ECE 445
SENIOR DESIGN LABORATORY
PROJECT PROPOSAL

TOUCH CONTROLLED PROGRAMMABLE DC POWER SUPPLY CIRCUIT

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1 Introduction

1.1 Problem

The operation of modern electronic devices heavily relies on DC power sources with varying voltage levels. This variability underscores the importance of voltage adaptation mechanisms for optimal functionality across consumer electronics. For example, while devices like cell phones consistently require a 5V supply, laptops may need a 12V output. The market offers a wide range of device models with differing specifications, including voltage requirements and connector types, posing compatibility challenges for consumers and manufacturers alike.

Our goal is to create a user-friendly, touch-sensitive, and programmable DC power supply system, overcoming limitations of different units. With intuitive controls and touch features, we aim to improve accessibility and allow effortless power adjustments. Users can customize power output, promoting versatility and adaptability. Ultimately, we aim to offer a flexible solution, encouraging innovation in diverse fields.

1.2 Solution

The Solution contains four parts to launch. EE team members will be responsible for designing the AC-DC Converter and variable regulated power supply and ECE team members will be responsible for designing the Touch Control Circuit and short circuit protection algorithm.

The first part is to realize the transformation from AC to DC. AC-DC converters have been developed to a matured level with improved power quality in terms of power-factor correction, reduced total harmonic distortion at input AC mains, and regulated DC output in buck, boost, buck-boost, multilevel, and multipulse modes with unidirectional and bidirectional power flow[1]. This component serves the crucial function of converting alternating current to direct current efficiently, providing the necessary power supply for the circuit to operate. Its design encompasses several key elements, including a step-down transformer, a bridge rectifier, a low-pass filter circuit, an LED indicator, a switch, and a fuse.

Next, we will design a component to regulate different voltage levels. This component serves as a reliable source of DC output, capable of meeting various voltage requirements with stability and adjustability. It incorporates advanced variable voltage regulator technology, ensuring precise control over the output voltage. Additionally, the variable voltage control circuits enables the generation of different voltage levels as needed, offering flexibility and versatility in powering various electronic devices and systems.

We also need to deal with the touch control unit. We need to design a component that provides touch-sensitive controls for user interaction. It includes touch sensors (touch plate), digital integrated circuits, and other circuits to generate control signals for the variable voltage control circuits. We plan to apply the CTSs, which include the touch sensor, analog front-end (AFE) integrated circuit (IC), and micro-controller unit[3]. Through the input from touch sensors, the digital integrated circuits can detect user touch actions and convert them into control signals, thus achieving precise control over the variable voltage control circuits. This touch-sensitive design enables users to conveniently adjust voltage settings

and provides a more intuitive and interactive operating experience.

Finally, the short circuit protection part plays a critical role in safeguarding the circuit and the connected devices by detecting and mitigating short circuits. It incorporates specialized current sensors and overcurrent protection components to monitor the flow of electrical current within the circuit. In the event of a short circuit or excessive current flow, these sensors promptly detect the anomaly and trigger the overcurrent protection mechanism. This mechanism includes circuit breakers, fuses, or other protective devices designed to interrupt the flow of current and prevent damage to the circuit or connected devices.
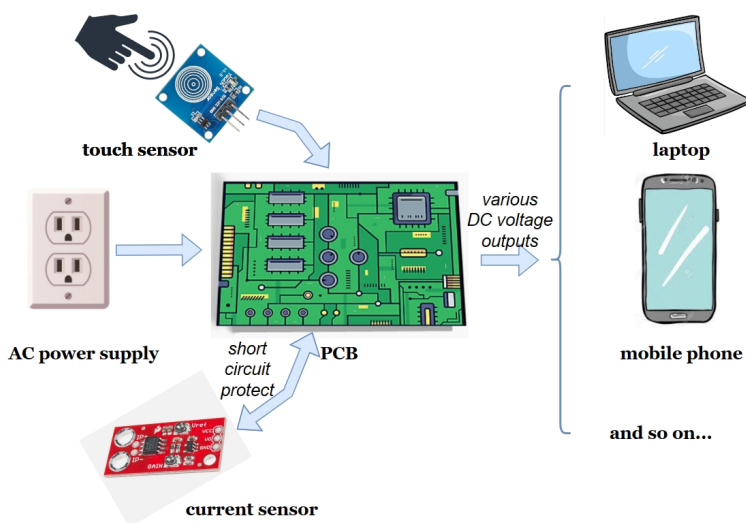
1.3 Visual Aid

Figure 1: visual aid

1.4 High-level Requirements List

- **The output range of DC voltage levels from 5 volts to 20 volts:**
  Our power supply circuit must be capable of providing a wide range of DC voltage levels, specifying the range based on application requirements with an accuracy of $\pm 5\%$ to ensure compatibility with diverse applications.

