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An LC Filter and IGBT-Based High Regulated Low Ripple DC Power Supply

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Abstract*: Transmission of stable ripple-free power to heating regions is necessary to maintain temperature stability. Ripples in the power supply would result in high power losses together with unpredictable and abnormal temperature rises and power state instability. Excessive current ripple causes electrolytic capacitors in the circuit to decrease their operational life span. This article presents a plan that reduces load management ripple factor to 0.4% by using simple cost-effective available electronic components.*

Keywords*: Operational amplifier, LC filter, IGBT, and ripple factor*

I. Introduction

The advancement of constant current voltage power source technology has resulted from two major developments including expensive high-speed control processors and fast-switching insulated-gate bipolar transistor (IGBT) technology. A growing requirement exists for an advanced power supply system which provides strict control together with low ripple characteristics and strong current capability to heat high-temperature filaments. The designing of filament power supplies has proven challenging because it requires consideration of non-ideal device characteristics alongside power source disturbances and load changes.

The development of advanced high-energy physics and novel particle accelerator applications within industries and healthcare demands improved regulatory power sources for filament systems. The research introduces a new method for developing a high current constant dc power supply. The system uses analogue electronics components for control operations. We utilize the IGBT capability to change current passage during linear operation through gate to emitter voltage adjustments.

II. Research Method

The controller circuit detects output voltage changes by providing enough gate-to-emitter voltage to modify the current flow and thus transform the load voltage. The procedure continues unless the load voltage achieves its target value. The load voltage remains mostly stable even though there are slight variations because these fluctuations become insignificant compared to the main load voltage. Hence the ripple factor stays low. Any sudden load alterations within the circuit produce minimal effect on the fixed output voltage due to minimal regulation. The schematic diagram of the proposed power supply for filaments is shown above. Diode converter combined with L-type LC filter, potential divider, IGBT, bleeder resistance, non-inverting buffer, inverter, differential amplifier, and REF01 form the circuit. A 180VA, 230V/18V transformer serves as the experimental unit to generate 10V at 10A output. Design parameters include 8V extra voltage to compensate the voltage drop that occurs in the rectifier and IGBT circuit. The transformer produces AC power at its outlet which becomes DC voltage using full wave rectifier bridge devices. A L type LC filter reduces the harmonics which appear in the rectifier output waveform.

A bleeder resistance helps the filter capacitor to drain energy when power supply interruption occurs. The output voltage stability function of the project relies on the G4PH50UD IGBT. The circuit joins the load to two 10k resistors as series combinations with feedback voltage taken from the middle point. Loading effects on the voltage controller circuit are blocked by the added buffer element. The feedback voltage acquires a negative polarity against the load circuit ground because measurements occur from the high potential load reference point.

