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REAL-TIME TEMPERATURE MONITORING AND CONTROL OF A POWER INVERTER IN A WIRELESS POWER TRANSFER SYSTEM

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Abstract:

This study presents a real-time temperature monitoring and control system for a Class E inverter in a low-power wireless power transfer prototype. The system was designed to monitor voltage, current, temperature and output power while supporting zero-voltage switching and protecting the inverter from overheating. MATLAB Simulink was used to model the transmitter and receiver stages, while Proteus supported PWM generation, control logic, and PCB design. The hardware prototype integrated a microcontroller, MOSFET driver, MOSFET, resonant coil network, rectifier, temperature sensor, LCD display, relay-controlled cooling fan and ESP32-based IoT monitoring. Simulation and hardware testing confirmed high-frequency power transfer, rectified DC output, and automatic fan activation at the 37 °C

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threshold. The findings show that active thermal control improves the safety, stability, and practicality of low-power wireless power transfer systems.

Keyword:

Class E Inverter; Iot Monitoring; Thermal Management; Wireless Power Transfer; Zero Voltage Switching

Introduction

Wireless Power Transfer (WPT) enables electrical energy to be delivered without direct physical contact. The technique is widely associated with applications such as wireless charging, embedded systems, electric vehicle charging, and other low-power electronic devices. A typical WPT system includes a DC-to-AC inverter at the transmitter, magnetic coupling through a coil pair, and AC-to-DC rectification at the receiver. The inverter stage is therefore a critical part of the system because it generates the high-frequency alternating signal required for magnetic energy transfer (Elst & Minnaert, 2025; Peirens et al., 2023; Feng et al., 2020). Resonant magnetic coupling has also been widely investigated for mid-range wireless energy transfer and range adaptation, which supports the need to study coil spacing and conversion stability in practical WPT prototypes (Kurs et al., 2007; Sample et al., 2011).

Although the operation of WPT is convenient, it may lead to thermal stress in switching devices. Overheating, switching losses, overcurrent, undervoltage and overvoltage are problems which can lead to a decrease in efficiency, MOSFET damage and influence on the stability of the whole system. These problems become more serious when the inverter operates continuously at high switching frequencies without real-time monitoring.

Previous works on Class E inverters, high-isolation gate-drive power supplies, electromagnetic interference reduction, smart temperature monitoring, and fan-based cooling show that efficient switching and thermal control are important for practical power electronics systems (Buchmeier et al., 2023; Yan et al., 2022; Li et al., 2024; Mokhtar et al., 2020; Haryanti & Yulianti, 2022). However, many low-power WPT prototypes still treat energy transfer, real-time monitoring, and thermal protection as separate design issues. The significance of this project is the integration of a Class E inverter, temperature sensing, active fan control, and IoT-based output monitoring in one compact WPT prototype. Therefore, the objective of this work is to monitor key electrical and thermal parameters, support zero-voltage switching (ZVS), and validate the safe operation of the power converter during wireless energy transfer.

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Methodology

System Design

The wireless power transfer system was developed with two primary circuit sections: the transmitter and receiver stages. The transmitter employs a Class E inverter to transform a 12 V DC input into a high-frequency AC signal for wireless energy transmission. As illustrated in Figure 1, the circuit includes a PWM generator, a MOSFET switching device, a choke inductor, a shunt capacitor, a tuning network, and a transmitting coil.

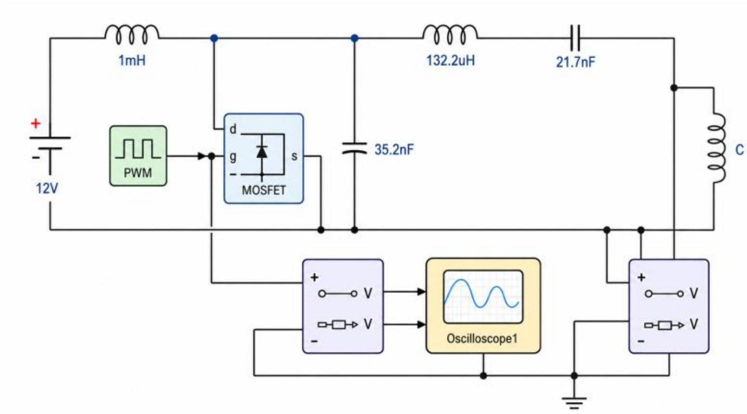

Figure 1: Transmitter Circuit Design of the Wireless Power Transfer System
Source: Authors (2026)

