliday et al., 2013):

Temperature-Dependent Resistance

The resistance of the conductive elements varies with the operating temperature according to the following equation:

$$R_T = R_0 [1 + \alpha(T - 25)] \quad (1)$$

(R_T is the temperature-dependent resistance (Ω), R_0 is the base resistance, T is the operating temperature ($^{\circ}\text{C}$), α is the temperature coefficient)

Total Conversion Loss

The total conversion loss is calculated as the sum of the individual component losses, which include conduction, switching, transformer core, primary rectifier, secondary diode, and PCB thermal effects:

$$P_{\text{loss}} = P_{\text{cond}} + P_{\text{sw}} + P_{\text{core}} + P_{\text{rect}} + P_{\text{sec}} + P_{\text{thermal}} \quad (2)$$

Input Power

The total input power required by the charger is derived from the sum of the rated output power and the calculated total conversion loss:

$$P_{\text{in}} = P_{\text{out}} + P_{\text{loss}} \quad (3)$$

(P_{in} is the input power (W), P_{out} is the constant output power (45 W), P_{loss} is the total conversion loss (W))

Conversion Efficiency

The overall conversion efficiency of the charger is expressed as the percentage ratio of the output power to the total input power:

$$\eta = (P_{\text{out}} / P_{\text{in}}) \times 100\% \quad (4)$$

(η is the conversion efficiency)

Design of Prompt and Algorithm

The dataset generation procedure was implemented with assistance of ChatGPT-4o using conventional thermal equations and a step by step computational algorithm is shown below:

```

+-----+
|          ALGORITHM FOR RCC SWITCHING POWER SUPPLY DATASET GENERATION          |
+-----+
INITIALIZATION
-----
Define constants:
Vout = 5 V
Pout = 45 W
Iload = Pout / Vout
f_line = 50 Hz
f_sw   = 65000 Hz
C_bulk = 6.8e-6 F
C_out  = 1000e-6 F
alpha  = 0.0039
eta_base = 0.88
R0     = 0.2 Ohms
k_pcb  = 0.3 W/mK
-----
PARAMETER RANGES
-----
Vin_range = [100, 101, 102, ..., 240]
PCB_thickness = [0.80, 1.20, 1.60, 2.00, 2.40, 2.80, 3.20, 3.60,
4.00] mm
Temp_range = [35, 36, 37, ..., 100] °C
-----
MAIN LOOP STRUCTURE
-----
FOR each Vin in Vin_range
  FOR each t in
    PCB_thickness
      FOR each Temp in
        Temp_range
          -----
          COMPUTATION STEPS
          -----
          Step 1: Temperature-dependent resistance
          -----
          R_T = R0 * (1 + alpha * (Temp - 25))
          Step 2: Conduction loss
          -----
          P_cond = Iload^2 * R_T
          Step 3: Switching loss (RCC transistor)
          -----
          P_sw = 1e-6 * Vin * Iload * f_sw
          Step 4: Transformer core loss
          -----

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-----
P_core = 0.02 * Vin
Step 5: Rectifier loss (IN4007 bridge)
-----
Vf = 0.7
P_rect = 2 * Vf * Iload
Step 6: Secondary diode loss (Schottky)
-----
Vf_schottky = 0.4
P_sec = Vf_schottky * Iload
Step 7: PCB thermal effect
-----
thermal_factor = 1 + (t / 4.0)
P_thermal = thermal_factor * 0.5
Step 8: Total conversion loss
-----
P_loss = P_cond + P_sw + P_core + P_rect + P_sec + P_thermal
Step 9: Input power
-----
Pin = Pout + P_loss
Step 10: Conversion efficiency
-----
Efficiency = (Pout / Pin) * 100
-----
DATA STORAGE
-----
Store results as:
[Vin, Temp, t, P_loss, Efficiency]
-----
LOOP TERMINATION
-----
        END (Temp loop)
    END (Thickness loop)
END (Vin loop)
-----
OUTPUT
-----
Dataset format:
| Vin | Temp | Thickness | Loss (W) | Efficiency (%) |
-----
END OF ALGORITHM

```

RESULTS AND DISCUSSION

This section presents the analysis of the performance parameters for the 45W RCC Switching Power Supply (SMPS) charger circuit under investigation. To isolate these interactions, this analysis focuses on specific input voltage lines, low (100V AC), medium (160V AC), and high (240V AC) lines under varying printed circuit board (PCB) thicknesses.