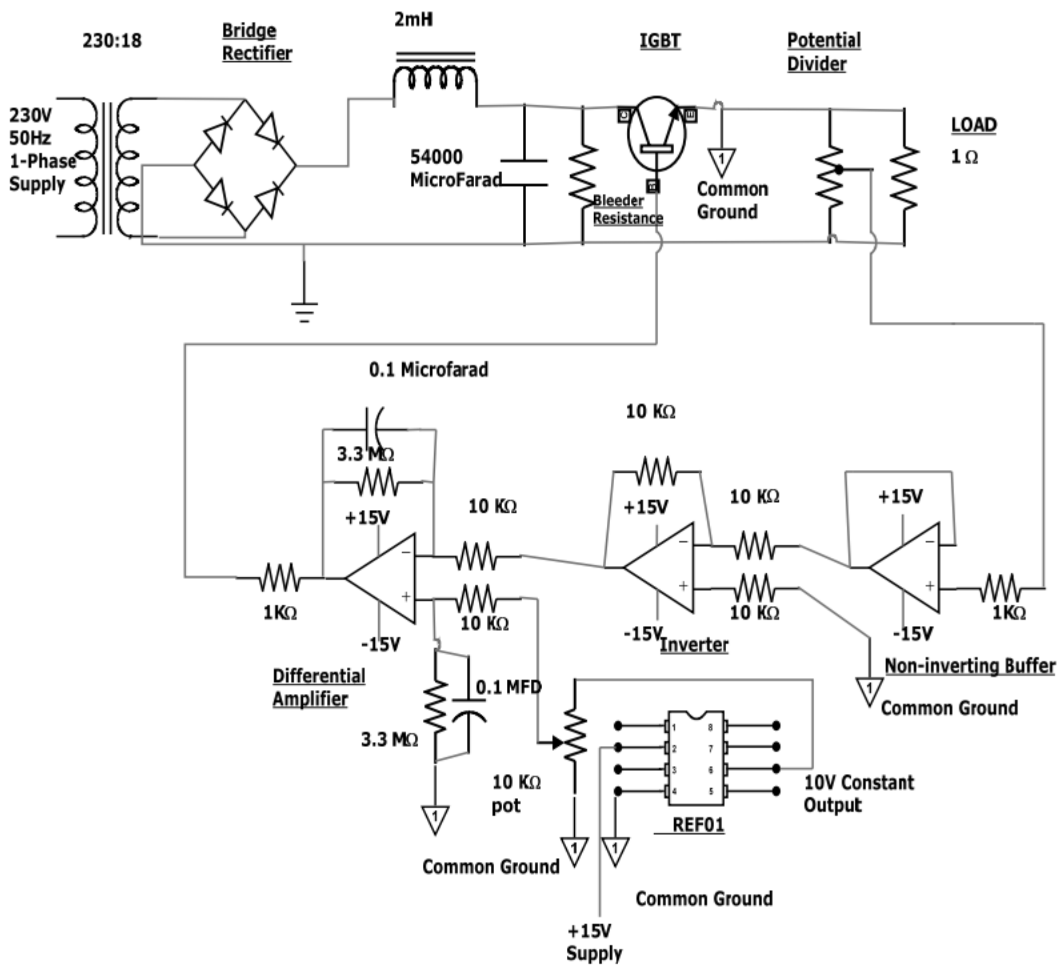

Fig 1: Principle and circuit topology

A gate voltage VGE above threshold voltage Vth operates as a device turn-on mechanism. The gate voltage elevates to create an inversion layer which links the drain sections to the source areas through a channel. During operation the source adds electrons to the drift area and at the same time junction J3 emits holes into the n-doped drift region. Injecting electrons and holes into the drift area changes its conductivity to higher levels because the electron and hole concentrations exceed initial n-doping values. The IGBT achieves low on-state voltage because its resistance decreases when the conductivity modulation takes effect.

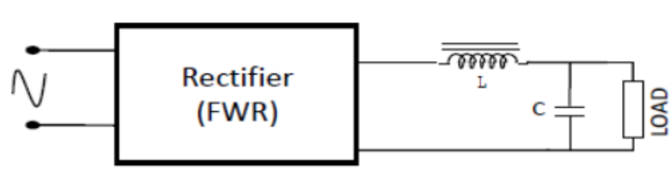

Fig 2: L Type LC filter

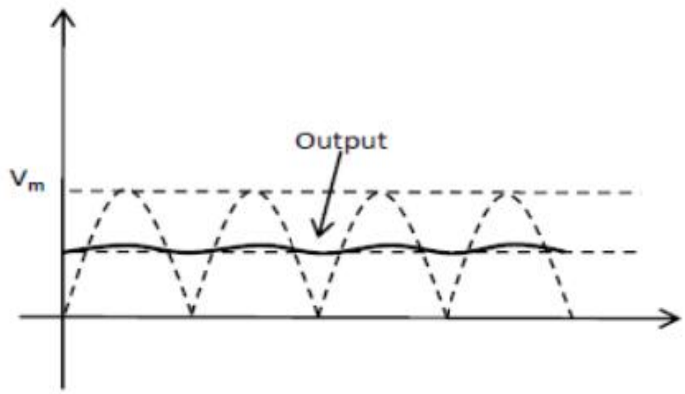

Fig 3: Output of L type LC filter

Some holes generated by injection in the drift zone will combine with each other while others will spread across the area to the p-type interface where they will become trapped. Through its MOSFET current the IGBT operates as a wide-base p-n-p transistor that allows channel current to serve as base driving current. A device requires rise time to advance from 10% to 90% of its base value. We can determine and estimate rise time theoretically by implementing a step input on the ref. The theoretical calculation of the increase time should match closely with the actual measured value.

