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ECEN 204 design report.

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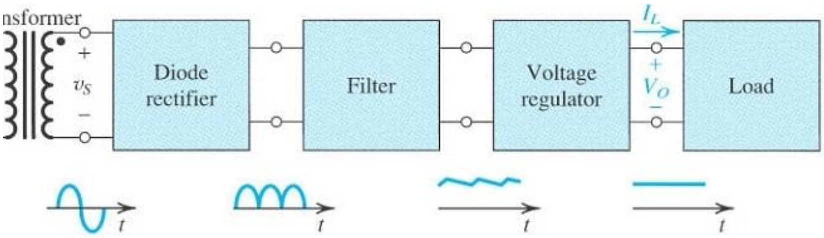
To complete the construction of an operational voltage rectifier/regulator circuit we had to go back to the basics of what the circuit fundamentally is, and how it's fundamental pieces worked together to give the desired results. So, looking at the individual "blocks/sections" of the rectifier we get the following.

Transformer/AC output → Rectifier → Regulator → Smoother → Load



(https://web.sonoma.edu/users/m/marivani/es231/units/experiment_05.shtml (21/05/18))

The Transformer reduces the voltage of the AC current from 240 to 12v to be used in this exercise, the rectifier is in this case a Wheatstone rectifier that takes in AC only allows it to pass a certain way. This effectively removes the negative component and adds a positive cycle every time there would have been a negative. The regulator takes the messy rippled now DC voltage (Approx. 10.6v after the constant drops from the diodes.) and reduces it to the 5-v stilled heavily rippled output. From there the voltage is passes to the smoother block which is a set of capacitors that charge and when the voltage dips discharge reducing the ripple, this ripple reduced DC voltage its what the load sees. We talk about the rectification process but how is it that diodes work together to rectify circuits? Well with diodes assuming you don't pass to much current/voltage in whether in reverse bias or forward bias work, similar to one-way streets, when again the rules are followed. I diode in forward bias has very low resistance and once the constant voltage drop is met to effectively turn them on allows the passage of current. But this is one way. If in reverse bias the diode has a very large resistance and theoretically completely stops the passage of current, hence their use in a bridge. AC as it is a wave flows positive and negative, using four diodes allow only have the signal through at anyone time, and inverts the negative, so the negative cycle is treated like a following positive cycle. Hence the voltage is rectified. Along with this rectification the voltage had to be regulated, we used the LM7805 regulator chip. With this chip however, there are some design options and trade offs that need to be assessed. The voltage regulators biggest trade off, was it being only useful for a certain range, as the LM7805 is a linear regulator we see that its efficiency declines as the difference between Vin and Vout increases and for example say we wanted to have an input of 3 volts and get it to 5 volts output, this is not possible, linear regulators can only step down a voltage never step up.

This task was simple in essence we were given diodes, capacitors and resistors along with a regulator and told to create a circuit that would successfully take a 12v AC signal and convert it to a 5v DC. The diodes had a constant voltage drop of 0.7 each dropping the 12-volt signal by 1.4 volts. With a 10.6-volt DC signal for the regulator. With the use of capacitators, we were tasked with taking the rectified 10.6v signal and reducing it and reducing the ripple so that we could attach a load and receive a steady 5 volts with as little ripple as possible while drawing current, without making the load or circuit catch fire.