Analysis of Conversion Loss against Temperature Rise for Various PCB Thicknesses

The analysis reveals highly consistent trends across low (100V AC), medium (160V AC), and high (240V AC) input voltages. Across all input voltages and printed circuit board (PCB) thicknesses, conversion losses increase linearly with temperature (see Figures 2, 3, and 4). The rate of this increase remains constant. This identical gradient proves that the converter's thermal sensitivity is fundamentally unaffected by changes in PCB thickness. While the temperature coefficient remains static, operating at higher input voltages raises

the overall magnitude of the losses. For example, the maximum loss for a 0.80 mm PCB at 100°C shifts from 2.9750 W at 100V AC, to 3.5750 W at 160V AC, and up to 4.3750 W at 240V AC as shown in Table 2, 3, and 4 respectively.

Increasing the FR-4 PCB thickness from 0.80 mm to 4.00 mm consistently raises the absolute conversion loss across all operating conditions. For instance, at 100V AC, the peak loss increases from 2.9750 W (0.80 mm PCB) to 3.2310 W (4.00 mm PCB). Ultimately, the data suggests that PCB thickness dictates the baseline conversion loss of the converter but has little to no effect on its temperature-dependent loss characteristics. For the investigated RCC smartphone charger, thicker PCB structures introduce additional electrical losses that entirely outweigh any thermal-management benefits provided by the thicker substrate. This behavior is consistent with reported high-frequency PCB parasitic and AC-resistance effects (Nguyen and Blanchette, 2020; Letellier et al., 2019).

Table 2: Conversion Loss (W) Against Temperature Rise for Various PCB Thicknesses at 100V

Temp (°C)	0.8 mm	1.2 mm	1.6 mm	2.0 mm	2.4 mm	2.8 mm	3.2 mm	3.6 mm	4.0 mm
35	2.00	2.03	2.06	2.10	2.13	2.16	2.19	2.22	2.26
40	2.08	2.11	2.14	2.17	2.20	2.23	2.27	2.30	2.33
45	2.15	2.18	2.21	2.25	2.28	2.31	2.34	2.37	2.41
50	2.23	2.26	2.29	2.32	2.35	2.38	2.42	2.45	2.48
55	2.30	2.33	2.36	2.40	2.43	2.46	2.49	2.52	2.56
60	2.38	2.41	2.44	2.47	2.50	2.54	2.57	2.60	2.63
65	2.45	2.48	2.51	2.55	2.58	2.61	2.64	2.67	2.71
70	2.52	2.56	2.59	2.62	2.65	2.69	2.72	2.75	2.78
75	2.60	2.63	2.66	2.70	2.73	2.76	2.79	2.82	2.86
80	2.67	2.71	2.74	2.77	2.80	2.83	2.87	2.90	2.93
85	2.75	2.78	2.81	2.85	2.88	2.91	2.94	2.97	3.01
90	2.83	2.86	2.89	2.92	2.95	2.98	3.02	3.05	3.08
95	2.90	2.93	2.96	3.00	3.03	3.06	3.09	3.12	3.16
100	2.98	3.01	3.04	3.07	3.10	3.13	3.17	3.20	3.23

Table 3: Conversion Loss (W) Against Temperature Rise for Various PCB Thicknesses at 160V