The receiving section captures the magnetic energy transferred from the transmitter and converts it into a practical DC supply. As depicted in Figure 2, this stage incorporates a receiver coil, full-bridge rectifier, smoothing capacitor, load resistor, and measurement devices. The high-frequency AC voltage induced in the receiving coil is converted into DC by the rectifier before being delivered to the connected load.

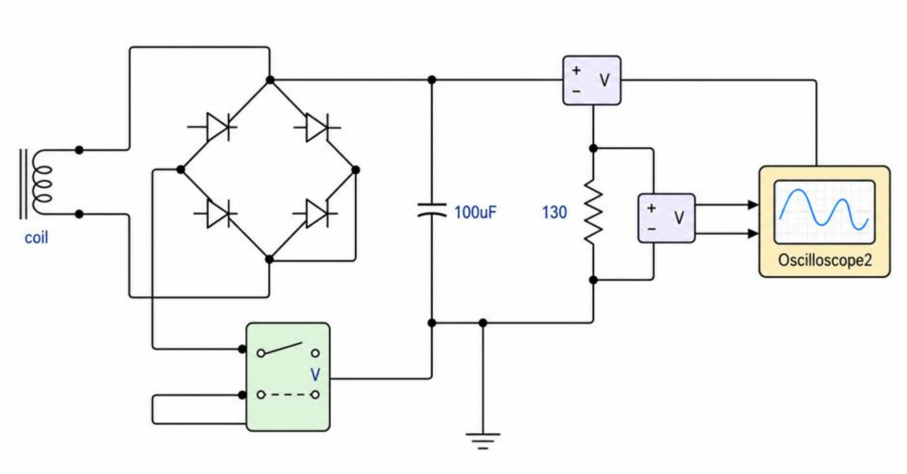

Figure 2: Receiver Circuit Design of the Wireless Power Transfer System
Source: Authors (2026)

The proposed system was organised into three principal stages: the transmitter, receiver, and thermal control sections. In the transmitter stage, a Class E inverter converts the DC input into a high-frequency AC waveform. This section consists of a PWM generator, MOSFET driver,

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N-channel MOSFET, choke inductor, shunt capacitor, impedance-tuning network, and transmitting coil. The receiver stage comprises a receiving coil, full-bridge rectifier, smoothing capacitor, sensor interface, and load connection. For thermal regulation, a temperature sensor is positioned close to the inverter switching device, while a relay-controlled fan is activated whenever the measured temperature rises above the predefined threshold.

The chosen hardware platform includes Arduino or ESP32 microcontroller units, a TC4420 MOSFET driver, an IRLZ44N N-channel MOSFET, a DS18B20 temperature sensor, an LCD with I2C interface, a 5 V relay module, and a 12 V cooling fan. The ESP32 was also used for IoT monitoring of voltage, current and power through a Blynk dashboard.

The proposed hardware platform employs a single ESP32 microcontroller as the main controller, replacing the need for three separate controllers. It has a dual-core processor to allow high-frequency PWM generation to run concurrently with other asynchronously operating tasks such as DS18B20 temperature sensing, I2C LCD updating, relay control, and Wi-Fi communication. The ESP32 also monitors voltage, current and power in real-time via the Blynk dashboard. The power control stage is composed of a TC4420 MOSFET driver, an IRLZ44N N-channel MOSFET, a 5 V relay module and a 12 V cooling fan to provide switching and thermal management.

These components were chosen for their ability to enable real-time control, low-power monitoring, switching functionality, and user-friendly feedback (Espressif Systems, 2019; INCHANGE Semiconductor, n.d.; Microchip Technology Inc., 2012; Handson Technology, n.d.; Dallas Semiconductor, 2005).