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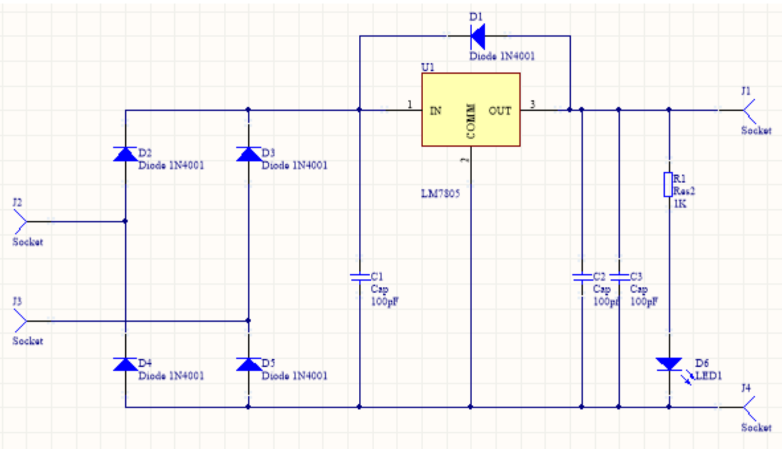
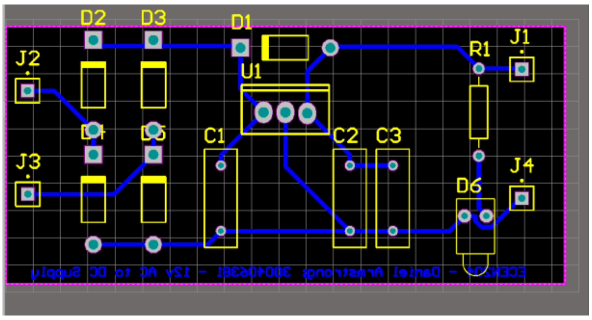
As well as this section looking at the design and its trade-offs, appendix 1 adds information. If you look at the photos and the design layout, the circuit I created used a smaller more compacted layout to reduce the amount of wasted space, this could have been reduced further but was avoided as it would create difficulties with construction. (Trade-off) The use of an electrolytic capacitor to reduce ripple was a trade off as it would have been more suitable if it was a non-polar, but we had nothing larger than 100nf for non-polar. The capacitor I used was 10uF which was not large enough, so the circuit still had extensive ripple, and needed to have a capacitor attached in parallel for it to work successfully. However the use of electrolytic and smaller capacitors still allowed for the signal to have the ripple reduce extensively even if not so elegantly. The use of silicon diodes arranged as a bridge rectifier was useful as it allowed us to understand how a component like this works, but this is a trade off as there are available components that are much smaller and more suited to application in the real world than using 4 diodes. However, it still met the requirements of the brief (To rectify AC to a highly rippled DC). Through whole components are simpler to attach to circuits but are larger, using surface mount is more difficult but is more compact and sleek (Trade off). In essence all of the components work together to do the what the circuit is designed to do. Better components could have been used, but the use of larger through hole components allows for better learning and skill building.

Printed circuit board design:



Notes: The schematic is the simplest form of the circuit design which shows the general placement of components and paths allowing the designer to see how the circuit will work and what paths the current may take. The difference between mine and many others is the extra capacitor that in reality played no extra part and would be removed if I rebuilt this circuit.



Notes: When designing the circuit, a key focus was size, working with what components that were supplied to create a circuit with a smaller board. One thing that had to be considered was the placement of components too close could cause problems with short. To far away could use up too much space or create the need for harsher angles. What we know is current passing through the board can be slowed by the use of right angles. Hence causing heat output at certain points if the circuit is driven too hard and causing combustion of the circuit.

The construction of my circuit began with Altium. Using the circuit design software and what we had learned about the rectifier/regulator set up I designed the board with a few goals in mind, for it to be small and for it to work. I wanted components on the board to have logical followable path, from the colour coded wires to the placement of the components, there is a logical route that is easy to follow. This was to add in problem solving should something go wrong. After sending off

our boards to be printed I researched some values and ran some calculations (In images appendix) to find the nominal value of components for the board. When it came to construction, I had a method of placing the components and then soldering this prevented error and allowed me to double check everything. There was an issue with this idea however. Soldering irons being very hot heat up components this heating can spread to other components even if not being worked on directly, this means there is a risk of components being damaged or destroyed thankfully this did not happen. With all my components placed I went on to solder them into their place. (With only minor problems) Once the components were in place I could go onto testing, using a continuity probe a manged to find a short which I then fixed with solder wick, after this there were no other issues, I went on to assume the circuit was not working and took signal readings from different points. The input, output of the diode bridge (Signal image 1), the output of the regulator (Signal image 3) and the output of the system (Signal image 3), this way we could see if any of the components were non-operational, so we could fix the problems. After taking the readings of that test I took many readings using a variable resistor to then find the load at which the ripple is reduced to near enough 0 or very small, while testing I went up from 0 to 4000 ohms in intervals of 1000, then went to 5000 with intervals of 500 ohms from there I went to 6000 with intervals of 100 ohms to see where the load impedance reduced the ripple. With these readings I took data for the output voltage the peak to peak and for the current, allowing me to see the full behaviour of my circuit. The Data is available in the appendix (Table 1).

