# **Electronics for Musicians**

***by***

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## **Introduction**

At the beginning was the magnet. People have observed that some metals would turn to the North every time they are left hanging with a proper mechanical sensitivity system. They decided to call this system a compass. The compass effect was not due to the Great Gods who guided sailors through the ocean but because the earth is polarised and there is a special force which attracts all objects to the North, the metals being more vulnerable, and this special force does not come from God but is rather caused by the properties of the materials. More on magnetism is not a subject on this article but it is available elsewhere.

" Why did you say "magnetism"? Shouldn't it be electro-magnetism?" Not, as far as I am concerned. Magnetism, I would call the force which ONLY attracts materials, i. e. only creates a mechanical force of attraction. At a lower level, physicists may say that magnetism and electro-magnetism are based on similar or the same principles but engineers deal at a higher level where they are interested in movement of the masses and interaction between the objects.

Electro-magnetism is a production of electricity by using magnetism and vice versa - production of magnetism by using electricity (which might have been produced from magnetism on the first place but the second magnetism is different from the first because it is derived from a different source and in a different way).

WHEN A CONSTANT MAGNET (A MAGNETICALLY POLARISED IRON) IS MOVED NEAR A WIRE... SPARKS WOULD FLY AND SHARKS WOULD CRY. Funny but true. When a constant magnet is moved through a spiral of metallic wire, or nearby, it is like the magnet wants to MECHANICALLY GRAB SOMETHING AND DRAG IT as it moves. It is logical, wouldn't you agree. The magnet creates a force, similar to the force you create when you want to glean wheat. You use your mechanical force which comes from your muscles and you would TRY TO GRAB as much of the wheat straws as possible. The same with the magnet. The magnet wants to grab and drag whatever can with the magnet’s force. A good example may be to spread small balls from a B. B. Gun on an epoxy resin. Then, quickly thereafter, pass a NOT-SO STRONG magnet on top. The magnet would attract the balls but not all balls would jump from the resin and stick to the magnet, ONLY SOME OF THEM WOULD, those which didn't get stuck deep in the resin or where the resin was not hardened that much that quickly. In Newton's words - where the force of the resin which tries to bond the balls to it and create a monolithic object is less than the force which the magnet exerts as it tries to get as many balls as possible.

Why do we not try to find a name for these balls since they are in these specific circumstances and in this specific situation so that when we call the name we refer to these circumstances too? What name would you propose? Big Balls? I would suggest to call them electrons. So when the magnet passes through the epoxy resin with balls the magnet tries to drive as many balls away from the mass as possible. Also, what would happen when we put a thin paper between the magnet and the balls? The magnet force would pass through the paper with a negligible reduction. This magnet force would try to collect balls and have the balls stick to the magnet. BUT the paper roof which covers the amassed epoxy resin and balls would prevent the balls to go to the magnet. Assume we put some wax or jelly on the lower side of the paper so the balls cannot get stuck. Then, when we drive the magnet around, SOME OF THE BALLS will follow. We will have a flow of balls wherever we drive the magnet around.

The epoxy resin and metallic balls from a small B. B. Gun are a good mechanical representation of any material AT THIS LEVEL ONLY - I. E. AT THE LEVEL OF SIMPLE MECHANISTIC APPROACH. (Sorry, Mr. Einstein and Mr. Oppenheimer, but I still don't believe there is another one.) So any material would have an epoxy resin and metallic balls. HOWEVER, SOME MATERIAL WILL HAVE A VERY STRONG AND THICK EPOXY RESIN AND VERY FEW BALLS AWAY FROM EACH OTHER AND STRONGLY HELD BY THE RESIN SO NO ONE CAN ESCAPE NO EVEN IN PRESENCE OF THE STRONGEST MAGNETIC FORCE. (The paper, for example, as well as most organic materials would be such an example and would have very few and very small balls which do not interfere with the magnet force, i. e. the force which stretches the paper is much higher than the force with which the magnet attracts one or two very small balls.) It may be assumed that some materials would not have balls, i. e. would not have electrons at all for the simplicity of this explanation. Small amount of electrons which are bound very well by the atom may be neglected, i. e. is no electrons.

So, when the magnet passes through a serpentine of a metallic wire, the magnet will drag the electrons with it!!! And this is called electric current. (Time and ago, the word current in English (as well as the translation of this word in any language) meant a flow and nothing else, for example, the river has a current which goes from Saint Paul, Meniscus to New Orleans, Alabama, or could be Tennessee, or could be Louisiana. There is a current of birds in the clear blue skies or a current of fish in the blue waters of Arizona.)

(MODERN PHYSICS SAY THIS IS NOT TRUE. PLEASE, IGNORE THE MODERN PHYSICS AND ACCEPT THE ABOVE AS TRUE FOR THE SIMPLICITY OF THE EXPLANATIONS HERE. ACCEPT IT THE SAME WAY AS WITH MECHANICS - GOOD ENOUGH APPROXIMATION FOR THIS LEVEL AND WOULD HELP PROVIDE A BETTER UNDERSTANDING IN THE MATERIAL. Then, at any level, one can adjust the result in accordance with the modern physics which says that ELECTRONS CANNOT MOVE. THEY STAY STUCK TO THE ATOM. ELECTRONS CAN ONLY HIT EACH OTHER AND GIVE ENERGY FROM ONE TO ANOTHER THIS WAY BUT CANNOT FLY AWAY. This is like the toy that has a lot of hanging balls lined up and when one bangs one of the end balls, the bells would "hit" each other but would not move because they "FULLY" transfer the force from one to another (the next ball stops the previous ball and sucks the energy out, then blows the energy to the next one, etcetera) until the last ball is reached which freely bounces.)

When the magnet is moved on a line and switches directions as it reaches one of the ends then goes all the way to the other then back and forward and back and forward and back and forward and back and forward and back and forward and back and forward (like a shuttle of a clothes' fabric manufacturing machine or the hand of a lead guitar player when the said plays a solo on the neck of the guitar and plays it right - covers the whole range, does not cheat on one position only), THEN THE ELECTRONS WILL BE DRIVEN BACK AND FORWARD TOO, and this is called ALTERNATING ELECTRIC CURRENT OR ALTERNATING CURRENT (A/C). When the electrons are dragged in one direction only, how are you going to call this? Obviously ONE WAY CURRENT. However, engineers have decided to call it DIRECT CURRENT (D/C) because the electrons fly directly and do not go back (unless there is a circle to return them back (coming soon) but the electrons DO NOT GO BACK THE SAME WAY, THEY PASS BY DIRECTLY FROM ONE SIDE TO THE OTHER - this is like children in rural America (the Real America, the rest is Europe just bigger, though quantity defines quality and despite so) when they look at the passing train (looked, they don't do it any more - they've got trains and private jets these days) - THE TRAIN DIRECTLY PASSES THROUGH THE STATION, as opposed to the train which manoeuvres and alternates from one end of the station to the other MANY TIMES).

So did you get the idea of AC/DC? Simple, eh? This guy is a joke. When so simple, why does the people, scientists and engineers still make a mistake between AC/DC and AV/DV (Alternating Voltage / Direct Voltage)?

Remember AC and DC deals ONLY with currents (flows) of electrons and ain't got nothing to do with voltage. Who mentioned voltage? Who farted? There ain't such thing. We ain't spoken of such parameter. Do NOT know at all for now. You better didn't know what current is but only know what voltage is but this is to come soon. For now try to remember: VOLTAGE (whatever that is) IS GOOD, CURRENT IS BAD. ALL CIRCUIT ANALYSIS MUST BE CARRIED WITH VOLTAGES ONLY (CERTAIN EXCEPTIONS APPLY) BECAUSE, AS A GROSS GENERALISATION, CURRENT CHANGES, VOLTAGE STAYS THE SAME - WE'VE GOT TO HAVE SOMETHING WHICH DOESN'T CHANGE WHEN WE DESIGN OTHERWISE THE CIRCUIT WILL HANG IN THE AIR LIKE BALLOONS OR BULLSHITS FROM THE SKY.

Just forget that voltage exists for now. And in all: There is only one PRIMARY PARAMETER - ELECTRIC CURRENT. Voltage is a secondary parameter which engineers MADE UP in order to simplify their explanations. This is like to say that 100 dollars is also a primary term for US/Canadian/Australian/New Zealand currency. No, it is 1 Dollar which is primary, not 100. When I ask you to drop ONE HUNDREDTH OF A HUNDRED DOLLARS in the cup as I sing and play guitar on the Beaches, how would you look at the question?

Well, one point for $100 to be a primary may be that with the current economic climates in the above-mentioned countries, as well as, the whole world, very soon the currency will be based on $100 because a hot dog would cost a couple of hundreds of dollars and nothing will be less than a hundred. The shops will be called A Hundred Dollar Shop and the children will ask why the grown-ups say a Million Dollar Question whether it is current and voltage that is primary. They would know that current is primary but they will wonder why the expression A Million Dollar is used for something insignificant whereas a million dollars in nothing. Can't buy even a lousy Telecaster with that little money.

Most likely, the US will recalculate the currency as they do in the Third World and the rest will follow, so the grown-ups may retain some common sense.

In other words, look at the economy - nothing is stable - everything is floating. And that's why nothing works. There is NO STABLE REFERENCE to which to compare the things. When you don't have a stable reference you can't get nothing to work right because no one cares what they do BECAUSE THEY CAN'T FIGURE OUT WHAT THEY'VE GOT. In other words, they can't estimate what the value of the things is.

As a consequence of which, people think with their dicks and pussies and not with their brains. People are put to be in a position of Lumberjacks who work for the weekend only because money ain't got no other value for them except to call Eugene on Saturday (more like Friday eve these days due to the prosperity of the Western Civilization) and then they go to a bar where they pick up some strange kinda women and they fuck all of their money out.

At least they are lucky to have a job - a basic human right which is made a privilege these days by the privileged ones. America is a country run by the privileged, for the privileged who got themselves elected through the privileged by the stupid people.

The economy will FOREVER CONTINUE TO DECLINE. There are two main reasons for that:

1. Economy is an engineering subject and not one for the economists. Economy has to be designed and not left on own. There ain't no feedbacks unless you make them. And sometimes it is impossible to make them or impossible to make them work with the desired parameters, such as accuracy, gain, or the so called deepness of the feedback.

2. THERE MUST BE A STABLE REFERENCE IN ORDER TO HAVE AN ECONOMY. The most stable reference found these days is GOLD. THE BIGGEST MISTAKE IN THE ECONOMY IS THAT SOMEONE CHANGED THE ECONOMY FROM ECONOMY WITH REFERENCE (GOLD) TO SUCH WITHOUT.

Who was this genius or leader of the free world? Was that an American? I've heard some Americans opposed to this. Was it a Frenchman (may have been a French woman)? Go ask the Congressman, I don't know.

In some countries, and partly in the US, they want to replace the stable reference with a reference which only or mainly appreciates and never loses value. They would use THE PROPERTY as such. However, in the US, being a bit more developed then the others, property also depreciates. Also property ages and eventually becomes unsuitable due to ageing Also, property is vulnerable on the political or economic decisions. When the mayor of NYC decides to privatise Central Park (coming soon) then Woody Alan and others who own lousy apartments around would lose a lot of money because there would be a lot alike, even better and at a better location then theirs, and John Lennon will thank Mark David Chapman that the said got Lennon shot so that John gets to wave the john on Jones Beach or other of the beautiful beaches of Long Island and forgets one ever had a property in the Dakota Buildings, which, as would appear to be, is one of the dumbest place to purchase property in the US.