Temp (°C)	0.8 mm	1.2 mm	1.6 mm	2.0 mm	2.4 mm	2.8 mm	3.2 mm	3.6 mm	4.0 mm
35	2.60	2.63	2.66	2.70	2.73	2.76	2.79	2.82	2.86
40	2.67	2.71	2.74	2.77	2.80	2.83	2.87	2.90	2.93
45	2.75	2.78	2.81	2.85	2.88	2.91	2.94	2.97	3.01
50	2.83	2.86	2.89	2.92	2.95	2.98	3.02	3.05	3.08
55	2.90	2.93	2.96	3.00	3.03	3.06	3.09	3.12	3.16
60	2.98	3.01	3.04	3.07	3.10	3.13	3.17	3.20	3.23
65	3.05	3.08	3.11	3.15	3.18	3.21	3.24	3.27	3.31
70	3.12	3.16	3.19	3.22	3.25	3.29	3.32	3.35	3.38
75	3.20	3.23	3.26	3.30	3.33	3.36	3.39	3.42	3.46
80	3.27	3.31	3.34	3.37	3.40	3.44	3.47	3.50	3.53
85	3.35	3.38	3.41	3.45	3.48	3.51	3.54	3.57	3.61
90	3.42	3.46	3.49	3.52	3.55	3.58	3.62	3.65	3.68
95	3.50	3.53	3.56	3.60	3.63	3.66	3.69	3.72	3.76
100	3.58	3.61	3.64	3.67	3.70	3.73	3.77	3.80	3.83

Table 4: Conversion Loss (W) Against Temperature Rise for Various PCB Thicknesses at 240V

Temp (°C)	0.8 mm	1.2 mm	1.6 mm	2.0 mm	2.4 mm	2.8 mm	3.2 mm	3.6 mm	4.0 mm
35	3.40	3.43	3.46	3.50	3.53	3.56	3.59	3.62	3.66
40	3.48	3.51	3.54	3.57	3.60	3.63	3.67	3.70	3.73
45	3.55	3.58	3.61	3.65	3.68	3.71	3.74	3.77	3.81
50	3.62	3.66	3.69	3.72	3.75	3.79	3.82	3.85	3.88
55	3.70	3.73	3.76	3.80	3.83	3.86	3.89	3.92	3.96
60	3.77	3.81	3.84	3.87	3.90	3.94	3.97	4.00	4.03
65	3.85	3.88	3.91	3.95	3.98	4.01	4.04	4.07	4.11
70	3.92	3.96	3.99	4.02	4.05	4.08	4.12	4.15	4.18
75	4.00	4.03	4.06	4.10	4.13	4.16	4.19	4.22	4.26
80	4.08	4.11	4.14	4.17	4.20	4.24	4.27	4.30	4.33
85	4.15	4.18	4.21	4.25	4.28	4.31	4.34	4.37	4.41
90	4.22	4.26	4.29	4.32	4.35	4.38	4.42	4.45	4.48
95	4.30	4.33	4.36	4.40	4.43	4.46	4.49	4.52	4.56
100	4.38	4.41	4.44	4.47	4.50	4.54	4.57	4.60	4.63

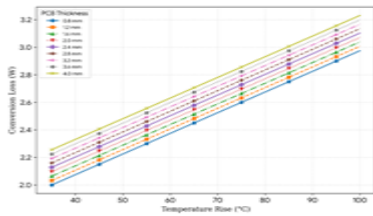


Figure 2

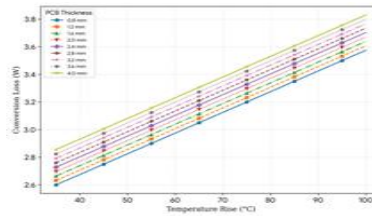


Figure 3

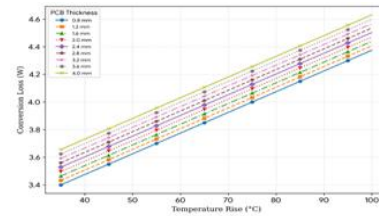


Figure 4

Figure 2, 3, and 4: Show the Variation of Conversion Loss Against Temperature Rise for Input Voltage at 100V, 160V and 240V Respectively

Analysis of Conversion Efficiency against Temperature rise for Various PCB Thicknesses

Conversion efficiency declines linearly when temperature rises from 35°C to 100°C, regardless of the parameter variation (refer to Figures 5, 6, and 7). Rate of this decline is very consistent. High input voltage affects the entire efficiency level of the charger. For the 0.80 mm PCB and 35°C, the efficiency decreases from the maximum value of 95.7450% (at 100V AC) to 94.5380% (160V AC) and then to 92.9750% (240V AC), Changing FR-4 PCB thickness from 0.80 mm to 4.00 mm results in consistent decrease in efficiency. For instance, at 100V AC, efficiency range varies from 95.7450% to 93.7990% (0.80 mm PCB) and from 95.2260% to 93.3010% (4.00 mm PCB) as displayed in Table 5, 6 and 7 respectively.