- **The output ripple voltage within** 2%**:**
  The ripple voltage of the output should be within $\pm 2\%$. The system should meet this requirement within the operation range, when the output voltage is 5 to 20 volts, and the output current is lower than 1 to 1.5 amps.

- **Maximum response time of A milliseconds of the touch-controlled interface:**
  It helps to specify the maximum allowable time for a touch event to register and execute a command with a touch detection resolution of B mm (specify the smallest detectable touch movement or object size), ensuring that the system is both intuitive and responsive for users.
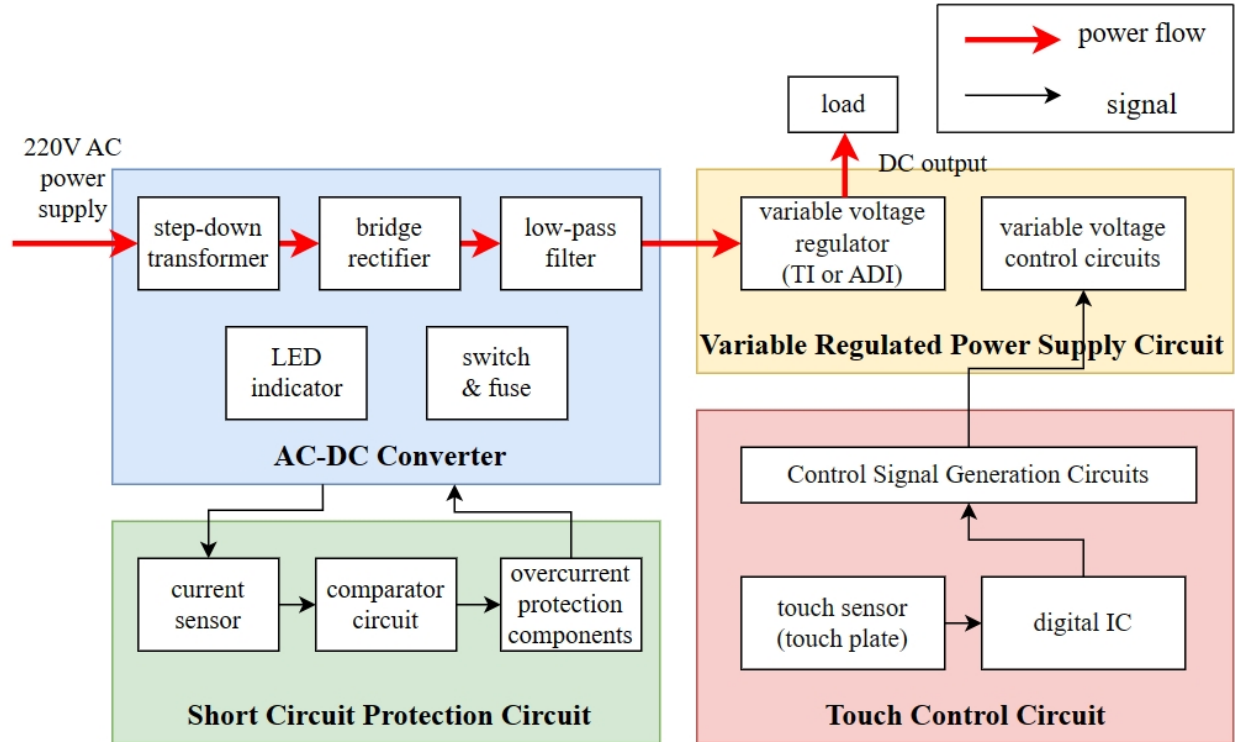
2 Design

2.1 Block Diagram

Figure 2: block diagram

2.2 Subsystem Overview

2.2.1 AC-DC Conversion Subsystem

The AC-DC Conversion Subsystem is intended to efficiently convert AC to DC to power the circuit. It includes a step-down transformer, a bridge rectifier, a low-pass filter circuit, an LED indicator, a switch, and a fuse to ensure efficient and reliable power conversion. The purpose of this subsystem is to flexibly connect external power sources and convert them to provide a stable direct current power supply for the entire system.