Table 1: Main Hardware Functions in the Summarised WPT Prototype

Subsystem	Main components	Function
Transmitter	DC source, PWM generator, TC4420 driver, IRLZ44N MOSFET, Class E resonant network, transmitter coil	Converts DC supply into high-frequency AC and delivers energy to the transmitter coil
Receiver	Receiver coil, full-bridge rectifier, filter capacitor, load and sensor interface	Receives magnetic energy, rectifies AC into DC and supplies a usable low-power output
Thermal management	DS18B20 sensor, microcontroller, relay module, LCD display and 12 V fan	Monitors inverter temperature and activates cooling when the threshold is reached
IoT monitoring	ESP32 and Blynk dashboard	Displays voltage, current and power data for real-time observation

Source: Authors (2026)

Simulation and Prototype Development

Several software tools were used to validate the project before hardware installation. The Class E inverter, transmitter coil, receiver coil, full-bridge rectifier and filtered DC output were simulated using MATLAB Simulink. The PWM generation was demonstrated using the Arduino platform and Tinkercad and temperature sensor logic and fan activation were

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simulated using Wokwi. Schematic Design and PCB Layout were performed using Proteus Design Suite. The transmitter control and receiver monitoring circuits were separated on the PCB for better serviceability and to reduce wiring.

The project measured the signal of the transmitter and receiver coils, the DC output following rectification, the temperature response, and the cooling activation. The coil distance was varied to achieve a steady DC output. During high-frequency operation, the inductor and other power components in the vicinity of the sensor point may be significantly hotter than the inverter sensor point, and therefore, the thermal threshold is set at 37°C at the sensor point.

Results and Discussion

Simulation Results

The simulation outcomes for the transmitter and receiver stages are presented in Figures 3 and 4, respectively. In Figure 3, the PWM signal regulates the MOSFET switching operation, while the ZVS waveform demonstrates that switching occurs close to the zero-voltage point, thereby reducing switching losses and improving system efficiency. The transmitter output waveform also confirms that the Class E inverter successfully converts the DC input into a high-frequency AC signal. As illustrated in Figure 4, the AC waveform induced in the receiving coil verifies the successful transfer of power. Meanwhile, the output voltage and current waveforms demonstrate that the rectifier and filtering circuits convert the received AC signal into a usable DC supply for the load.

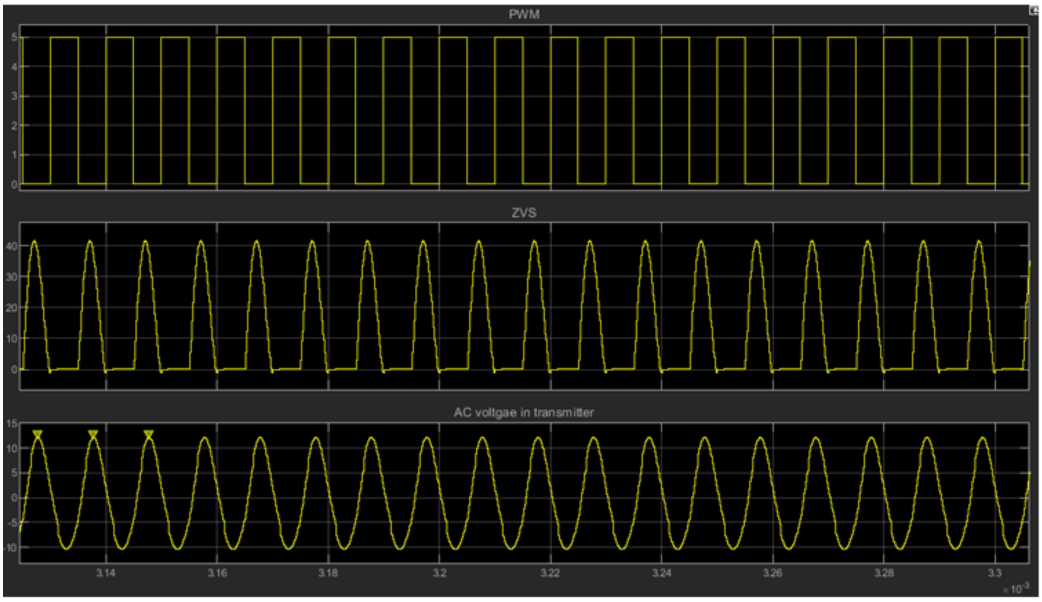

Figure 3: Simulated Waveforms of the Transmitter Stage
Source: Authors (2026)