When it came to designing constructing and finally testing the circuit there were a few errors we managed to solve with relative ease. With construction there was an issue with soldering one of the wires which made a slight mess. Though this didn't impact the working of the board it did detract from whatever aesthetic the board had. I manage to rectify it somewhat by using solder wick to absorb the solder. During testing there were problems encountered, the main one was a short somewhere in the circuit, from there we used pin point continuity testing to find the location of the short, which turned out to be the middle common pin for the regulator, with some solder touching another track using a solder sucker and a small about of solder wick the solder was removed. And with it the short was also removed. Even after calculations and advice for which values to use for components. I encountered very odd phenomena with the components I used, confusing as they were the same as everyone else's. Compared to others to reduce the ripple to 0 or near enough my circuit had to have a load impedance of 10kohms. Compared to others of 330 ohms. Running tests, I discovered that have 57 microfarads would reduce load needed to about 440. Using 410 micro fared it dropped to 230 ohms. What I know is capacitors can differ by as much as 20% so running individual tests on the capacitor to check capacitance may shed some light in the future. As testing components while in circuit becomes problematic due to added capacitances and resistances from other components.

In reality the circuit I designed and constructed is not applicable in the real world, with components and items getting far smaller. Having a PCB so large with so much empty space results in wasted materials and inefficient systems. For application in the real world the circuit itself would have to be much smaller. Using surface mount instead of through hole would allow me to accomplish this. If we still had the same equipment, my capacitor at C1 would have a much larger capacitance, and still my board would be smaller dropping a lot of the white space.
This project was something else and by far the most enjoyable thing I've done at university this far. And reignites my passion for this degree (That's what I would call a benefit). To be fair there is not much I would change, this has been challenging especially from never doing anything like this, but this has been a highlight of my year so fair, this is what I wanted to do ECEN for, in simplest

terms I like to build things like circuits. I want design and create things to help people. And I enjoyed this project very much. I think getting my solder to be at least good was the most difficult part with a few times having to employ the use of solder wick and the solder sucker. On that topic I think the hands-on skills like soldering provides massive benefit, on top of this, for a second year this is as close to a real-world project many of us have experienced. We had deadlines specific components and had to design something. This experience in itself is very beneficial. I find myself a bit of a perfectionist and with this there's still one area that annoys me on my board because of bad soldering that no matter how much I tried to fix it, I couldn't.

5. Additional questions (Excellence).

(a) In our current design, we start with an AC supply which is first stepped down by a transformer to ~ 12 V and then rectified and regulated to 5V. However, what will happen if we start with a DC voltage > 5V and use this as the input to our power supply? Will the same circuit still be able to regulate this down to 5V? What will be the requirements on this DC input voltage for successful regulation? Do we need to make any changes to the circuit?

In thinking the diode bridge would not need to rectify however it would let current pass. Without researching I suspect the caps that deal with ripple as it is not an interchanging wave would begin to charge, which would completely impede current flow. The voltage regulator, assuming that the DC is not in excess of what it can handle then that component alone would reduce the voltage to an acceptable level. Without the need for most other components on the board.

(b) The role of a capacitor in reducing ripple in the output from the rectifier stage could clearly be seen from the Part 2 of the design. However, we have used four capacitors in our final design – discuss the role of these different capacitors.

In my final design there were 3 capacitors, however to correctly work the circuit a forth had to be added in parallel of the first capacitor before the voltage regulator. In essence a fixed final design would have the need for 2 only. There are ripple capacitors which charge and discharge with the positive cycles of AC or what comes from the bridge that then discharge as the voltage drops to 0 this provides a voltage in place of the AC for that time, hence producing a constant voltage for the regulator to then regulate. The capacitors that follow the regulator I need to do more research but in my understanding are there to prevent major damage to the regulator.

(c) You are using a piezoelectric energy harvester as part of a remote sensor network. This harvester generates an AC voltage of maximum value 1 Vp-p when it is subjected to environmental vibrations. This voltage must then be rectified to charge a battery or capacitor that can then be used to power the sensors and network electronics.

(i) Discuss how appropriate your current design (diode bridge) will be for use with this vibration harvester. What problems may be encountered?