The results demonstrate a clear inverse relationship between temperature rise and conversion efficiency, directly corresponding to the increased power losses analyzed in the previous section. For the RCC smartphone charger under consideration, increasing the thickness of the PCB resulted in additional electrical losses that exceed the benefits of having a thicker PCB for thermal management. Although higher input voltages reduce the efficiency baseline even further, the degradation gradients remain highly comparable, emphasizing that PCB thickness dictates the base performance level while temperature governs the operational decline.

Table 5: Conversion Efficiency (%) Against Temperature Rise for Various PCB Thicknesses at 100V

Temp (°C)	0.8 mm	1.2 mm	1.6 mm	2.0 mm	2.4 mm	2.8 mm	3.2 mm	3.6 mm	4.0 mm
35	95.75	95.68	95.61	95.55	95.48	95.42	95.36	95.29	95.23
40	95.59	95.53	95.46	95.40	95.33	95.27	95.20	95.14	95.08
45	95.44	95.38	95.31	95.25	95.18	95.12	95.05	94.99	94.92
50	95.29	95.22	95.16	95.09	95.03	94.97	94.90	94.84	94.78
55	95.13	95.07	95.00	94.94	94.88	94.81	94.75	94.69	94.62
60	94.99	94.92	94.86	94.80	94.73	94.67	94.60	94.54	94.48
65	94.84	94.77	94.71	94.64	94.58	94.52	94.45	94.39	94.33
70	94.69	94.62	94.56	94.50	94.43	94.37	94.31	94.24	94.18
75	94.54	94.47	94.41	94.35	94.28	94.22	94.16	94.09	94.03
80	94.38	94.32	94.26	94.19	94.13	94.07	94.01	93.95	93.89
85	94.24	94.18	94.11	94.05	93.99	93.93	93.86	93.80	93.74
90	94.09	94.03	93.97	93.91	93.84	93.78	93.72	93.65	93.59
95	93.95	93.88	93.82	93.76	93.69	93.63	93.57	93.51	93.45
100	93.80	93.74	93.67	93.61	93.55	93.49	93.42	93.36	93.30

Table 6: Conversion Efficiency (%) Against Temperature Rise for Various PCB Thicknesses at 160V

Temp (°C)	0.8 mm	1.2 mm	1.6 mm	2.0 mm	2.4 mm	2.8 mm	3.2 mm	3.6 mm	4.0 mm
35	94.54	94.47	94.41	94.35	94.28	94.22	94.16	94.09	94.03
40	94.39	94.33	94.26	94.20	94.14	94.07	94.01	93.95	93.89
45	94.24	94.18	94.11	94.05	93.99	93.93	93.86	93.80	93.74
50	94.09	94.03	93.97	93.91	93.84	93.78	93.72	93.65	93.59
55	93.95	93.88	93.82	93.76	93.69	93.63	93.57	93.51	93.45
60	93.80	93.74	93.67	93.61	93.55	93.49	93.42	93.36	93.30
65	93.65	93.59	93.53	93.47	93.40	93.34	93.28	93.22	93.16
70	93.51	93.44	93.38	93.32	93.26	93.20	93.14	93.07	93.01
75	93.36	93.29	93.23	93.17	93.11	93.05	92.99	92.92	92.86

80	93.22	93.15	93.09	93.03	92.97	92.91	92.85	92.78	92.72
85	93.07	93.01	92.95	92.89	92.83	92.76	92.70	92.64	92.58
90	92.93	92.87	92.81	92.74	92.68	92.62	92.56	92.50	92.44
95	92.78	92.72	92.66	92.60	92.54	92.48	92.42	92.36	92.30
100	92.64	92.58	92.52	92.46	92.40	92.34	92.28	92.22	92.16

Table 7: Conversion Efficiency (%) Against Temperature Rise for Various PCB Thicknesses at 240V