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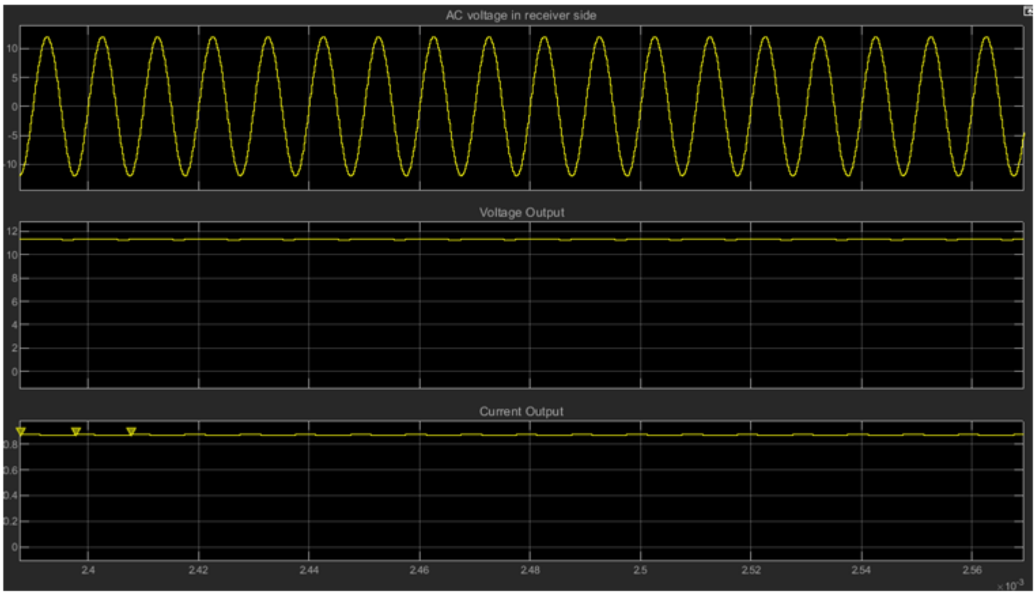

Figure 4: Simulated Waveforms of the Receiver Stage
Source: Authors (2026)

The PWM simulation produced a square-wave gate signal with approximately a 50% duty cycle. This PWM signal was used to drive the MOSFET through the gate driver, enabling switching in the Class E inverter circuit. In the MATLAB Simulink transmitter model, the waveform across the switching device was designed to drop close to zero before turn-on, which represents the intended ZVS condition. The simulated transmitter waveform produced a high-frequency AC for the coil stage, with an AC signal waveform of approximately +/-12.5 V at 100 kHz.

At the receiver side, the simulated coil signal was converted through a full-bridge rectifier and a filter capacitor. The receiver simulation produced a comparatively stable DC voltage and current, showing that the rectifier and filter were able to smooth the high-frequency received AC signal. The temperature-control simulation also showed the expected logic: the cooling output remained inactive under normal temperature and became active when the temperature exceeded the set threshold.

Hardware Results

Figures 5 and 6 show the hardware results of the AC signals measured at the transmitter coil and receiver coil, respectively. In Figure 5, the waveform confirms that the transmitter circuit successfully generates a periodic AC signal for wireless power transfer. In Figure 6, the waveform confirms that the receiver coil is able to receive the transferred energy through magnetic coupling. The receiver waveform is slightly different from the transmitter. However, both show that the wireless power transfer system has been shown to work at the hardware level.