Some people drop US dollars (in their quarter shape, much to the dismay of many people) when I play by the beach. I do not blame them that they do not appreciate the significance of singing out of tune and fucking up the beat while bucking up the... legs BUT I wish I could ask them one question:

WHAT THE FUCK WOULD I DO WITH THESE BRAZILIAN REALS CALLED US DOLLARS? To get a pussie and stick them up the pussie's ass? What shall I do with these? Go get a prostitute in the bar and get diseases? Case I want to have a cute redhead from the country, the Irish girl wouldn't care that much about the ass-wipers I bring, called US dollars. Country Irish girls want real things. They ain't that stupid like the city bitches.

Hope they wouldn't answer to get a Telecaster because then I would sing them a song.

Generally speaking money is nothing and people know it - some of them fully consciously, some of the sub consciously. The only point which keeps the economy in this way is that the people who thought it over relied on one important factor in people's stupidity: People think short term only. They are stupid, and that's one of the thing stupid people do. The people in power relied on this and trapped the stupidos like animals in Arkansas.

NO ONE HAS EVER EXAMINED THIS. This is because all kind of governments, inclusive of the Soviet ones (Certain exceptions apply. I do not want to mention these, because this writing will become political whereas, right now it is economics' one.), wanted to use the short term thinking of the stupid people and mainly the strongest instrument for the use of this short term thinking - the money, and it's instability and political or non-political manipulability.

Anyways, you would not understand the above lines but your children will. Or the children of your children or their children or their or... One day, this will be understood. When this day (The Redemption Day) would come depends on how strong the politicians and their backbones who pull their strings are.

Fortunately, the politicians nor their backbones, protégés of whom the politicians are have not been able to handle the engineers very well.

Back to electricity then.

The engineers have decided that they need to do something, to create some tools in order to be able to use this tool to more easily design and understand electric products. This ingenious invention is a tool called voltage. It is an incredibly useful thing but very difficult to explain.

In order to explain voltage, I have to pass through many more things.

I have mentioned that electric current is the primary parameter of electricity. I would also say it is THE ONLY PRIMARY ONE. One may argue that what follows is also primary. I would say that what follows belongs TO EVERY FLOW not only to the flow of electrons and thus it is not primary for the electricity whereas the flow of electrons is a flow just like any other else but is the subject which flows that defines it whereas in the case of general flow parameters - these parameters are the same for any flow.

IMPORTANT: When you think of electric current, always imagine water current, when you think of electricity, always imagine water. Water is natural and people have been using it for ages and every child, one way or another, is exposed to the natural water flows since a very early age, as well as to various parameters of these flows.

When water flows, the flow is subject to many influences - many objects may affect it. These objects have been examined and found to affect the flow by one of the following ways: RESISTANCE, CAPACITANCE AND INDUCTANCE.

Resistance is the most important flow parameter. As a given flow flows, this is a subject to resistance of non-floating or floating objects under Newton's low that every force has a counter-force, every object tries to counter-force to the abnormal force of the flow using it's normal force - the gravity. At the level of the planet Earth, gravity is the only normal force. The rest is abnormal. Not primary. Not defined by the creation of the Earth but a rather interaction of forces, secondarily created by the gravity itself. So the gravity may create one force and also may create a counter-force of that force trying to keep everything in equilibrium.

So the flow flows. At this point, it ain't important WHY THE RIVER FLOWS. Assume that God drives it. But do not assume that God does the rest on the flow so that we can find out the truth. As the river flows, the river meets objects like stones which are strongly held by gravity and can't be moved by the river (ignore the movable ones for now). These stones counter-act the force of the flow by using energy from the gravity. When you have many big strong stone fuckers on the flow, these will RESIST to the flow. They would NOT ALLOW the flow to flow THAT MUCH. They would exert FORCE to try to stop the flow. Therefore, the stones create the action of RESISTANCE to the flow.

So far we have two parameters DEFINED BY ACTION: flow and resistance to the flow. Is this possible there are such materials that would create RESISTANCE TO THE ELECTRIC CURRENT? Yes, these materials would some kinda resist to the flow but will not be able to stop it fully. Carbon is one of these materials. One can drive electrons in a carbon but much more difficult because there aren't that many and because the strength that keeps them to the atom of the carbon is stronger (the epoxy resin is harder and drier). Again, the quantity defines the quality. Case there was one stone on the river, the resistance is very small, case there are many, the resistance is considerable, case there are huge amount of stones put together next to each other, the flow will stop. Hence, when you go to the countryside, you can throw many stones across the river and you will stop the flow. Or a better example - when you throw stones at the spring, you will eventually stop the flow.

So, the amount of carbon across the electric current (flow) would exert a reaction to the flow, called resistance to the electric current or electrical resistance. When you peel a pencil and get the carbon from the inside, you can cut one inch and put it across electric current. This one inch of carbon cylinder with a given diameter would exert whatever resistance. Two inches of carbon with the same diameter would exert a greater resistance. (For now it is not important whether the resistance is twice as strong or not.)

So far, we have defined the one and only primary electrical parameter, called Electrical Current and another secondary electrical current parameter called Resistance.

And have you ever asked yourselves what does drive the river flow. Why does the river flow? Some people would say because the river springs from the top and goes to the bottom of a given piece of the Earth. Why? Not very many people would have thought so, because they stop at that level and because the rest seems natural to them. It is because of the gravity which wants to get everything stuck to a bigger object (the Earth). So the gravity wants to get push the water down. The internal Earth forces (the Earth burns like a furnace a few yards below the surface - how and why? ask Mr. Einstein but Mr. Oppenheimer who will want to make a bomb out of the Earth) push the water up overcoming the gravity force and the water springs out of the Earth, however, there ain't no internal forces no more, so once out, the water is run by the gravitation only.

The gravitation always exists. Regardless of whether there is water or not. THE GRAVITATION IS CALLED BY PHYSICISTS A POTENTIAL ENERGY. Potentially, the gravitation has a force but it ain't never used it. Kinda useless. Like most of the governments. They have armies which ain't no one has ever used. What for? Why do the stupid people pay 90% of their taxes? To support the conservative parties through supporting the army which is supported by the conservative parties? Too many ifs in this questions. Well there ain't no even one. Thinks are pretty simple. Cut the army, cut the taxes. How does this look to use conservatism against the conservatives? (In the same fashion asholism can be used against the democratic parties. I don't know how. Go figure. (Well, figure, don't go, in this case).

So gravitation is kinda useless like navy and army. "Yes Sir, but you've just implied that gravity drives flows, how can it be useless like a University employee, then? You must be contradicting (or better: You contradict") with yourself." Yes, it is true that gravity drives the water flow from top to bottom, but no, there ain't much of a contradiction. Just wait. Gravity is useless. Gravity has only a potential force like a Brazilian with lots of Reals in the US. The Brazilian has a lot of money but no one wants nor uses nor gives even a shit for Brazilian money (Reals) - most people may give a shit or some food but only FOR FREE, as a charity, but they do NOT want, nor need, nor take the Brazilian money called Reals. The same with the gravity. The gravity is a force which is pretty useless. HOWEVER, when the Brazilian goes to Brazil, then and only then the Brazilian gets a lotta pussie. The same with gravity. ONLY WHEN THERE IS WATER OR A FLOW, THE GRAVITY MAY BECOME USEFUL FROM USELESS. In that case, the potential force of the gravity (the Brazilian Reals) becomes a kinetic force (gets a lotta pussie). So, the potential energy is useful only when it becomes kinetic and does something - gets some interaction, gets some movement, gets in motion and gets into action.

So, when the water flow (the river) flows and meets a lot of stones the water flow has a resistance which counter-acts to it AND CREATES THE OPPOSITE EFFECT TO THE ONE DESCRIBED ABOVE - CONVERTS IT'S KINETIC ENERGY INTO A POTENTIAL ONE. I. e. The water flow keeps pushing and pushing and pushing on the stones while the water flow is not stopped FULLY. Two important things PUSHES and NOT STOPPED FULLY.

Assume that the flow is stopped fully. Then it only pushes on the stones. Assume the flow is not resisted to at all. Flows fully and does not push on anything. Assume that the flow is resisted to (partly stopped) but NOT FULLY STOPPED. Then there is some push on the stones but not as strong as when the flow is fully stopped, also there is some flow but not as strong as when there aren't stones (when there isn't resistance).

Therefore, there are two type of forces: A POTENTIAL FORCE which just pushes on the stones and creates pressure and does nothing useful and the KINETIC FORCE which drives the flow.

Case a girl on the beach wants to wash the ice cream which fell on the upper portion of the tits, above the bra, and the girl has a container with water, then the container is there, the ice cream is there but nothing happens. When the girl lifts the container up - still nothing happens. While is the container lifted up, no one knows, probably to warm the water up, closer to the sun! HOWEVER, when the girl tilts the container and the useless potential energy of the water staying above the tits of the girl is converted into a useful kinetic energy which drives the water down, then the girl gets to wash the ice cream off the tits.

THE KINETIC ENERGY DOES THE WORK THE POTENTIAL ENERGY DOES NOT DO ANY WORK, JUST SITS AND WAITS.

So, the flow has a potential energy which just pushes on the stones and a kinetic energy which drives the flow through. The same about the electric current through resistance. There is some that passes through but there is a push on the device which creates the resistance, which is creates a POTENTIAL energy called a potential or VOLTAGE. And the device which creates the resistance to the electric current is called a resistor.

So, we have found another parameters of the flow: POTENTIAL ENERGY and named the device which creates the resistance a RESISTOR. So far we have ELECTRICAL CURRENT (the one and only primary parameter), RESISTANCE (with the devices who make the resistance possible called resistors) and POTENTIAL DIFFERENCE (VOLTAGE).

Ops, who farted? Who said difference what is this?

This is kinda important and nasty to explain. When one talks about potential energy one talks about a LEVEL of the potential energy too. The example of the ice cream and the tits - in case that there was another container, a 100 miles above the girl, then the gravity force of this container would have been smaller and therefore this container would have a smaller potential energy. The earth would have a potential energy of zero because things go until the earth is reached. Therefore, there is a difference in the potential energy of each object and position.

The water flow BEFORE a given stone PUSHES STRONGLY ON THIS STONE, then the strength of the flow is decreased because of SOME BUT NOT FULL counter-action of the stone, so the next stone gets a weaker push by the flow. Therefore, there is a potential force which works on the FIRST STONE and a weaker potential force which works on the SECOND STONE. Therefore, the flow has a POTENTIAL ENERGY on the first stone, higher than the POTENTIAL ENERGY of the second stone. And the current still flows. What would have happened had the second potential energy been higher the first? (Impossible but good to assume.) Then the flow would have run the other way around. THEREFORE THE DIRECTION OF THE FLOW IS ALWAYS FROM HIGHER TO LOWER POTENTIAL ENERGY AND THE DIRECTION OF THE ENERGY IS FROM HIGH TO LOW AS PER THE DIRECTION OF THE FLOW.

The same with the electrical current. The potential energy gets lower and lower with every inch of the carbon in the direction of the current flow. Thus, there is a difference in the potential energy between one point of the carbon and another when the two points are away in the line of the flow. This is called a POTENTIAL DIFFERENCE between two points or VOLTAGE.

Each point of an electrical flow has its own potential energy against any other point. In case we take a given point as a reference, we may compare all potential energies of all points against one another. Example: In case a given point has a potential energy measured with the number 5 against a second point and a third point has a potential energy measured against the second point measured with 3, then there will be a difference in the potential energy between the first and the third point equals to 5-3=2. In case there is a path between point one and point three, then there would be a flow.