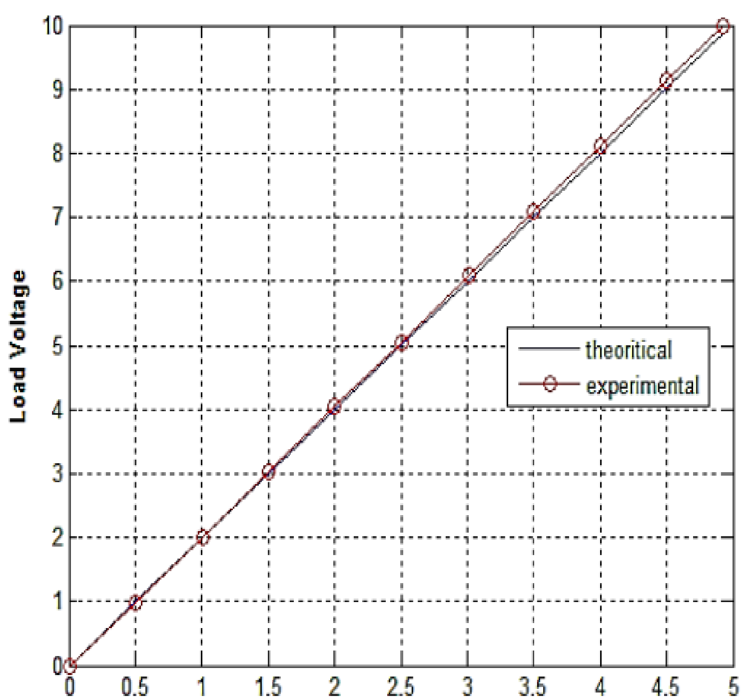

Fig 4: The variation of output voltage across the load

We can abruptly turn the ref input on to its highest value by using a switch at the input. The output of this operation is the system's step response, which can be thought of as a step change in input. The plot provides us with the system's step reaction. The output is CH1 (yellow), whereas the reference input is CH3 (purple).

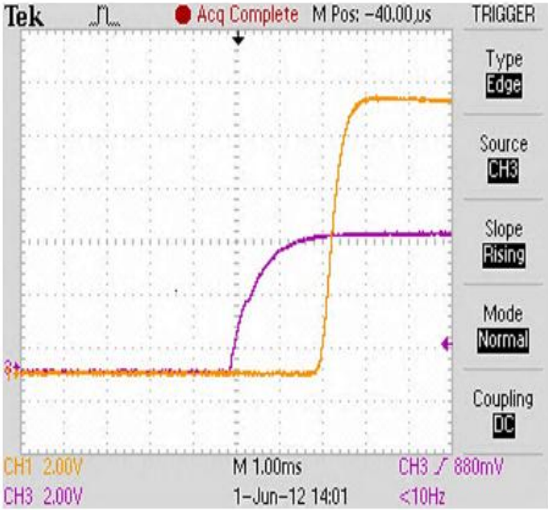

Fig 5: Rise time

The input and output are separated by a considerable amount of delay. This loop delay is brought on by all types of capacitances in the circuit, both real and stray. This delay can be decreased by employing more linear circuit components and proper wiring. In this case, the load is connected across Channel 1. A rising time of 608 µs was recorded by the oscilloscope. Our computed value, 341.542 µs, was sufficiently near the practical value.