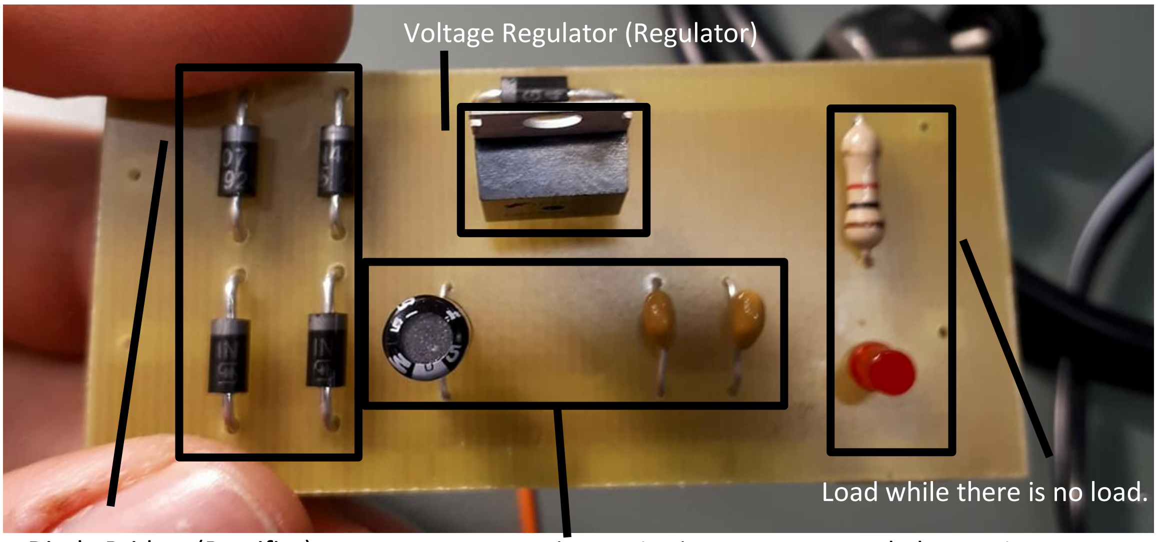
A Diode bridge uses a series of diode to then rectify an AC signal to DC, However the AC passes through 2 diodes to be rectified at anyone time. This is problematic as for silicon diodes there is a constant 0.7v drop once. As there is 2 that's 1.4v drop in total. What this means is that 1 v p-p cannot actually pass through the rectifier as it is not great enough, if thinking about the current design.

(ii) Can you come up with a better circuit design for this task? (It may help to do some reading on small signal rectifiers).

If we think about using different diodes as the simplest ramification then germanium diodes would be a good start as they only have 0.3v drops which result in a total of 0.6v, this means only 0.4 v of signal may pass. So, there must be better ways to do this. After doing some reading I found that using two op amps allow the buffering of the input signal, this compensates for the voltage drops across the diodes which allow smaller signals to be full rectified, this combination of diodes and op amps is known as a precision rectifier

Appendix:

This is where I will store my data and Images.

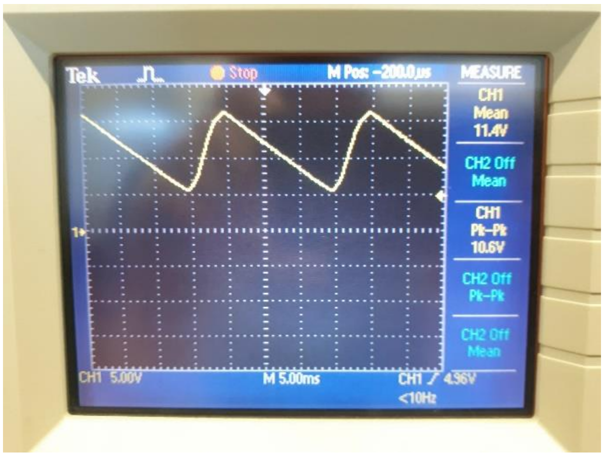


Diode Bridge. (Rectifier) Capacitors (Smoother) LED 1kohm Resistor.

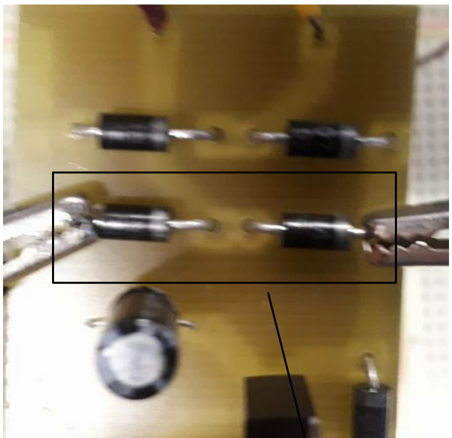
This Image was taken after the final construction of the circuit. What we have is the full-wave rectifying Wheatstone bridge which takes the input 12v AC and rectifies it to about 10.6 volts (This drop is due to the constant drop from the diodes. At any one time the circuit is on the signal passes through two diodes. This is an approximately 1.4 voltage drop.) of extremely rippled DC (Signal Image 1). This signal passes through the first capacitor which reduces the voltage. Each time the signal raises to its max pk-pk it charges the capacitor when it drops to 0 the capacitor discharges allowing it to act as a source. This effectively reduces the ripple. This reduced ripple circuit is passed through the voltage regulator inspecting the internal components of the diode (Circuit diagram 1) we see that through a series of diodes, resistors and transistors we reduce this 10.6-volt ripple reduce the signal to 5v reduced ripple (Signal image 2). This is then passed through more capacitors which are there to prevent spikes that could destroy the LM7805. This output is then passed through a resistor and LED this provides a load to the circuit when there is no actual load attached. Preventing the circuit from combusting.