How do we define the potential energy of this second point? We can randomly select a number. Just like the US Federal Reserve. Who said what the initial value of the dollar is? The US Federal Reserve! So we can say that the second point has a potential energy of 100. Then the first has a potential energy of 105 and the third - of 103. Then the difference between the potential energy of the first and the third point is 105-103=2. So the potential difference is NOT AFFECTED BY THE VALUE OF THE REFERENCE. Why do we not call this potential energy of the reference ZERO! And this is the so called "GROUND" of the electrical circuits. The word ground ain't got nothing to do with the electrical potential of the ground's core. Someone just chose it. Every circuit has a point which is called ground. NO TWO GROUNDS HAVE THE SAME POTENTIAL ENERGY UNLESS CONNECTED WITH A RESISTANCELESS FLOW PATH (METAL) or unless it happened to be coincidental. So the ground of one circuit has got nothing to do with the ground of another circuit - yet another reason why the term ground is not good but this is how it has been decided to do. We just have to accept that there are many grounds instead of one.

"Well, you've just said that there are different grounds and that the ground point has been chosen randomly, what is the difference then between the electric circuitry and the US Federal Reserve. The difference is that the electrical circuit has at least one stable point.

So we have some things, can we make a circuit. Yes, we can.

We can make a circuit ONLY WITH THE PRIMARY ELECTRICAL PARAMETER - THE ELECTRICAL CURRENT:

We have a magnet, a metal spiral (serpentine) (called with the stupid name SOLENOID) and a long wire with which we can just connect the two points of the spiral (solenoid) and keep the wire as straight as possible. Then we move the magnet. What happens? NOTHING EXCEPT THAT WE HAVE OUR FIRST ELECTRICAL CIRCUIT.

May I congratulate the speaker of the parliament and the Chancellor of the Exchequer with the high prices of cigarettes as I go for a break to have a smoke (have a quick crap)?

Remember one nasty thing, though. The water flow can be slowed down with resistance on it. The electron flow can be REDUCED but never slowed. Kinda strange. The scientists claim that the electrons flow with the speed of light ONLY and only with the speed of light. The modern scientists claim that the electrons exchange their energy and this exchange happens with the speed of light. Hopefully we can disregard that the flow of water is slowed down and assumed that always flies with the same speed disregarding the effect of slowing down when there is a resistance. In the modern physics terms, the resistance (the resistors) decreases the amount of energy which passes through the resistors but not the speed.

It is kinda similar to a flow of same cars WITH STUCK GAS PEDALS on a road. The cars cannot be slowed down. They can either move or stop (smash). In case of a resistance (one lane blocked with a concrete barrier) SOME of the cars will continue with the same speed, others will smash into the concrete barriers (assume they cannot change lanes).

Back to our first electrical circuit. We move the constant magnet in the two directions along the solenoid and we generate electric energy by moving the magnet from one end of the solenoid to the other in the short distance defined by the length of the solenoid. Then the dragged electrons continue to travel (assume alike balls by inertia without any resistance on their path) along the wire. Then they re-enter the solenoid. (Assume the balls have very little inertia or not at all when they re-enter the solenoid (the acceleration point). Then they are accelerated by the magnet. Then they travel the distance again. Then they enter again and are accelerated and travel the distance again. And this continues until we keep moving the magnet. When we move the magnet in one direction, the electrons move in that direction. When we change the direction, the electrons cannot continue the same way due to the small inertia they have and the much stronger force we make by moving the magnet, so the electrons change direction and then again and again and again. This way we sit on a chair on the desk and move the magnet and the electrons travel miles and miles and miles and return back. So far they do not do nothing else except they travel the distance.

What happens when we introduce resistance on the path of the electrons Then the electrons will exert pressure on the resistance device (the resistor) when they meet. The pressure will be decreasing along the resistor because with every thousand of an inch passed, the electrons see less and less resistance on their path. Thus there will be a difference in the PRESSURE at the entry point and the exit point. This is the so called difference in the potentials of the two points and thus there is a VOLTAGE across the resistor. When we change the direction of movement of the magnet, the entrance of the resistor becomes an exit and the exit becomes an entrance. Then the pressure changes the direction too. The new entrance has higher pressure then the new exit. Then, when the magnet changes the direction again, the entrance and exit are changed. And again and again and again. Therefore, the pressure, the potential energy and the voltage look like also CHANGE DIRECTION. Sometimes one point has higher potential then the other, sometimes it is the other way around. The concentration here is on LOOK LIKE. The potentials are not currents. The do not fly. They just increase and decrease.

Now we have our second electrical circuit and the first one which does something. What. Pretty much same as before but not exactly. Just moves electrons one way and the other. Just the electrons travel the distance. BUT the electrons see resistance. They overcome this resistance and continue. They also build pressure points and create potentials and voltage across the resistor. They also hit the resistor AND LOOSE ENERGY but not speed. The loose the energy which they have acquired from the moving magnet, i. e. from the muscles of the person who moves the magnet.

When they hit the resistor they WARM UP the resistor. This is like a strong pressurised gas which flows through a narrow pipe. There is a friction between the pipe and the air and this friction warms the pipe.

In case we have an adequate resistor, then the resistor will warm up so much that it will become red and may melt down. In case we adjust the movement of the electrons just to warm up the resistor until it becomes red but not to melt it, then we get warmth and light. In case we put this hot resistor in a sealed jar with some special gas, the resistor will ignite the gas and we will have a light bulb. The gas will "ignite" but will not burn out because there isn't any oxygen. Assume that the gas gets ignited at the point of contact with the hot resistor but doesn't burn and goes away from the resistor where can cool down and gets extinguished, then circulate to the hot resistor and then ignite and gets extinguished and the ignite and then circulates and gets extinguished and over and over and over again and again and again. The trick that the gas gets ignited but not burned has something to do with some transitional properties of the gas similar to the resistor which gets hot but doesn't melt. So, the gas takes the energy from the hot resistor and gets hot, then the gas takes the energy of the resistor and cools the resistor down so we can put more energy into the resistor without melting it and then the gas takes this more energy, cools the resistor and ignites stronger and then we can put more energy until a given point when the gas will not be able to take this much energy and the resistor will melt down. However, in case we stop increasing the energy before the resistor melts down then we will have a continuous process which CONVERTS THE ELECTRICAL ENERGY INTO LIGHT ENERGY. Remember, energy cannot be generated. Energy can only be converted. So, the magnet and the solenoid convert the muscle energy into electrical energy (flow of electrons through a resistive material which wants to prevent them from flowing but the electrons are stronger due to the fact that the muscles of the person who moves the magnet are stronger), then the resistor is warmed up and in a way facilitates a conversion of electrical energy into warmth, i. e. converts the muscle energy of the person who moves the magnet into warmth, then this warmth is converted into light by the gas in the jar and thus the energy of the muscles of the man who moves the magnet is converted into light.

Therefore we have built two things: A GENERATOR OF ELECTRICITY AND A CONSUMER OF ELECTRICITY. The generator uses some other energy and converts it into electrical energy. From this point on everything is electrical. The consumer takes the electrical energy and converts it into another type of energy. From this point on nothing is electrical except in a case when the consumer would convert the electrical energy also into electrical energy passing through some other energy, as for example a transformer which takes electrical energy, converts it into a magnetic energy with its primary coil, moves that energy through the secondary coil which, in turn, converts the magnetic energy into electrical one.

However, for now remember one thing: we have a generator and a consumer. The generator creates electrical current. This electrical current passes through a resistor. There is an electrical voltage built across the resistor.

Also remember: Electricity can be created by a magnet which is moved near a wire. To increase the amount of energy we generate (TO INCREASE THE EFFICIENCY OF THE CONVERSION OF THE MECHANICAL ENERGY INTO ELECTRICAL WITH AS LITTLE LOSS OF MECHANICAL ENERGY AS POSSIBLE) we roll the wire into a serpentine, called a solenoid. We can take it one step further. We can put a coil instead of the serpentine (the spiral) and the coil would provide with a possibility for even higher efficiency.

Electric current is the flow of the electrons in a given direction. The electrons flow with the speed of light ALWAYS and regardless of the resistance and can be assumed at our level as having NO inertia. The electrons can change direction instantaneously. Thus the electric current can change directions. This is called Alternating Current (AC).

The resistor converts SOME of the energy of the electric current of electrons from kinetic into potential, thus building a pressure across the resistor which is called ELECTRIC POTENTIAL DIFFERENCE or VOLTAGE.

IGNORE THAT THERE IS A CONSUMPTION OF ENERGY INTO THE RESISTOR. ASSUME THERE ISN'T AND ASSUME THAT THE ONLY THING THAT THE RESISTOR DOES IS TO CONVERT SOME OF THE KINETIC ENERGY OF THE ACCELERATED BY MOVEMENT OF MAGNET ELECTRONS INTO POTENTIAL ONE. I. E. TO CONVERT ELECTRIC CURRENT INTO VOLTAGE!!!

For purposes of ease to create electric circuits we can say the THE BIGGER THE POTENTIAL (THE PRESSURE) AT A GIVEN POINT AS COMPARED WITH THE POTENTIAL (THE PRESSURE) AT ANOTHER POINT, THE MORE POSITIVE THE POTENTIAL OF THE FIRST POINT. Here we define another complication: POSITIVE POTENTIAL. To make the simple things more complicated, the engineers decided to make up another term: DIRECTION OF THE VOLTAGE where the direction of the voltage is said by the inventors to be I. E. FROM A POSITIVE POTENTIAL TO A LESS POSITIVE POTENTIAL OR TO A NO POTENTIAL.

To confuse the people even more and to keep their precious jobs, the engineers have decided to take a given randomly selected point as a point which engineers DECLARE to have a ZERO potential. For even further confusion, they call this point GROUND. Every GROUND of every circuit is different from one another unless connected. There are two ways to connect grounds, either with a wire or through another object. Planet Earth is used as such an object more often. Hence the term GROUND. PLEASE, DO NOT TAKE THE CONNECTED POINTS CALLED GROUND OF EACH CIRCUIT. Thus AS CONNECTED. ASSUME THEY ARE DISCONNECTED AND EACH GROUND IS DIFFERENT AND AIN'T GOT NOTHING TO DO WITH ANOTHER GROUND, I. E. EACH CIRCUIT IS SEPARATE FROM ANOTHER.

The engineers DECLARE that a given point in the circuit is always stable and everything changes around this potential but the potential is always said to have the same stable number of zero. THIS IS PERFECTLY LOGICAL AND LEGAL AND DOES NOT SCREW ANYTHING UP. In case you have many objects moving relative from one to another, one can pick any object up and say that this object does not move but all others move around it and this is perfectly OK because even when taken that this object moves this object moves RELATIVE TO WHAT? Relative either to nothing or to any other object. By selecting this object as non-moving we just screw that the objects moves relative to NOTHING. Not that much of a screw up, ain't it.

To confuse the economy even more the economists avoided the possibility to screw nothing and screwed every other person. However, some people seem to have realised this partly or fully and have decided to select a given currency as stable and to assume that every other currency moves around also, to assume that every commodity moves price up and down but the stable currency never changes. This stable currency was selected to be the US Dollar. This has improved the economy of this countries tremendously as compared to what it would have been without this assumption and without any radical change as for example a non-money society. Now a days, Euro is used as a stable currency in most countries, i. e. Euro is the stable point, Euro is the reference and Euro is the ground.