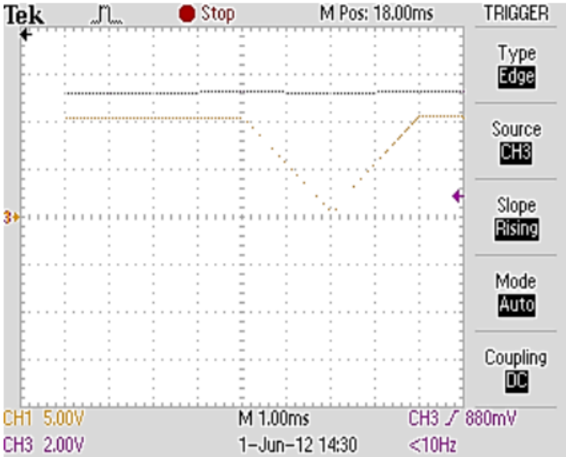

Fig 6: Response time at no load

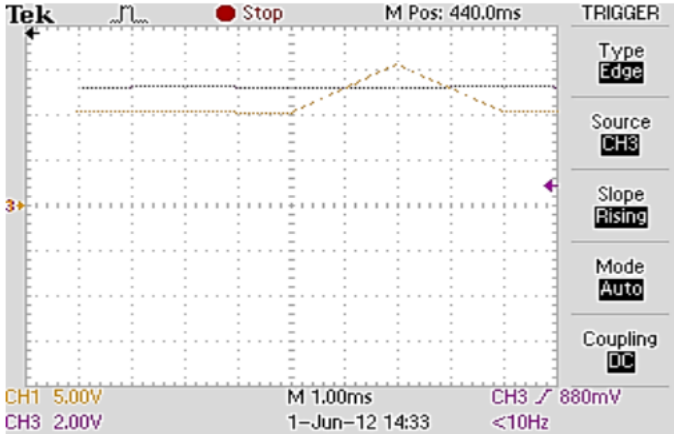

Fig 7: Response time at full load

The output waveform is represented by CH3 (yellow), and the input reference voltage waveform is represented by CH1 (purple). The reference input's full value is used to compute the ripple.

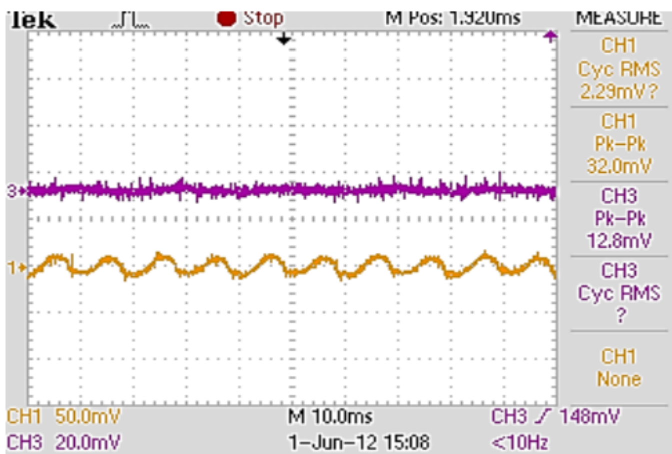

Fig 8: Ripple Factor at full load

The system output voltage shows a downward trend with the increase of load value from zero to maximum. Capsule depletion rate becomes reduced because the IGBT experiences decreased current when operating without a load. Switching the load abruptly will reduce the capacitor voltage because the circuit acquires immediate uniform current flow. The drop in load voltage causes an accompanying change to the feedback voltage measurement. The voltage regulator conducts procedures to restore the load voltage to its original value. The device performs the reverse action when a system moves from full load operation to no load conditions.

III. Conclusion

To match the impedance in the feedback path, the differential op-amp's non-inverting terminal is connected to a 0.3 μF capacitor and 2.5MΩ resistors. The differential amplifier's subtractive feature allows for higher noise suppression from the output when both input terminals have the same impedance. Because of the controller circuit's quick controlling action, it is also evident that the ripple factor from the theoretical calculation has significantly decreased. In order to guarantee quick dynamic reaction, the rise time is likewise relatively short. Additionally, it has been found that raising the differential stage's gain to an ideal level actually makes the input-output response more linear because the IGBT's base signal is likewise amplified.

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