Temp (°C)	0.8 mm	1.2 mm	1.6 mm	2.0 mm	2.4 mm	2.8 mm	3.2 mm	3.6 mm	4.0 mm
35	92.97	92.91	92.85	92.79	92.73	92.67	92.61	92.55	92.49
40	92.83	92.77	92.71	92.65	92.59	92.53	92.47	92.40	92.34
45	92.69	92.63	92.57	92.50	92.44	92.38	92.32	92.26	92.20
50	92.55	92.48	92.42	92.36	92.30	92.24	92.18	92.12	92.06
55	92.40	92.34	92.28	92.22	92.16	92.10	92.04	91.98	91.92
60	92.26	92.20	92.14	92.08	92.02	91.96	91.90	91.84	91.78
65	92.12	92.06	92.00	91.94	91.88	91.82	91.76	91.70	91.64
70	91.98	91.92	91.86	91.80	91.74	91.68	91.62	91.56	91.50
75	91.84	91.78	91.72	91.66	91.60	91.54	91.48	91.42	91.36
80	91.70	91.64	91.58	91.52	91.46	91.40	91.34	91.28	91.22
85	91.56	91.50	91.44	91.38	91.32	91.26	91.20	91.14	91.08
90	91.42	91.36	91.30	91.24	91.18	91.12	91.06	91.00	90.94
95	91.28	91.22	91.16	91.10	91.04	90.98	90.92	90.86	90.81
100	91.14	91.08	91.02	90.96	90.90	90.84	90.79	90.73	90.67

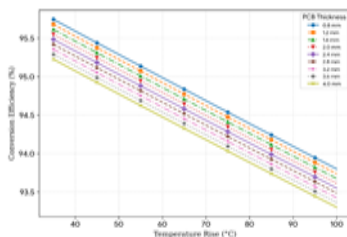


Figure 5

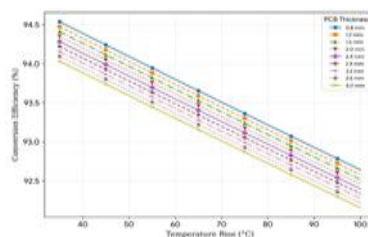


Figure 6

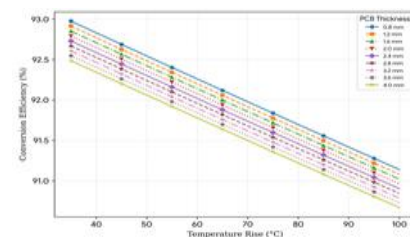


Figure 7

Figure 5, 6, and 7: Show the variation of conversion efficiency against temperature rise for input voltage at 100V, 160V and 240V respectively

Assessment of the Impact of PCB Thickness on Heat Dissipation

While increasing printed circuit board (PCB) thickness is typically expected to improve heat dissipation (Alade and Adewole, 2026), it was found in this research that this results in increased conversion loss and decreased efficiency. Data indicates that the use of thicker FR-4 PCB structure results in greater electrical losses than the advantages provided by their greater thermal mass. The observed behavior is consistent with high-frequency switching theory. In the RCC configuration considered in this study, the use of thicker PCB increases the separation between the current paths, resulting in a larger loop area and higher parasitic inductance. The higher inductance can contribute to switching losses, voltage oscillation, and snubber losses. Moreover, the effects of high frequency, such as skin effect and proximity effect would further increase AC resistance (Letellier et al., 2019).

CONCLUSION

The study concludes that temperature rise adversely affects the electrical performance of an RCC smartphone charger by increasing conversion losses and reducing conversion efficiency. Although PCB thickness influences thermal behaviour and performance characteristics, its effect is less significant than that of operating temperature in RCC based chargers. Based on the findings of this research, the following recommendations are made:

- To maximize efficiency and minimize heat generation, power supply designers should prioritize thinner FR-4 PCB thickness range (0.80 mm to 1.6mm) which performed as lowest-loss configuration.
- Future research should investigate the thermal-electrical tradeoffs of alternative high-conductivity substrates, such as metal core PCBs, and evaluate

these thickness impacts across different switching topologies.

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