As said above: ANY POINT CAN BE SELECTED TO BE THE GROUND POINT WITH A STABLE POTENTIAL WHICH NEVER CHANGES. ALSO ANY NUMERIC VALUE CAN BE GIVEN TO THIS STABLE POTENTIAL AND THIS NUMERIC VALUE WILL NEVER CHANGE. The engineers have decided to give a numeric value of this point a ZERO. Thus, every point with a higher potential then the potential of this GROUND point is said to have a POSITIVE POTENTIAL AND IS GIVEN A NUMERIC VALUE. Every point with a smaller value then the potential of this GROUND point is said to have a NEGATIVE POTENTIAL AND IS GIVEN A NUMERIC VALUE. The numeric values are used by engineers in order to put a mathematical control over the electric circuitry which will facilitate them to perform a better analysis and control.

The numeric values given to the electrical current characteristic the FORCE of this electrical current and the value of this FORCE of electrical current and is calculated on the basis of a stable value postulated by the INTERNATIONAL SYSTEM OF MEASUREMENTS AND WEIGHTS in Paris, France and MUST be used in every country in the world. This basis is called AMPERE after the name of a famous scientist and engineer who worked in the field of electricity long time ago when the electricity was discovered and pioneered. The basis for ELECTRICAL PRESSURE (POTENTIAL DIFFERENCE, VOLTAGE) is postulated by the same organisation and is called VOLT after the name of another similar scientist and engineer. The basis for electrical resistance is called OHM after another similar scientist and engineer and is also postulated by the same organisation. H is not pronounced in OHM.

The value of 1 AMPERE is also postulated by the same organisation. An electrical current with twice as strong force is to have twice as many AMPERES, i. e. the basis is applied in linear way. The same about the VOLT and OHM.

AMPERE is abbreviated with A. VOLTS with V. OHMS with GREEK O, a letter of the Greek alphabet called by the Greeks Omega.

Before the end of this first part of this writing, I must mention the favourite: The basis for distance postulated by the same international organisation where there are a lot of US scientists and engineers and signed and approved by the US government is called a METER and is abbreviated with m. Similar about the basis for weight - GRAM, abbreviated with g and the measure for volume of fluid (fluid combines liquid and gas into it and could mean either liquid or gas or the two thereof) called LITRE abbreviated with L.

Now, here comes the favourite: ANY USE OF ANY OTHER MEASURE FOR THESE OR OTHER QUANTATIVES THAN THE MEASURES DECLARED BY THIS ORGANISATION AND AGREED UPON BY THE GOVERNMENT OF THE U. S. A., IS AGAINST THE US LAW AND THE WORLD LAW. Remember this when you purchase the next pint of beer next time.

## **Resistors and Resistance**

There are two basic resistor circuits. These are also used to analyse complex schematics because every schematic can be broken down into multiples of combinations of these two basic resistor circuits.

The two basic resistor circuits are known as PARALLEL RESISTOR CIRCUIT AND CIRCUIT OF RESISTORS CONNECTED IN SERIES.

Resistors connected in series contains two or more resistors which, in case of two, have one of the ends of each of them connected to one of the ends of the other one. They are chained like a train one after another.

The current passes through the first resistor and creates voltage across. Then passes through the other resistor and also creates voltage across.

NOW PAY ATTENTION: EXTREMELY IMPORTANT: THE CURRENT THROUGH ALL OF THE RESISTORS CONNECTED IN SERIES IS THE SAME.

It is difficult to explain why. I will, therefore, go for a cup of coffee. See whether I can explain it in a while.

Again, when there is a trouble, the speed of light comes to play and the so called immediate response of circuit which do not contain capacitors and inductors (coils).

So, have yourselves on the go. The water flows passes through the first barrier of stones (resistors) then the speed of the flow decreases and the second barrier of stones is reached with a decreased speed and then the speed of the flow decreases again. Similar things should happen with the electric current and probably they do happen but with a negligible effect and/or at the very beginning for a negligible amount of time.

REMEMBER: The electric current cannot decrease speed. It either flows with the speed close to the speed of light or doesn't flow at all. (Again: I do not know why so is and I do not care. Einstein and Oppenheimer may now. Modern physicists claim that the speed of the electrons is VERY CLOSE BUT A BIT LOWER than the speed of light. They also claim that electrons do not fly but just exchange energy. What is the speed of this energy exchange? Is this lower than the speed of light but very close to and higher than the speed of what they call FREE ELECTRON (an electron that breaks away from the atom and travels)? They claim that the free electrons have been proven. Even that the CRT monitor works that way. Is that so? Do they really get a beam of free travelling electrons or some kinda a bit more concentrated electromagnetic wave with a direction?)

I DO NOT GIVE A SHIT ABOUT QUANTUM MECHANICS NOR ABOUT THE THEORY OF RELATIVITY WHICH I THINK AIN'T TRUE.

I do not care what you believe in, I just prefer that you do not care about so low level of understanding, not only because I do not know the answer but because the subject of this writing is electronics for musicians and not quantum mechanics for musicians.

In electronics and in engineering, engineers know how to cut the bullshit. They ain't interested in how the resistor works, they just know this is a resistor and the resistor creates a voltage drop when current passes through. They don't care why. From this point on, they design their circuits and leave quantum mechanics to more knowledgeable and more useless.

When a big shot classical musician with many degrees from reputable conservatory of music plays a piece of sheet music, that musician don't give a shit as to why the musical ladder has been divided into twelve equal intervals called half-tones neither does the said give a shit as to why some are called tones, some half tones and the major ladder starts with three full tones and the minor with one tone and one half tone. The musician just knows that this sign on the sheet (note) requires that the neck of the musical instrument is pressed on that place with one of the hands while the string is activated with the other. Also, the said thinks how to fuck whoever member of the orchestra, hopefully from the opposite sex.

Of course, another reason not to go to a very low level is because the engineers do NOT know many things and they are not supposed to.

SO ASSUME AS AN ACXIOM THAT THE ELECTRIC CURRENT PASSES THROUGH IMMEDIATELY AND CANNOT BE SLOWED DOWN BY RESISTANCE!

Then the electric current passes immediately through the two resistors and continues with a speed of infinity and can pass any distance for no time. This is pretty much similar to seeing one resistor which is made as a sum of the two. The distance on the wire between the two is passed for no time so is the whole distance from the source to the resistor as well as through the resistor.

Does the above make the point that the current through the two resistors is the same? To some extend explains something.

Another way to find a logical explanation is that the current ain't got nowhere to go except through the wires, resistors and solenoid/coil. So therefore it must be the same in amount. Can’t be lost after one of the resistors and before the other. Ain't got no path to travel through.

Here is a cool explanation: Think not of the speed of the water flow but of the amount of water. In case of stone barriers (resistance) the amount of the water is the same through the first as well as through the second barriers. The water just ain't got nowhere to go. (Disregard spillage and overflow of the banks, assume the banks are high enough from higher water in the spring as opposed to the summer).

Cool. NOW TRY TO REMEMBER BECAUSE THIS IS INCREDIBLY IMPORTANT FOR THE FUTURE: THE ELECTRIC CURRENT THROUGH A GIVEN PATH OF THE ELECTRIC CIRCUIT IS THE SAME NO DIFFERENCE WHETHER THERE ARE RESISTORS, CAPACITORS AND/OR INDUCTORS.

What does a path mean? A path is part (or the hole) of the schematic which DOES NOT BRANCH and the current ain't got nowhere to go except to pass through the whole path without any possibility no single electron to escape. The path can have resistors, can have capacitors, can have inductors and can have wire but goes from one point to another without diversion and intersections. THE CURRENT MUST PASS THROUGH ALL OF THE COMPONENTS ON IT AND THERE IS NO WAY AROUND IT OR MUST NOT PASS AT ALL BUT CANNOT PASS ONLY THROUGH SOME COMPONENTS AND AVOID OTHERS.

Components of an electric circuit are ONLY resistors, capacitors and inductors. The power supply is not to be considered a component. The power supply is not to be taken into consideration in analysis of electronic circuits except in certain exceptions. We will see why. We will see how the engineers have functionally built different circuits without interaction between one another and the interaction may, in case necessary at all (will not be in most of our cases), be separately calculated without analysis of the combined circuit but by using the analysis of each of the circuits.

This is called a functional approach towards engineering and is very important and helps simplify and speed up BUT, be careful, may lead to misleading and mistakes.

The functional approach is very similar to a musician who studies a piece of music. The musician may decide to learn the piece in smaller pieces and then all the musician have to worry about is the TRANSITION from one piece to the other.

Back to the circuit: So, we have a generator of electric current defined by a moving magnet around a coil or a solenoid and two resistors in series. The generator pushes the electrons through the wiring to the first resistor, they pass through and get reduced and build pressure on the entry point (voltage across the first resistor) and then goes to the second, builds pressure at the second, gets reduced as it passes through then goes through the source and continues BUT DOES NOT GET REDUCED any more. Only the first pass. Once defined how much can pass this is what can pass and no more. In other words, when you put a valve on a water flow, when you fully open the valve you get a flow. Then when you close the valve by half, you reduce the flow. ONCE REDUCED, the flow continues at the same rate and does NOT continue to get reduced.

Now, what is the voltage across the resistors? In case the resistors are the same the voltage will be the same: THE SAME CURRENT FLIES THROUGH THE SAME RESISTANCE, THEREFORE THE PRESSURE CREATED ACROSS THE RESISTORS MUST BE THE SAME.

What happens when the resistors ain't the same? Whatever happens when the necks of the guitars ain't the same? It's a bit more complicated. We'll get there. Don't rush. We have to pass through mathematical analysis of the quantity of the electric current (and voltage) and one of the things to worry about is what Mr. Ohm has described.

For now think logically, NOT mathematically: Case you have the same current through different resistances (PLEASE NOTE AGAIN THAT THE CURRENT IS THE SAME NO DIFFERENCE WHETHER THE RESISTORS ARE THE SAME OR ARE DIFFERENT), obviously, the more difficult to pass the more the pressure (voltage) and the easier to pass the lower the pressure (voltage). And this is the first logical derivation of Mr. Ohm.

More, Mr. Ohm claims that this dependence between voltage and current is linear and depends on the quantity of the resistance. How can I prove this second point logically? I don't know. I don' think there is too much of a way to prove the linearity logically. Philosophically, yes it is possible to observe the power of one factor in primary derivations and bullshit alike but that ain't logic. Philosophy ain't got nothing to do with logic but might as well want to use it from time to time – it may be helpful.

REMEMBER: THERE AIN'T NO NOTHING IN THE WORLD EXCEPT MOVING MATERIALS. ALSO REMEMBER: THERE AIN'T NOTHING IN ENGINEERING EXCEPT SIMPLE LOGIC. SAME APPLIES TO MUSIC.

That's why I like musicians.

BTW, do you know a girl musician who ain't got no male friend at the moment?

So, what does linear mean. Linear is when with equal changes of one of the parameter the other also changes equally. No need to change at the same rate, as long as, towards itself, towards the previous changes of itself, every change is equal.

Here is a simple linear function:

x=3\*y

In case:

y1=1, then x1=3

y2=2, x2=6

y3=3, x3=9

y3-y2=1

y2-y1=1

Therefore y1, y2 and y3 have the same difference between each neighbouring values.

What happens with each CORRESPONDING neighbouring values of x?

Have a look:

We said y3-y2=1, what happens with x3-x2? x3-x2=9-6=3.

We said y2-y1=1, what happens with x2-x1? x2-x1=6-3=3. ALSO EQUALS 3!!!

So for equal increases of y we've got different but also equal increases of x. This is called LINEAR DEPENDENCE OF X ON Y AND OF Y ON X. The same is called when the for equal increases of y we've got THE SAME AND, OF COURSE also equal increases of x.

And the constant number 3 is called the COEFFICIENT of the function with x and y being the variables because we can change their values to see what happens but we can't change the coefficient.