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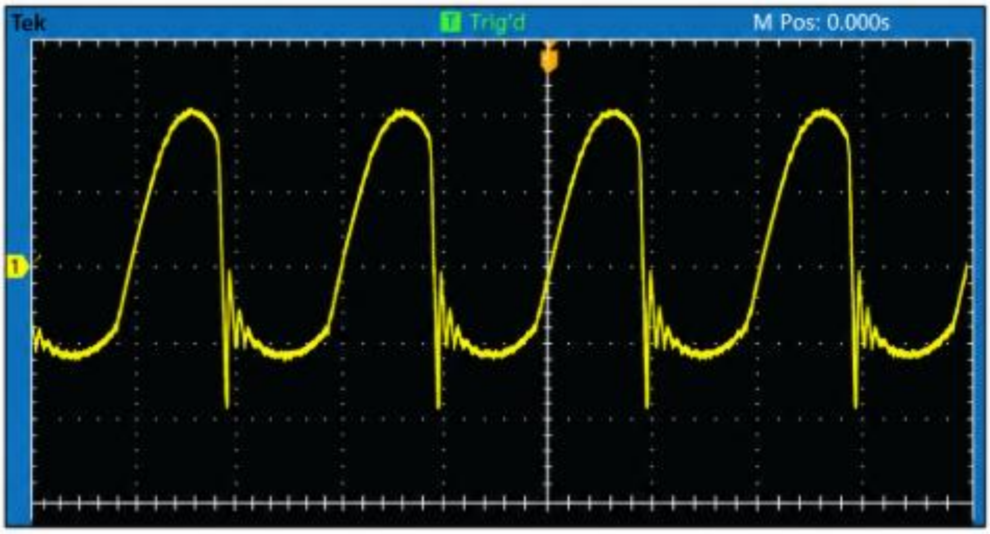

Figure 5: Hardware Waveform of the Transmitter Coil AC Signal

Source: Authors (2026)

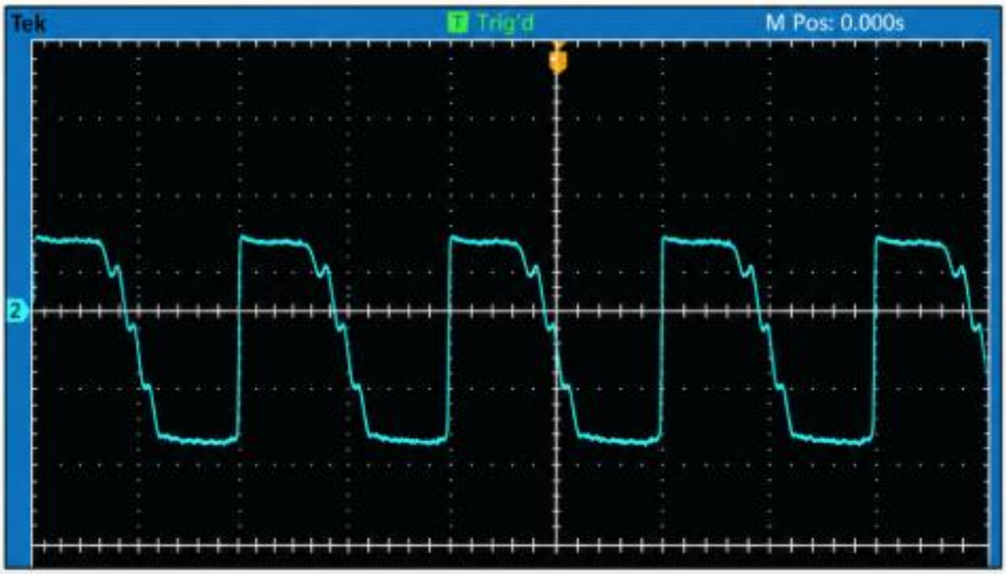

Figure 6: Hardware Waveform of the Receiver Coil AC Signal

Source: Authors (2026)

The results of the hardware experiment are shown in Table 2, which shows the relationship between the coil distance, the increase in temperature, and the output voltage. The results show that the closer the coil distance, the greater the output voltage because the magnetic coupling between the transmitter and receiver coils is stronger. Nevertheless, this situation also generates thermal stress in the circuit. The output voltage was initially high at 25 V under the closest distance of 1.1 cm, but the temperature increased from 27.5°C to 42°C and the output voltage decreased to 12 V after 30 min. This indicates that a high thermal stress can decrease the stability and efficiency of the system.