- **Transformer:** Transfers electrical energy from one circuit to another.

- **Rectifier:** Used to convert the input AC signal V_s to a one-sided signal.

- **Filter:** The output of the rectifier is passed through a filter block to reduce ripple in the signal.

- **Regulator:** Used to further reduce the ripple in the voltage and to give a stable DC output voltage. In this subsystem, there is a regulator to provide a stable 5V power supply for chips in the touch control subsystem. The adjustable regulator is applied in the variable regulated power subsystem.
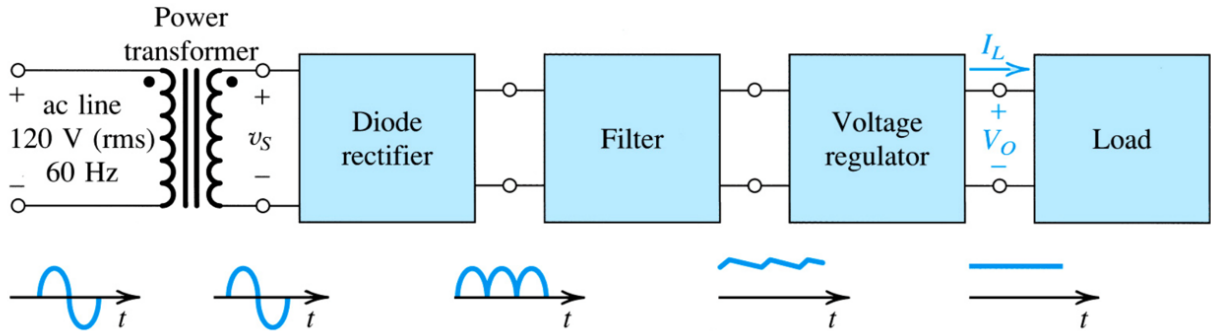

Figure 3: AC-DC power supply

2.2.2 Variable Regulated Power Subsystem

The Variable Regulated Power Subsystem serves as a stable and adjustable DC output to fulfill diverse voltage requirements. It includes a Variable voltage regulator from TI or ADI, and variable voltage control circuits for outputting different voltage levels. The role of this subsystem is to provide the main system with a stable direct current power supply with adjustable output voltage. By adjusting the set value, the output voltage can be flexibly changed within a certain range to meet the requirements of different functions of the overall system.

- **Variable Voltage Regulator:** Integrated circuits designed to provide a regulated output voltage that can be adjusted or programmed to a desired level. These regulators typically accept an input voltage and deliver a regulated output voltage, which can be set within a specified range using external resistors or digital control interfaces.

- **Variable voltage control circuits:** Electronic circuits designed to control or adjust the output voltage of a power supply or voltage source.

2.2.3 Touch Control Subsystem

The Touch Control Subsystem is intended to allow touch-sensitive controls for user interaction. It includes touch sensors (touch plate), digital IC, and other circuits to produce control signals for the variable voltage control circuits. This subsystem can achieve the transition between different states through programming and digital logic circuits. It recognizes input signals and processes them to provide corresponding outputs. Basically I will use capacitor touch sensor as my touch control unit. The IO part with the voltage part will be using realy control.The purpose of this subsystem is to create a simple interactive interface that allows users to control different states of the system through touch sensors, enabling the transition between various system states.

2.2.4 Protection Subsystem

The Protection Subsystem is intended to ensure the safety of the circuit and the connected devices by detecting and preventing short circuits. It includes current sensors and overcurrent protection components. This subsystem is an auxiliary protection device that promptly cuts off the circuit in the event of an unexpected situation, protecting both the circuit and the user.

- **Current Sensors:** Used to measure or sense the electrical current flowing through a conductor.

- **Overcurrent Protection Components:** Used to detect and interrupt or limit the current when it exceeds a certain threshold, preventing damage to the circuit or equipment and ensuring safety.

2.3 Subsystem Requirements

2.3.1 AC-DC Conversion Subsystem

- This subsystem ensures the safe conversion of 220V AC voltage to lower DC voltage, and maintain the accuracy of the final output even with slight fluctuations in the input voltage.

- The capacitance of the filter capacitor should be sufficiently large to ensure stability of the output voltage even under low load resistance conditions, including adjustable final DC output and power supply for chips in other systems. The ripple voltage of the output of the whole system should be less than 2%.