So Mr. Ohm has figured out that VOLTAGE AND CURRENT THROUGH ANY RESISTOR ARE IN LINEAR DEPENDENCE AND THE COEFFICIENT DEPENDS ONLY ON THE RESISTANCE AND NOTHA ELSE!

## **Ohm**

Mr. Ohm (or others) decided to abbreviate this coefficient with R. Again, some have decided to abbreviate voltage with V and to use I for current.

So the Ohms law can be written:

VOLTAGE=RESISTANCE \* CURRENT

or

U=R\*I

You can remember this that way. In case you do NOT know Ohm’s law you will be tried in court by a jURI. And the sign = is after the first letter as normal in mathematics (or better in the middle of the word). So jURI, hence jU=RI, hence U=RI.

Now shall we go more? We have said that FOR A GIVEN RESISTOR, the more current the more voltage. HOW ABOUT IF WE HAVE THE SAME CURRENT WITH DIFFERENT RESISTANCE. Well, then the bigger the resistance, the more pressure the current builds (the more the voltage). This can also be seen from the above formula. When we decide to twist the formula a bit and to decide that the current (I) is our CONSTANT COEFFICIENT and we just change the resistor (R) with different resistors with different values, the when I is the same, then the higher the R the higher the multiplication product R\*I, then the higher the voltage.

Now, what happens when the voltage is constant (VERY IMPORTANT BUT A BIT TOO EARLY FOR THIS) and the resistor and the current change: then when you have a pressurised air tank, THE MORE YOU OPEN THE VALVE (LESS RESISTANCE) THE MORE AIR FLOWS OUT (HIGHER CURRENT).

How can that be found with the formula. One of the way is to move the R on the other side of the equation:

U/R=I

and to represent it better:

I=U/R

When U is constant, then the higher the R, we divide U by a higher divider then the division gives a lower result.

And what happens when we change I:

Then we can take the original U=R\*I and move I to the other side:

U/I=R

and turn the formula around for a better view:

R=U/I

Then the higher the I the lower the R.

Then can we use the formula to design something? Yes. For example: When the current that we generate is 3 AMPERES, what resistor shall we put to achieve 30 VOLTS?

U=R\*I

30=R\*3

30/3=R

R=30/3

R=10

Therefore, we need to have a resistor with a value of 10 OHMS.

How do we know that we will push 3 AMPERE CURRENT THROUGH?

We can use an AMPEREMETER which will show how much current we put through. Then we can adjust our magnet and muscle strength to ensure the AMPEREMETER reads 3 AMPERES.

We can also measure the voltage by a VOLTMETER and the resistance by an OHMMETER.

How much force do we apply? How much muscle energy do we use? To answer this we need to see how to find out what power and energy we need.

What is the difference between power and energy?

Energy can neither be made nor lost. Energy can only be converted from one type to another. The same applies to the materials.

About the magnet and the person who drives the magnet: There is only two sources of energy on the planet earth: The sun energy and the gravitation. Due to the sun energy and the gravitation, the Earth was possible to create organic and non organic materials (inclusive of water) and atmosphere. These make possible for humans to gain energy from their food and to use this energy as they want. The person who moves the magnet uses this energy to convert it to electrical energy.

Electrical energy is energy which may be used in order to do something, some work. In the example of the connection of the two ends of the generator (the solenoid or coil) just moves the electrons from one end to the other and does nothing else. Therefore, there is some energy necessary to be provided by the magnet operator in order to move the electrons. This energy is negligible and is not to be taken into account. The engineers are interested in the work done by the electrons, not in the energy for these to be moved. The latter would be a subject to quantum mechanics, particle physics, theory of relativity and other. This is alike a company which supplies goods between two places. The company is not interested in the movement of empty cars but in the movement of loaded cars, this is when the work is done. In case one orders a truck full of goods and the truck arrives empty, this is not very useful for the person who ordered it.

When there is at least one resistor, connected to the generator, the current passes through the resistor and builds some pressure (voltage) across the resistor. When a water pump passes water through a small hole, there is a pressure built across the narrow hole. This pressure acts back on the pump and in case the pressure is too high, the pump will not be able to keep the increase rate of the pressure. When we replace the pump with a person who pumps water with a manual pump (better to pump beer) then the higher the pressure the stronger the person has to pump.

When the electric current builds pressure (voltage) across the resistor, the effect is similar. This pressure is a barrier which has to be overcome by the generator. I. e. the electrons can't pass so easily through the resistor as through the wire without any resistance (practically, the wire is considered to have a zero resistance, theoretically every material has a resistance which depends on the material (how freely the electrons can travel through – in this case, the more electrons there are and the easier it is to break free from the atom, the easier to drive them through – alike the metal balls and the resin)) because there are a lot of electrons before the resistor and they impede each other to pass through as well as they impede the new electrons which come. So, there isn't any build up or clog in some materials (metal) called conductors but there are electrons which sit and wait and would easily break away in case of a magnetic field to drive them. However, they can go through but there aren't that many so that build up occurs. The newly arrived can pass through too. This is like a divided highway where the cars can drive quickly through when there is a reason for so (a rock concert, for example). The cars just sit and wait on the driveways and are easily attracted by the rock concert for which they drive on the divided highway and also other cars also drive on and others come from other towns and are still able to drive. However, in case of a problem on the highway, one of the lines may be blocked and then the cars can't pass through freely and quickly but there is rather a pile build-up on the road. Some of the cars may wish to reverse direction at the nearest exit and drive in the opposite direction.

The pile build-up of electrons does not allow themselves as well as new electrons to pass so easily. The electrons which are at the build up try to either slow down or push the new electrons backwards towards where they came from. In order to keep them on the run, the generator have to push more and more electrons to counteract the force of the build-up electrons and, case you will, to push them through the resistor. This is alike when stuck cars are hit by new cars, the newly arrived cars push the stuck cars and move them ahead. In Hollywood, they like a trick when there are cars which blocked a given street and there is a car which wants to pass and then the car will push the stopped cars with a great force to move them though they are stopped. Usually, the car which pushes on is a powerful truck.

To get more and more electrons, we have to pick them from the material of the generator by pushing the magnet stronger. That way a stronger current will be generated (more electrons pushed through the circuit). This stronger current have to pass through the solenoid or the coil because there ain't nowhere else to pass through in order to continue to circulate. Electrons do not leave the circuit and no new electrons come from the outside to the circuit. When electrons pass through a coil or solenoid they generate a magnetic force outside of the coil or the solenoid. This force is opposite of the force which drive them through (the magnet which moves). Thus, the person must drive the magnet with a stronger force and use more muscle energy in order to make the current pass.

Even when current passes through wire, the current will generate a magnet force. The straighter the wire, the weaker the generated force. The effect of a generation of magnetic force by the current is the opposite of the effect of the drive of electrons through the wire by a magnet.

Why do the electrons which move generate magnetic force? Why is the force in the opposite direction to the force of the magnet? The explanation may be a bit difficult and may be a subject of quantum mechanics. A simplified representation may prove to be impossible of very difficult. A simplification may be to think about the water and metallic balls which acts on the pipes and tries to expand them.

Another way may be to realise that the metallic balls get magnetised by a magnet when they are put close to it. In other words, when one put metal to a magnet, the metal gets magnetised. When one wants to pick a magnetised metal with a magnet, then the two will either attract stronger or repel. When one tries to put two magnets together they may push each other away or get stuck stronger than a magnet and a piece of metal, as depends on the polarity of the magnets.

Hence, what is important for the musicians is to try to keep their guitar cables as straight as possible (although they are shielded by a grounded copper around) and as far away from any coil or solenoid through which electrical current passes. The problem is that the coil/solenoid where the current passes through will also release a magnetic force which in turn will generate current in the guitar wire and thus drive current through which will add/subtract to the current which passes through the wire (generated by the guitar humbuckerer) and thus add NOISE to the guitar sound. Usually, the transformers in the power supplies of electrical and electronic equipment (inclusive the musical equipment) contain coils that generate magnetic field which in turn generates electric current which is higher where there is any coil/solenoid/turned wire SUCH AS THE HUMBUCKERER, THE LOUDSPEAKERS AND THE GUITAR/MUSICAL INSTRUMENTS CABLES (THE MORE TURNED AND TWISTED, THE HIGHER THE CURRENT.

The shields will reduce this effect. However, the humbuckerer cannot be shielded.

The humbuckerer is kinda similar to the movable magnet. The humbuckerer is an isolated wire rotated many times (a coil) around constant magnets. The strings are metallic. When the player activates the strings, these start to MOVE, to vibrate in alternating fashion. This vibration TRIES TO MOVE THE MAGNETS: ALIKE A METAL OBJECT (HAMMER) WHICH PASSES NEAR THE MAGNET : THE HAMMER CAN MOVE THE MAGNET DUE TO THE MAGNETIC FORCE OF THE MAGNET WHICH WANTS TO CATCH THE HAMMER. Note that the same way one can pick metal objects with a magnet, one can pick a magnet with a metal object. The same way the magnet moves the balls, balls can move magnet(s). A strong current of balls, shot continuously from a pneumatic pump which passes close to a magnet will try to move the magnet with the current.

The strings try to move the magnet(s) of the humbucker but the magnet is strongly secured on the guitar. So, what moves is the magnetic field. Assume that the magnet is a laser beam. Assume this laser beam is always shined at the moving string by some kinda system. So, when the string vibrates, the beam will also vibrate and move one way and the other in an alternating fashion. The same with the magnet force which kinda connects the string and the magnet by attraction from one to the other. When ones hands are connected to the prison bar with chains and one moves hands, the CONNECTORS (the chains) move too.

So, when this magnetic force moves and vibrates, that magnetic force moves and vibrates CLOSE TO THE COIL OF THE HUMBUCKER. FROM THE POINT OF THE SECURED AND NON MOVABLE HUMBUCKER, IT IS THE SAME AS SOMEONE WILL MOVE THE MAGNET CLOSE TO THE HUMBUCKER COIL. The humbucker coil doesn't care whether the magnet is moved or the magnetic force is moved another way. AS LONG AS THERE IS A MAGNETIC FORCE MOVED AROUND A COIL (WIRE) ELECTRIC CURRENT WILL BE GENERATED WITHOUT ANY DIFFERENCE WHERE THE MAGNETIC FORCE COMES FROM AND WHO/WHAT MOVES IT.

Hence the sound. Note, the humbucker cannot be fully shielded because otherwise the string will not BE SEEN by the magnet. This is alike to put an opaque surface on the path of the laser beam. Can't go through.

BECAUSE THE HUMBUCKER CANNOT BE SHIELDED AND BECAUSE THE HUMBUCKER MUST BE MADE SENSITIVE ENOUGH TO DETECT THE MOVEMENT OF THE STRINGS, THE HUMBUCKER WILL CONVERT NOT ONLY THE MAGNETIC FORCE GENERATED BY THE STRINGS BUT ALSO ANY OTHER MOVABLE MAGNETIC FORCE AROUND NO DIFFERENCE WHERE IT COMES FROM.

When the electrical current from the mains passes through the coils of the power supply transformers of the musical equipment, this current generates moving magnetic force which may be powerful enough to reach the humbucker and hence the noise. Because the electrical current from the mains which passes through the coils of the power supply transformers alternates with 50 or 60Hz (changes direction 50 or 60 times per second) where the number of alternations (the frequency of alternations, the frequency of the mains electrical power) is 60Hz (60 cycles as the old engineers would say) in North America and 50Hz in Europe. Hence the musicians who travel to Europe and bring their equipment which is designed to reduce 60Hz noise would have more noise in Europe unless their equipment is designed to reduce the noises with either of the frequency or the band carries their own generators or uses European generators purchased from the US or European equipment.