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Table 2: Experimental Analysis of Coil Distance, Temperature Rise and Output Voltage

Coil distance	Timer (min)	Temperature (°C)	Output voltage (V)
Closest (1.1 cm)	5	27.5	25
Closest (1.1 cm)	7	29	23
Closest (1.1 cm)	10	33	20
Closest (1.1 cm)	15	37	19
Closest (1.1 cm)	30	42	12
Farthest (4 cm)	5	27.5	5
Farthest (4 cm)	7	29	4.92
Farthest (4 cm)	10	29.9	4.72
Farthest (4 cm)	15	31	4.6
Farthest (4 cm)	30	33	4.2
Chosen (2.1 cm)	5	27.5	12
Chosen (2.1 cm)	7	29	11.98
Chosen (2.1 cm)	10	30	11.45
Chosen (2.1 cm)	15	33	10.5
Chosen (2.1 cm)	30	37	7.9

Source: Authors (2026)

The temperature rises slightly from 27.5°C to 33°C at the farthest distance of 4 cm, while the output voltage is very low, at 4.2 V compared to 5 V. This means that the magnetic coupling was weak and that the power received was inadequate. Thus, the chosen coil distance of 2.1cm is more appropriate as it gives a balanced relationship between output voltage and temperature rise. The system delivered 12 V at the start of the experiment and the temperature slowly rose to 37°C after 30 min. This value is significant because the temperature of 37°C was chosen as the control temperature for the cooling fan to turn on. In conclusion, the result demonstrates that temperature monitoring is required to keep the system stable, prevent overheating and minimize voltage drop while the wireless power transfer is in operation.

A separate transmitter and receiver PCB were used to build the hardware prototype. Two Arduino Uno modules, a buck converter and a relay module, along with the Class E inverter components, were mounted on the transmitter PCB. The rectifier, current sensor, and the ESP32-based monitoring were all included on the receiver PCB. This modular design simplified programming and troubleshooting, and provided more permanent soldered connections for power-handling sections.

Testing with an oscilloscope revealed high-frequency AC signals on the transmitter coil and receiver coil. In the tests, an inverter output of approximately 30 VAC was achieved, with approximately 25 VAC at the receiver coil due to coupling and noise losses. The system can be rectified and output a DC voltage for low-power applications. The closest coil configuration was able to generate a maximum of 25 VDC at approximately 1 A, and the selected operating distance was set so as to generate a 12 VDC output, which is the desired design value.

Validation of thermal protection by continuous operation was also carried out. The sensed inverter temperature was raised to 37°C and the cooling fan was automatically turned on during a 15-minute test. This cooling effect lowered the temperature of the MOSFET and avoided further overheating. The hardware observation also shows that with the converter sensor

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temperature of 37°C, the inductor temperature of about 67°C can already be reached, which supports the use of a conservative control threshold for the protection of the components.

Troubleshooting Observations

Two main troubleshooting lessons were identified. First, combining high-frequency PWM generation and LCD display updates on a single Arduino Uno caused instability because blocking display updates affected the timing-critical PWM output. The solution was to separate tasks between two microcontrollers, with one dedicated to PWM switching and another handling display or input functions. Second, the MOSFET driver initially produced no output because the Arduino and TC4420 driver did not share a common ground reference. Adding a common ground and placing a 0.1 uF capacitor near the driver supply pins produced a clean driver output waveform. These findings highlight the importance of timing separation, stable grounding, and proper decoupling in mixed-signal power electronics prototypes.

Conclusion

The temperature monitoring and control for a class E inverter in a low-power WPT prototype were successfully demonstrated in this work. The main objectives were accomplished by monitoring electrical and thermal parameters, application of Class E inverter with intended ZVS operation and through simulation and hardware testing. The prototype produced a high-frequency AC output for wireless power transfer, rectified the received power to a usable DC output, and automatically cooled the inverter when the sensor hit the 37°C setting.

The use of PWM switching, MOSFET gate driving, coil-based power transfer, rectification, thermal protection with LCD, ESP32 monitoring, and fan-assisted thermal protection enhanced the safety and usability of the WPT system. The results also indicate that thermal protection needs to be designed conservatively, as the inductor and other power components may be exposed to much higher temperatures than the measured sensor point. Potential areas for improvement include coil alignment, higher efficiency power devices, enclosure airflow, closed loop power control and more detailed long duration efficiency testing.

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