Signal Images:

Signal image 1)



Signal 1: The rectified non-regulated or smoothed circuit. Was used to test if the diode bridge was constructed correctly.



Oscilloscope measuring over the diode bridge.

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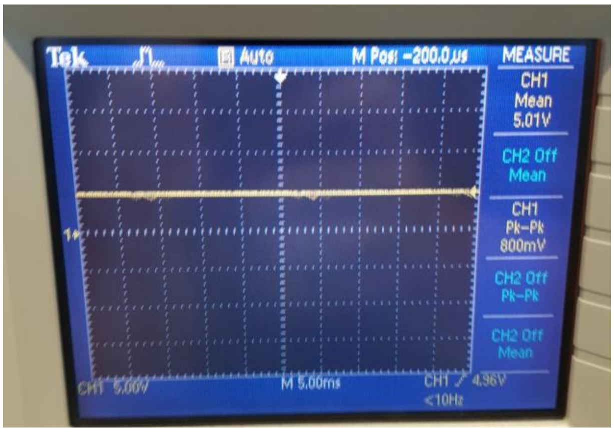
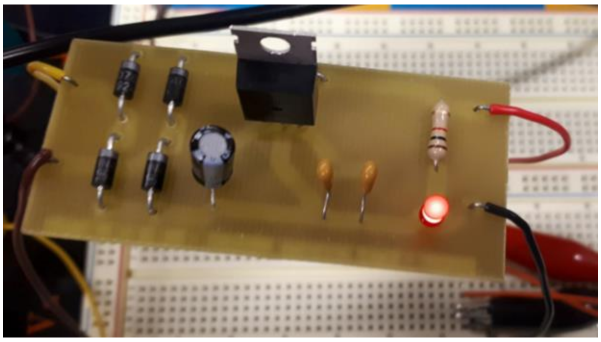
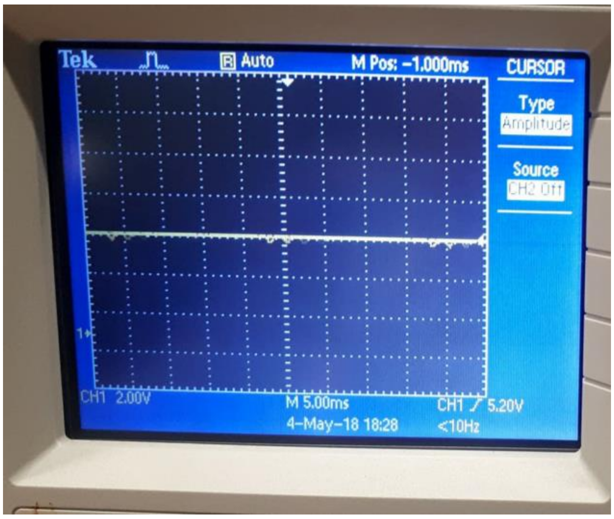
Signal image 2)

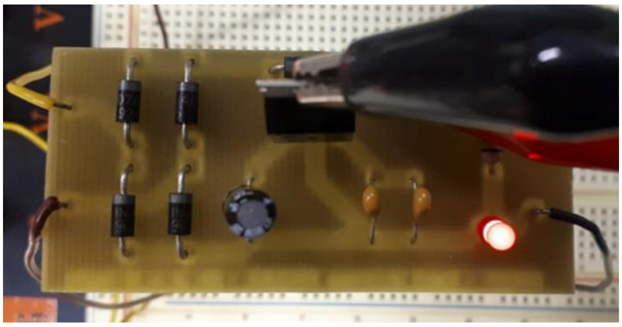




Signal 2: The final output of the circuit under 4000 Ohm load. Giving a constant voltage and a constant 1.25mA Current.