So, the same (but opposite in direction) way as a magnet moved near a wire moves the electrons inside the wire, the electrons that travel through the wire would try to move the magnet. The more curved the wire is the stronger the two effects. Coils would experience the strongest effects.

Think of the electrons as of a huge number of very small, miniature magnets or magnetised metallic balls.

The above is true as far as the quantum physics is concerned. The electrons have negative electrical charge and emit electromagnetic field (just like a magnetised metallic object). Some may say that the electrons rotate around the atom and around themselves just like the Earth around the Sun. Hence some look for similarity between the macro space and the micro space. Whether true or false, I ain't much too sure.

So, the electrons are not only movable particles but movable magnetic particles. More, the electrons have an electric charge.

What is an electric charge? Pretty much similar to magnetic force. When a stick made out of amber is rubbed with a cloth, the amber stick starts to attract materials just like a magnet would attract metals. Therefore, another force exists in the Universe, called electrical force. Some materials can attract other materials not by magnetic force but by electrical force. The materials charged with this non-alternating (static) force are said to have static electrical charge. The said can be discharged (zeroed) when near another (not charged or oppositely charged) object and a spark is generated. Expect from the spark, it's kinda similar to the two magnets, either strongly attracted or repelled by each other as depends on the polarity. Electricity also have polarity.

Why does static electricity appear? Most likely because static electricity has something to do with concentration of electrons with easy to discharge energy on the surface of the amber stick and other materials.

Static electricity is a reason for three interesting things. The lightings, the sparks generated when girls undress a synthetic pullover and one of the ways to damage electronic equipment.

Although the second is more pleasant then the third, it is a subject of this writing to concentrate on the third in case we can.

It is early to mention now, but some electronic components built by MOS and CMOS technologies (MOS stands for Metal Oxide Semiconductor) are extremely sensitive and can be destroyed by electrostatic discharge as for example from the fingers of the person who touches these.

The static charge on the fingers/skin of the person may be created not only by the synthetic clothes but also by walking mainly (but not only) on the synthetic carpets. This is why the electronic technicians and assemblers wear special conductive shoes and the floor is painted with conductive paint and may be grounded.

The static charge will be discharged when an object with a different charge and larger size is touched. This object may be conductive, non-movable and grounded. A good object to touch before touching electronic components is the chassis of the equipment part of which the component is. Other metallic objects would be the handles of the door, pipes etcetera.

Thankfully, the engineers also know about this effect and have taken the necessary precautions, for which, they have to often sacrifice the quality of the circuit and they are not very happy about that. (Most engineers and technicians would refer at the precaution statements as BULLSHITS.) However, DOESN'T HURT TO DISCHARGE BEFORE A TOUCH ON THE ELECTRONIC EQUIPMENT.

Even when you know that the electronic equipment is supposed to have been built by a non-sensitive technology in its main functionalities, in now-a-days equipment, there is often a mixture of sensitive and non-sensitive technologies, for example most of the musical equipment may have a microprocessor inside and most of the microprocessors are built by MOS technology thus it is better that electronic equipment is not touched before a touch on a large metal object.

MOS technology can be destroyed by applying voltage at the entrance higher than the voltage at the power supply inputs. The said has practically infinite input impedance to ground (supply) and there is no path for the current to pass except through the component. (It is too early to discuss these things.)

Also, avoid synthetic clothes. Rubber shoes is difficult to be avoided and also, these have important protection as insulation when one touches the phase wire of the electrical system – no current can fly through the person because there ain't nowhere to fly – the rubber shoes break the circuit.

So back to the power and energy. When there is a resistor connected to the generator (magnet and coil/solenoid) there is a build up of pressure (voltage) across the resistor which pressure tends to impede the electrical current and thus stronger push on the magnet is required, i. e. more energy is required. Everywhere where there is a CURRENT AND VOLTAGE, THERE IS A POWER. When there isn't any voltage, the current freely travels through the wires and there is no need for power (theoretically at all). When there isn't any current but there is a CHARGE of voltage (pressure) as on the surface of the amber stick, then nothing happens – the voltage just stays there as a potential energy and doesn't get discharged, i. e. doesn't get converted into kinetic energy. This is like a stone that stays on the top of the mountain – nothing happens. No power. When the stone is pushed from the top of the mountain, then the potential energy of the stone (due to gravity) gets converted into movement (kinetic energy) and thus a huge power is available. So when the charged object is away from other objects (no current) then the released power is zero. When the charged object touches another object, then current flies and there is power.

So with the availability of one or more resistors, more power is needed. So what is this power needed for? It can't disappear (power does not disappear and does not come from nowhere). The standard answer is that the power from the generator (muscle power from the person who pushes the magnet) is CONSUMED BY THE RESISTOR. HOW? THE RESISTOR CONVERTS THE ELECTRICAL ENERGY INTO HEAT (AND LIGHT) AND THE HEAT GETS DISSIPATED AROUND.

This is one of the escape explanation as to why when the current flies freely through the wire connected generator (without any resistance across), no power is needed. The other is lack of counter-pressure to the current.

Then why, the fuck, the current which circulates and passes through the generator does not generate even stronger counter-force? Why would this magnetic force be generated only when there is a resistor, contrary to the logic?

Not that much of an answer. Some kinda consideration that the electrons fly freely without any counter force through the wires like air through a strengthened car tyre. When one end of the tyre is plugged then the tyre starts to expand.

The connection of two points with a wire is called a SHORT (SHORT CONNECTION, SHORT (part of a) CIRCUIT).

Looks like the electrical short is a magnetic short. That means that a magnet could be demagnetised by a metal object which touches the two poles (at least when the two poles are connected). Kinda strange and doubtful. I don't know. I doubt but try and see.

Another explanation would be that when the electrons see the back pressure of the built across the resistor pressure (voltage), this pressure is felt not only inside and around the resistor but everywhere, inclusive in the coil/solenoid which is true, then the moving-through-the-coil electrons would release (generate) magnetic energy ONLY when hitting each other, ONLY under pressure, only when the exchange of energy between them is made difficult.

An explanation taken from ass.

Most likely this is why the modern physicists think that the electric current is not due to a motion of the electrons but due to exchange of energy in between them. When this exchange is impeded they kinda spin around and ain't got nowhere to release the steam so they generate magnetic energy to do so.

Anyway, when there is a resistor, there is a current and voltage and power is consumed which result to e counterforce to the force which moves the magnet then the magnet is more difficult to push and more muscle energy is necessary.

## **Power and Energy**

Due to the necessity of the two thereof: VOLTAGE AND CURRENT to have power consumption/generation, a measure for the power has been decided to be the product of the two, i. e.:

POWER=VOLTAGE x CURRENT

and is measured by the internationally approved measure called Watt after Mr. James Watt who released some power out of the first steam machine.

Remember, also that:

CONSUMED POWER=GENERATED POWER

no way around.

More minutely said:

GENERATED POWER=CONSUMED POWER and LEAKAGE

Takes the leaking and keeps on ticking...

Another piece of musical equipment that would usually pick up a lot of electromagnetic noise is the microphone. Microphones are usually built in such a way so that a coil is attached to a membrane which vibrates when the voice of the person who talks/sings into the microphone reaches the membrane. The human voice as well as everything audible is realised by a vibration of the air (media) with certain frequencies (number of alterations per second). These vibrations activate the membrane which vibrates in similar way (ideally the same). A magnet is position close to the coil, thus there is a vibration of a coil close to a magnet which is the same as vibration of a magnet close to a coil. There is a movement of coil in reference to magnet. In general sense, this movement can be made possible either by movement of a coil with a still magnet or movement of a magnet with a still coil or movement of the two thereof. This movement generates electrical current in the coil. The coil is connected (with thin wires) to the circuit which may be simplified as to contain a resistor. This resistor gives voltage when the current passes through and this voltage is the input signal to the amplifier. The amplifier amplifies this voltage and provides voltage at the output as well as the necessary current to maintain this voltage while the current passes through the coil of the loudspeaker(s).

The loudspeakers require alternating current to be passed through a coil, which coil will be positioned close to a magnet or metal object which will vibrate with the frequency of the alternating current.

Please, note that alternating current through a coil creates electromagnetic field which can move a magnet as explained above BUT NOT ONLY MAGNET. The electromagnetic field is magnetic field generated by an electrical current through a conductor. This magnetic field is the same as the magnetic field generated by a moved magnet. The magnet can pick NOT ONLY magnets but any metal objects. The same way, the magnetic field, no difference how generated, can pick or move a metallic object.

When a large and light object is attached to a moved object, this large and light object also vibrates with the vibration of the moved object. This is a mechanical hard connection between two objects. So, when a piece of cardboard is attached to the metallic object that piece of cardboard would move the same way as the metallic object.

The same effect can be achieved when the coil is attached to the cardboard and the metallic object or a magnet is still. Movement can be generated either when the coil is still and the magnet (metal) moves or when the coil moves and the magnet (metal) is still or when the two thereof can be moved.

The above principal applies in the first example of this writing – the moved magnet against a coil/solenoid. Instead, the coil/solenoid can be moved against the magnet. Or the two can be moved against each other. MOVEMENT MAKES ELECTRICITY, no difference what is moved.

So, the cardboard vibrates with the frequency of the electric current through the coil which drives it which, in turn, is the frequency of the output voltage of the amplifier, which is the frequency of the input voltage of the amplifier which is the frequency of the output of the microphone (the same), which is the frequency of the vibration of the membrane, which is the frequency of the voice.

Mechanically, the cardboard may be thought as a membrane. This membrane pushes air in two main direction and this is what sound is as long as the air is pushed with audible frequencies (vibrations).

MECHANICALLY, membrane generates sound and is also driven by sound.

Now did you notice something: there are two coils? ANYTHING THAT CAN MOVE MAGNETIC FORCE THROUGH THESE COILS WITH AUDIBLE FREQUENCIES WOULD GENERATE CURRENT WHICH WILL GENERATE MOVEMENT OF THE MEMBRANE OF THE LOUDSPEAKERS, NO DIFFERENCE WHETHER PASSES THROUGH THE AMPLIFIER OR NOT. Again, the magnetic force of other coils which have electric current passed through them would generate magnetic force(s). THIS FORCE(S) WOULD DEFINE THE MAGNETIC FIELD AROUND. WHEN THIS MAGNETIC FIELD IS MAINLY PROVIDED BY ELECTRICAL CURRENT THROUGH COILS AND WIRES, RATHER THEN MECHANICAL MOVEMENT OF MAGNETS, THIS FIELD IS CALLED ELECTRO-MAGNETIC FIELD.

These forces, when strong enough, would act on the microphones' coils, loudspeakers' coils, musical equipment coils, wires, components and connections and will make NOISE – sound which was not made by the musicians but by the environment.

This noise is often called HUM by the musicians and is mainly generated by power supply of equipment and powerful appliances in the houses or factories around and is in the air, like love, and nothing can be done to stop it. The engineers have done some things to decrease but they can't stop it. Not at normal prices and prices must be as low as possible and it is better for the musicians to learn to listen to music in noisy environment then for people to pay more.

Every piece of equipment must comply with the regulations of a given organisation (FCC in the US) and the methods to achieve so are kinda standard. The problem with the US and most countries in the world is that these are run by morons without any common sense. These morons have declared what the level of the noise is to be and did not declare the MANDATORY methods to achieve so. As a consequence of which, with almost no money, a tremendous improvement can be done on some devices which meet the FCC regulations but can be made to emit much less noise. One of these devices do not make any difference on the background of the noise emitted by other devices. Many do.