- The power rating of the transformer and the operating range of each component should be large enough to ensure the size of the output power (output voltage 5-20V, stable output current capable of reaching 1-1.5A)

2.3.2 Variable Regulated Power Subsystem

- This subsystem must ensure that the adjustable output voltage remains within an accurate range, for example, up or down by no more than 5%, without significant interference and fluctuations.

- When the desired DC voltage value changes, the system needs to respond quickly in 1 second.

- The output current must be stable, which remains in an accurate range(5%).

2.3.3 Touch Control Subsystem

- This subsystem must ensure a simple and clear interactive mode, easy operation, clear logic, and corresponding commands that enable the system to respond correctly.

- Ensure short response times for interactive commands, providing quick and accurate feedback.

- For safety considerations, it is necessary to prevent the hazards caused by accidental or random touches to the circuit. There should be a self-locking time implemented.

2.3.4 Protection Subsystem

- This subsystem must ensure the safety of the circuit and the user, minimizing harm in the event of a short circuit.

- Protective measures need to respond quickly, detect, and disconnect faults, and illuminate a fault indicator light.

- While disconnecting the fault, it is possible to make an initial assessment of the location and area where the fault occurred and provide a notification.

2.4 Tolerance Analysis

The hardware of the touch control circuit itself may be difficult to choose, as a touch-controlled programmable touchpad is difficult for us to directly implement, so we may need to choose and purchase the appropriate one. This touch control circuit needs to meet our requirements for power regulation and detection, stably receive signals from the circuit, and be able to run the programming language we use to implement the functions.

In our scheme of using relays to control different resistance voltages to achieve different gear voltages, the circuit of the control part and the circuit of the voltage part are connected with each other using relays to realize the digital signal of the control part to decide which resistor to access and adjust the voltage.

This leads to a problem, that is, the contact resistance of the relay and the voltage part of the circuit may be connected to the circuit, affecting the resistance partial voltage.
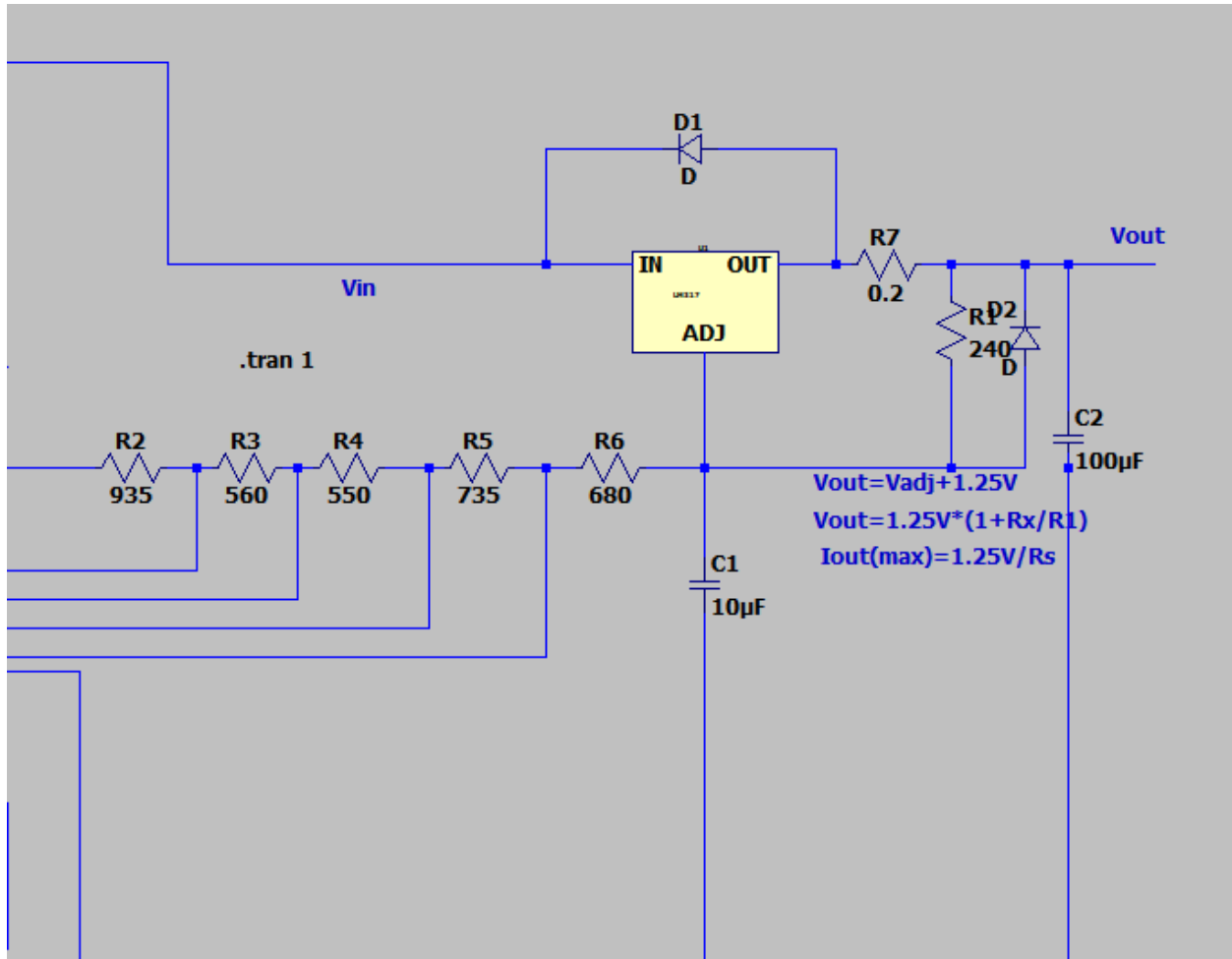
Figure 4: bleeder circuit