Signal image 3)





Signal 3: The output of the voltage regulator circuit under 4000 Ohm load. With some ripple and a higher voltage than the output.

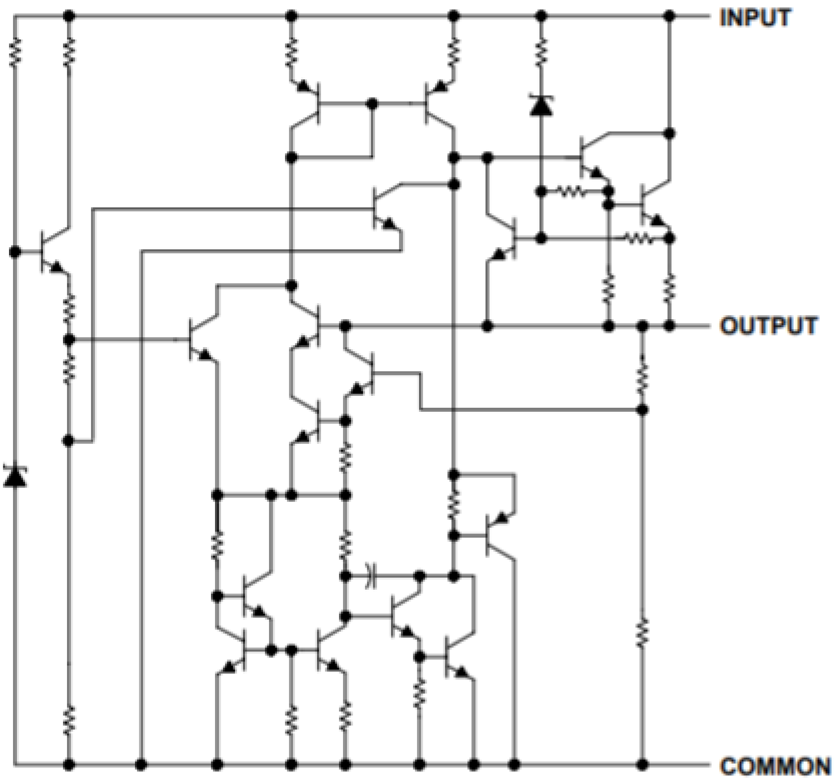
Table 1:

Resistance (R)	***Mean Voltage (V)***	***Pk-Pk (V)***	***Iout (mA)***	***Vout (v)***
0	***80uv***	***200m***	***22***	***0.001***
100	***2.17***	***5.12***	***17.11***	***1.668***
200	***1.88***	***5.12***	***10.97***	***2.166***
300	***2.74***	***5.12***	***8.68***	***2.577***
400	***3.36***	***5.12***	***7.39***	***2.939***
500	***3.67***	***5.12***	***6.53***	***3.246***
600	***3.8***	***5***	***5.89***	***3.523***
700	***3.97***	***4.8***	***5.39***	***3.755***

800	*4.14*	*3.8*	*4.96*	*3.940*
900	*4.38*	*3.6*	*4.59*	*4.113*
1000	*4.49*	*1.8*	*4.22*	*4.245*
2000	*4.87*	*1.2*	*2.37*	*4.733*
3000	*4.96*	*880m*	*1.63*	*4.868*
4000	*4.98*	*800m*	*1.24*	*4.919*
4500	*4.99*	*740m*	*1.1*	*4.933*
5000	*5*	*640m*	*1.00*	*4.943*
5500	*5*	*560m*	*0.91*	*4.950*
6000	*5*	*480m*	*0.83*	*4.956*

The Results above show the continued trend of the out puts of the circuit. As the load impedance is heightened the current produced is dropped and the voltage produced becomes closer to the 5-volt input. With this the ripple decreases as the impedance of the load is increased.

Circuit diagram 1:



what we can see within the LM7805 is a varied amount of Bipolar junction transistors, Resistors, Polar capacitors, Diodes and specialty diodes. This set up allows for a high input DC voltage to then be reduced to a lower voltage by dissipating voltage over various components. [1]

References:

Bibliography

[1] Texus Intruments, "LM340, LM340A and LM7805 Family Wide VIN 1.5-A Fixed Voltage Regulators," Texus Instruments, 2 2000. [Online]. Available: http://www.ti.com/lit/ds/symlink/lm7800.pdf. [Accessed 21 05 2018].