Another nasty factor is the wireless telecommunications. Mainly in Europe where people can talk and can be heard as opposed to the US and Canada where neither can be done even when one carries a truck battery in the backpack. We'll see why.

The cell phones in Europe emit extremely strong signal thus exhausting the battery but the signal which the towers emit is even stronger, which (depends how the equipment is made) may save the power in the batteries. The Europeans complain that these signal levels may be cancerogenic. However, they have 100% coverage throughout the whole continent and they can talk to each other whereas, in the US and Canada, there ain't no so high level but the questions as to why the cell phones exist is very reasonable because there ain't no coverage almost nowhere even in the highest density populated areas and wherever there might be something alike, one can't hear nor can be heard and the conversation would get interrupted almost in whole, i. e. there ain't no conversation.

That's why the same Europeans who complain for a possible cancerogenic effect of the telecommunication complain that the said is so lousy in the US and Canada so that they think they are in a third world country or in the moon.

Good thing most of the noise is out of audible range. HOWEVER, before the European GSM's ring there is a noise which is so high in the audible range that I am thinking of a possibility to write music on that noise and rhythm. Ringo Starr has already composed the song “Obladi, Oblada” which has pretty much the same itntroduction as a European GSM's ring electro-magnetic noise.

So, imagine a situation when a big US rock band goes to Europe on a concert tour and beautiful naked girls wait for the musicians next to the speakers. Imagine they have cell phones and these are called to ring. The noise will be higher than them electric guitars. Now imagine where the naked girls carry their phones!

Don't panic, though, engineers also know everything about the noise and precautions have been undertaken at the specific (musical) noise susceptive equipment where and as much as possible.

However, why not help a bit. Just try to position the microphones, the loudspeakers, the guitars, other instruments, AS FAR AWAY AS POSSIBLE FROM THE ELECTRICAL EQUIPMENT.

The parallel resistor circuit contains two or many resistors connected in parallel to each other, i. e. when the two ends of each of the resistors is connected to the two ends of the other.

The current passes through the generator and the wires and reaches the one of the common points of the parallel resistors. Then the current has two ways to go – through each of the two resistors. In case that the current was to go through one resistor only, then the current would have created a pressure across this resistor (voltage) and it would have been difficult for the electrons to pass through BUT there is another way to go, so, therefore SOME of the electrons would have gone that way. In case of a wire connection (short) across the resistor then ALL of the electrons would have travelled FREELY through the short rather than to pass through the resistor. Electrons ain't crazy to pass through the resistor when they can pass through the short. This is alike when there is a blocked road and there is another road in parallel which is wide open, the all cars would pass through the wide open road rather than sitting and waiting for the blocked road to become unblocked.

When there is a resistor in parallel of the resistor then some of the electrons would pass through one of the resistors some through the other one. This is alike two blocked roads in parallel. SOME of the cars would pass one way others the other. When the first road gets blocked all of the cars would want to go one way. Then the second one would also get blocked. Then some of the cars would go the other way. Then when one of the roads becomes a bit less clogged, the cars from one would go to the other and hope they would pass faster. At the end of the day the current of cars would be spread on the two roads. The less blocked the road is, the higher the amount of cars that would pass through. The same with the electrical current except that when we take time into account we must remember that time is very good for explanation but the physics says that the electric current (the electrons) travel with the speed of light. So, assume that the above spread would take 0 time to get settled across the two resistors.

## **Kirchhoff**

But when current passes through a resistor the current builds pressure (voltage). Therefore one of the currents through one of the resistor would build voltage one and the other current through the other resistor would build voltage two. THESE VOLTAGES WILL BE THE SAME, I. E. VOLTAGE ONE WILL BE EQUAL TO VOLTAGE TWO. Why?

Because, when you have two hoses connected together to a third one in a fork alike way, then the common point of the three hoses will have the same pressure no difference where and when the other two pass through. There is no way to separate the air in this point. Same about the cars: before the junction of the two roads, the cars would be piled up the same way as in case there was one road only the same capability to allow cars through as the combined two roads (i. e. with the same rate as the sum of the two rates of the two roads).

IMPORTANT:

1. ONE JUNCTION POINT ALWAYS HAVE ONE POTENTIAL ONLY. ONE PRESSURE ( VOLTAGE ) AGAINST ANY OTHER POINT OF THE CIRCUIT.
2. THE SUM OF ALL OF THE CURRENTS AFTER THE JUNCTION POINT IS EQUAL TO THE CURRENT BEFORE THE JUNCTION POINT.

These are extremely important deductions in the electrical analysis known as Kirchhoff laws.

OK. We said that the potential one of the connected ends of the resistors is the same for the two resistors (the two connecting ends). In accordance with the rule number one above, which we have logically deduced, the other connected ends will also have the same potential for the two resistors (the two connecting ends). So, when two points of a given circuit have two different potentials, the voltage (pressure) from one to another will be equal to the difference of these potentials.

The above is difficult to understand and is to be chewed a bit:

Assume there is an air pressure generator and a hose comes out of its output, then forks into two different branches as explained above, then each of the branches passes through a different narrow point (resistance on the path of the air) then forks backwards into one hose, then that common hose goes through another narrow path (another resistance) back to the generator through the input in order to be recycled into the hose circuit. There will be pressure before the first fork and another pressure after the second. The first pressure will be the same before the fork common point and after the common fork point in the two now hoses. The same about the second pressure would be the same in the two hoses before they combine into one and after. HOWEVER, THE TWO PRESSURES WILL NOT BE THE SAME. ONE IS BEFORE THE FIRST TWO NARROW PATHS IN PARALLEL TO EACH OTHER, THE OTHER AFTER. THE DIFFERENCE OF THESE TWO PRESSURES WILL GIVE THE PRESSURE DIFFERENCE BETWEEN THE PRESSURE AFTER THE PARALLEL PATHS AND AFTER. THIS PRESSURE DIFFERENCE IS CALLED PRESSURE ACROSS THE PARALLEL PATH. THIS PRESSURE WILL BE THE SAME FOR EACH OF THE PARALLEL PATHS.

The same with the potentials before the diversion of the wire into two different wires and convergence from two parallel paths into one of the electrical circuit with two parallel resistors. The difference of the two potentials (whatever they are as long as they are measured against the same third point of the circuit) is called voltage and is the same across each of the resistors in the parallel circuit.

Now, which point in the circuit shall we take in order to measure these two potentials? Take the lower point of the solenoid/coil. Which one is the lower? ANY ONE CAN BE LOWER. Depends on how you draw the circuit. Or you may decide to select the one that is physically positioned towards South on the set with the person, the magnet and the solenoid/coil. In case of alternating current they have the same functionality anyway, just different direction of movement of the magnet with the hands. So, take the lower point on the diagram which you have drawn. Call this potential Plow (potential low). Call the potential of the connection point which is at the lower point or the diagram P2. (In case you have drawn the circuit in a different way, call P2 the potential of the point which is connected to the point with potential Plow with a wire directly.) OK. So P2 is connected to Plow with a wire. The wires have the same potential all over and the same current passes through each wire from one end to the other. This is the same as the pressure at different points of the same air hose. Assume an air hose which is connected to a pressure generator at one point and plugged at the other. The pressure will be the same all over the hose. The air cannot get pressurised at one point of a container more than at the other. At the beginning, the air is not pressurised. The compressor puts new air at the compressor the new air molecules push the old air molecules. The more new air is pushed which pushes the molecules of the previously put one (assume no air mixing), the new air is pushed which pushes the previously pushed one and so on. At the end of the day, the generator will not be able to push more because it ain't got enough pump force to overcome the back push by the compressed air from the hose to the generator and the system will reach equilibrium where the pressure in the hose will be equal in all points and will be equal to the maximum pressure the generator can pump. Confusing? Assume that the hose is a balloon which cannot expand after a given limit is reached and the generator ain't powerful enough to brake the balloon. Assume these plastic, PVC, Mickey Mouse balloons.

So, therefore P2 and Plow are the same. P2=Plow.

However the P1 is different as we said current through resistor makes pressure. In case they were to be the same, there wouldn't be any pressure across the resistor. Pressure across the resistors = Difference between the pressure at upper and lower connecting point of the two resistors – as said above. Then there is a difference between the potentials of

1. the lower connecting point

(this potential must be towards something, some other point, otherwise ain't possible to be measured – same like the stone above the mountain has a potential energy as compared (measured) towards (against) the potential energy of the ground below the mountain. The gravity makes the upper position to have one potential energy and the lower potential – another. When released, the stone will go from the point with one potential towards the point with another potential. The stone can't fly from the level where it is to the same level horizontally. Must go down, to the ground or a lower level (lower terrace of the mountain). What goes up must come down. In the example, it is “What is up must come down”.)

1. the upper connecting point

(Ditto)

Therefore, we are interested in the difference P2-P1. This is the same as to be interested in the difference P1-P2, the same shit different sign: 5-3=+2, 3-5=-2 – the same value (2) different sign (+ in the first case, minus at the second).

Now, remember when it was said that ANY POINT ON THE CIRCUIT AND ONLY ONE, CAN BE SELECTED AS A REFERENCE POINT AND CALLED “GROUND” and we can postulate that this point has a potential of any value, for example 0, BUT THIS IS FOR EACH CIRCUITRY SEPARATELY – IN CASE WE HAVE TWO CIRCUITRY, THEN WE MAY HAVE CALLED GROUND AND PO POSTULATED AS A ZERO POTENTIAL A POINT IN EVERY CIRCUIT (THEREFORE WE WILL HAVE TWO DIFFERENT POINTS THAT WE HAVE CALLED WHATEVER WE WANT AND POSTULATED WHATEVER WE WANT BUT THE LAWS OF PHYSICS DO NOT DEPEND ON WHAT WE SAY, SO ONE TO ANOTHER THEY MAY, AND PROBABLY WILL HAVE DIFFERENCE BUT WE ANALYSE EACH CIRCUIT FOR ITS OWN. Of course, in case we were to connect these points of two different circuits with a wire, we make the same point as we said above: a wire has the same potential all over and therefore there isn't pressure between one point of the wire towards any other point of the same wire but there might be a pressure between this wire and another.

So, we have only one circuit, we select a given point and call it GROUND and decide to say that this GROUND has a potential of zero. Then the difference between the upper connecting point of the resistors and the lower (of the potentials) is P1-P2 which is the same as P1-Plow but Plow has been selected to be 0, then the difference is P1-0.

The difference of two potentials is called VOLTAGE (pressure from one point to the other).

Call this pressure U (why not V? Because V is used to denote the measure for voltage called Volt after the physicist Alexandro Volta thus the physicists and/or engineers decided to denote VOLTAGE with U, also because U and V used to be the same letter in old Latin).

Then U=P1-P2=P1-Plow=P1-0=P1

Confusion: How can Voltage be equal to Potential? Voltage is a difference of two potentials, how can it be equal to one of them. IT CAN'T! PHYSICALLY IT CAN'T.

So, physically, it must always be written U=P1-0 but, since in most cases (but not all) people are interested in the numeric value of the voltage (how many volts), then, to subtract zero from something is alike not to subtract anything at all, this is why the engineers would avoid that way of writing.

Calculation of the overall resistance of sequential and parallel circuits is possible because of a simple observation carried out above: no difference where the current passes through (how many branches), there is always a voltage build-up (pressure build-up). OK. And another observation has been made (even before) that when there is a single resistor, on the path of the current there is to be a voltage build-up. That voltage depends on the resistor and the current. Exactly the same happens when there are branches or multiple resistors in sequence. So, the question is what resistance of a single resistor will make the same voltage build-up as two resistors in sequence or in parallel or any combination thereof?