R_1 is the fixed resistor is always plugged into the circuit and participates in the calculation of the partial voltage, V_{out} is the voltage we need to output, R_{x} is the resistance of different gears according to different voltage requirements, controlled by the relay is accessed, which is where the error may occur.

$$V_{\text{out}} = V_{\text{adj}} + 1.25V \tag{1}$$

$$V_{\text{out}} = 1.25V * (1 + \frac{Rx}{R1}) \tag{2}$$

$$L_{\text{out,(max)}} = \frac{1.25V}{Rs} \tag{3}$$

According to the above schematic diagram and voltage calculation, it can be seen that when the contact resistance is large enough, the contact resistance will divert part of the voltage, thus affecting the final output result. At the same time, this part of the pressure may cause the problem of heating at the interface, affecting the stability of the equipment.

3 Ethics and Safety

Undoubtedly, we need to learn many existing code structures and purchase some integrated hardware to implement our functions. So we should pay attention to avoiding plagiarism and large-scale technology appropriation, and ensuring that the core content of the project is implemented by ourselves.

In addition, there are several points based on the corresponding documents to note:

- **IEEE Code of Ethics[4]:**
  8452 - Software Engineering Code of Ethics: Develop software that is reliable, and which meets the stated requirements.
  8460 - Sustainability of Software Engineering in an Evolving Global Population: The impact of technology on society should be considered to ensure it does not harm individuals or groups.

- **ACM Code of Ethics:**
  1.1 - Contribute to society and human well-being.
  1.3 - Honor property rights including copyrights and patents.
  1.4 - Give proper credit for intellectual property.

- **To avoid ethical breaches:**
  Ensure the DC power supply design is reliable and meets all stated requirements.
  Consider the societal impact of the technology, ensuring it does not cause harm.
  Respect property rights, including any copyrights or patents related to components used.
  Properly credit any third-party work or ideas incorporated into the project.

- **Safety and Regulatory Standards:**
  Federal Regulations: Compliance with Federal Trade Commission (FTC) rules on product safety and labeling.
  Industry Standards: Adhere to UL standards for safety, such as UL 60950 for information technology equipment.
  Campus Policy: Abide by any university regulations regarding research ethics and safety.

- **Potential Safety Concerns:**
  Electrocution Risk: The AC-DC converter must be designed to prevent electric shock.
  Overheating: The circuit should be designed to dissipate heat effectively to prevent burns or fire.
  Short Circuit Protection: The design includes a short circuit protection circuit, but it must be thoroughly tested to ensure it functions as intended.
  User Interaction: The touch control system should be designed to prevent accidental activation, especially when not in use.

4   References

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[2] Malla, S. G., Deepu, D. J., Kumar, D. P., & Malla, J. M. R. (2016, October). Solar powered mobile phone: An innovative experiment. In 2016 International Conference on Signal Processing, Communication, Power and Embedded System (SCOPES) (pp. 1015-1020). IEEE.

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