When the resistors are in sequence, the top resistor builds-up voltage on the top of the voltage build up of the lower resistor, because the upper potential is higher than the middle potential which is higher than the lower potential. (The difference of the upper and the lower potentials) is, therefore, the sum of (the difference of the upper and middle potentials) and (the difference of the middle and lower potentials).

Case we call the upper potentials Pu, the middle potential Pm and the lower potential Pl, then:

Pu-Pl=Pu-Pm + Pm-Pl

Therefore the overall voltage build up across of the resistors is:

Uul=Uum+Uml

where Uul=Pu=Pl; Uum=Pu-Pm; Uml=Uml

However, it has been said that the voltage across the resistor (the pressure) is equal to the current multiplied by the resistance or U=RI (the Ohm's law).

Also, points u and m are at the two ends of the upper resistor and points m and l are at the ends of the lower, therefore Uum is across the upper resistor and Uml is across the lower.

Also, the current which passes through the whole resistor passes through the second one and only this current passes through the second on and there ain't no other current around. And the current ain't go nowhere else to run and nowhere to hide.

The engineers would say that the current through the second resistor is the same as the current through the first and is the same as the only current available throughout the circuit. (The engineers would say equal, the better way is to say the same – more clear and gives the physical origin and reason, not only quantitative values – the engineers are interested that the circuit works and is calculated accurately, not why it works. A better way is to also express the why at a given level.)

So, there is only one current. Then the voltage across the upper resistor depends on that current and the resistance of this upper resistor and the voltage across the lower resistor depends on that current and the resistance of this lower resistor and these dependencies are based on the Ohm's law, thus:

Uum=Ru I

Uml=Rl I

where Ru is the upper resistor's resistance and Rl – the one of the lower.

Therefore, because Uul=Uum+Uml (see above),

Uul= Ru I + Rl I

and this is like to multiply I by the sum of the two resistances:

Uul=(Ru+Rl) I

AND THUS YOU CALCULATED YOU FIRST CIRCUIT. YOU ARE ENGINEERS FROM NOW ON!

CAN YOU, HOWEVER, BECOME ALSO PHYSICISTS ANALYSTS (there ain't no such but there should be, i. e. engineers – logicists (preferably pronounced with c as s)? Can you analyse a bit more? You are very close.

So, the same voltage is to be gotten by a single resistor because one can adjust the value of the said resistor as much as one wants and thus pass through the whole possible unlimited voltage range (spectrum). Therefore, one can adjust the resistance of a given resistor to be such so that when the same current, as in the double resistor in the sequence circuitry passes through, the same voltage Uul is built up.

When we decide to name this resistance R the value of R is:

R=Ru+Rl

SO, EVERYTHING ELSE EXCEPT WHAT HAPPENS INSIDE THE SEQUENTIAL CIRCUIT (BLACK BOX) WILL BE THE SAME WHEN WE SUBSTITUTE Ru AND Rl WITH R. WE WILL NOT HAVE TH MIDDLE POTENTIAL Pm, THOUGH.

WHENEVER WE DO NOT NEED IT, WE CAN ASSUME THAT Ru AND Rl ARE ONE RESISTOR R FOR CALCULATIONS, AND when WE NEED TO CALCULATE SOMETHING WITH Pm (Uum OR Uml) THEN WE CAN USE THE TWO SEQUENTIAL RESISTORS.

Do we really need Pm. YES! This potential and the two voltages it gives have a tremendous use in electronics and the simple circuit with two sequential resistors is one of the most simple yet the most important circuits in Electronics, and I, personally, would call it the most important. It is called VOLTAGE DIVIDER!

The best way to explain the voltage divider may be to switch from the AC generator (magnet, moved near a coil) to a DC VOLTAGE power supply such as a battery. The DC power supply stands for Direct Current power supply and when the word voltage is used, there may be some confusion. Direct Current is a constant current which flies from one point to another in ONLY ONE DIRECTION and does not alternate. UNIDIRECTIONAL VOLTAGE power supply should mean a CONSTANT IN DIRECTION PRESSURE which would try to push electrons (current) in only one direction. The boiler of a train builds pressure which passes through a valve and pipes in one direction to drive the train. In case one is to switch the direction where the steam blows instead of the use of gears, one can move the train backwards and forwards and make the train to alternate. The same with alternating voltage – pushes electrons one way and the other. Unidirectional (CONSTANT IN DIRECTION) voltage pushes electrons one way only.

There is something important to mention here: Pay attention on the term CONSTANT IN DIRECTION as opposed to CONSTANT IN VALUE. Constant in value voltage would be voltage (Unidirectional or alternating) which NEVER CHANGES VALUE NO DIFFERENCE WHAT THE CURRENT IS. This is the so called IDEAL VOLTAGE SOURCE. CIRCUITS WHICH WORK WITH THIS KINDA VOLTAGE ARE SAID TO WORK IN REGIME OF NEVER CHANGING VOLTAGE (CONSTANT IN VALUE VOLTAGE). A BATTERY IS APPROXIMATED TO BE A SOURCE OF THIS KINDA VOLTAGE (assume that the battery never discharges).

CONSTANT IN VALUE CURRENT (AC OR DC) power supply is this which never changes the value of the current, no difference what voltage builds up due to this current. Circuits which work with this constant value power supply are said to work in REGIME OF CONSTANT VALUE CURRENT.

The value of the current or voltage is a quantitative measure of how big or small the current and the voltage is, not for direction - not for AC or DC. Alternating in direction voltages (currents) can have a given value (strength) which never changes but the direction may change. When the valve of the boiler is switched to change the direction of the steam, the strength of the steam may remain constant (UNCHANGED).

On the top of this, there are two type of sources of electricity to distinguish: SOURCE OF ELECTRICAL CURRENT AND SOURCE OF ELECTRICAL VOLTAGE. The magnet pushed near a coil is a source of electrical current. The moving magnet pushes electrons and there ain't no voltage unless there is a resistance where the electrons will build pressure. This power source, thus, gives current to the circuit and allows the circuit to do whatever the circuit wants with this current. When there is a resistance, pressure (voltage) is built up. More force is necessary to push the magnet and maintain the value (strength) of the current to remain the same.

The battery is a source of electrical voltage: when you do not connect the battery to the circuit, the battery holds a voltage (theoretically - for ever, practically – not). When you connect the battery to a circuit, the battery gives the voltage (the potential energy) to the circuit and doesn't care what the circuit does with this voltage.

IDEAL CURRENT SOURCE IS SAID TO BE THIS WHICH, AS EXPLAINED ABOVE, DOES NOT CHANGE VALUE (STRENGTH) OF THE ELECTRICAL CURRENT NO DIFFERENCE WHAT THE VOLTAGE (PRESSURE) IS. IDEAL VOLTAGE SOURCE IS SAID TO BE THIS WHICH, AS EXPLAINED ABOVE, DOES NOT CHANGE VALUE (STRENGTH) OF THE ELECTRICAL VOLTAGE NO DIFFERENCE WHAT CURRENT IS PASSED BY THIS VOLTAGE SOURCE INTO THE CIRCUIT.

In case the person which pushes the magnet monitors the current and adjusts the force to reflect the change of the current with the change of the resistance (load) then the current source is an ideal current source. When assumed that the battery never gets discharged, the battery is almost an ideal voltage source.

Ideal voltage sources have zero internal resistance and ideal current sources have an infinite internal resistance. Internal resistance is the resistance which the source may have inside of it – such as the resistance of the wires, contacts, electrolyte and whatever other materials. It is easy to explain physically why ideal voltage sources have zero internal resistance – no difference how much the current which circulates through them changes, there ain't no internal resistance to change the voltage which is provided by this same ideal voltage source. It is a bit more difficult to explain physically why the ideal current source has an infinite internal resistance. The best may be to explain that whatever the external voltage (pressure) is no current can be passed through the ideal current source by this external voltage build up. The pump which drives water must not be affected by other pumps or pressurised water (air) tanks which drive the same water when the pump is ideal. The current source must not be affected by other current and voltage sources when the current source is ideal. Thus the ideal pump will not allow other pump or pressurised tank to pass water through it. Therefore, the ideal pump has an infinite internal resistance to the other pumps (resist them infinitely strongly to push water through it). The ideal current source will not allow other batteries to pass current through it with their voltages (pressures). Therefore, the ideal current source has an infinite internal resistance to the other voltage/current sources (resist them infinitely strongly to push current through it).

Ideal drummer is this who will not change the rhythm no difference how many other drummers there are who drum with a different rhythm.

Generally, real voltage sources have low internal resistance and real current sources have high internal resistance.

Important practical derivation: Sources of voltage MUST NOT BE CONNECTED IN PARALLEL. Otherwise, the higher voltage source will discharge through the low internal resistance of the lower voltage source. Even when the voltage is rated the same, such parallel connection is not to be done because the voltages are not exactly the same. A better way is to connect one of the outputs of one of the battery to the corresponding output of the other and to connect a diode in sequence to each battery in a connection of the possible current and the other ends of the diodes to be connected to each other and then the rest of the circuit is to be connected to this common diode point and to the common point of the batteries. Thus it is not possible for one of the batteries to discharge through the other because the diode of the other will not allow a current to flow in an opposite direction through this battery. Diodes are to be explained in a while. For now, diodes are valves which allow current to flow in ONE DIRECTION ONLY AND NOT IN THE OTHER.

Similarly, current sources must not be connected in sequence. Otherwise, the source of the higher current will not be able to pass current through the source of the lower current unless there is a diode in parallel of the lower current source in the direction of the current, which diode will allow for the current to surround the lower voltage source.

Of course, the above two assume that the voltage sources and the current sources are to be connected to drive current in the same direction otherwise they would discharge into and cancel each other.

AS YOU MAY HAVE NOTICED, WHATEVER IS SET FOR VOLTAGE IS SAID FOR CURRENT THOUGH, IN MOST CASES, THE OTHER WAY AROUND. THIS IS BECAUSE VOLTAGE AND CURRENT ARE RECIPROCAL AS PER THE OHMS LAW (voltage is equal to 1 OVER the current times the resistance) and because the voltage and the current are logically opposite to each other. This will become clearer as we go.

## **Voltage Divider**

Finally, back to the voltage divider.

R1

+

I

R2

U

-

FIGURE 1: VOLTAGE DIVIDER

Before we continue with the voltage divider, a resistor question:

What happens when two resistors are in sequence to one another? The current passes through one of them, is unhappy with the resistance, then continues, reaches the other, is unhappy with the resistance, then goes out and continues. So, when two resistors are in sequence, they act as one resistor with a resistance equal to the sum of the two resistances: R=R1+R2. And, of course, the two resistors of the voltage divider are in sequence because current CAN pass through them ONLY one after another and not simultaneously. Simultaneous is accepted to be the speed of light. The electric current travels with the speed of light and is accepted to spread simultaneously but it ain't.

Now, in the voltage divider circuit, voltage U is applied at the input of the two resistor circuit. Current flies through R1 and R2 to get back to the voltage source. The current makes (generates) voltage across the resistors. The voltage across R1 is UR1 and the voltage across R2 is UR2. The current I is the same for the whole circuit. Ain't no place where the current to go. Nor a place where other currents to come from. The current just follows the circuit, runs through it. As it runs from the start, the current reaches R1 (sees R1) and passes through it making a voltage (pressure) difference of UR1=R1\*I. Exactly the same happens through R2 – UR2=R2\*I.

(Please, note, there isn't transitional process of establishment of the current. As previously mentioned, it is assumed that the electrons or the energy thereof travels instantaneously, physically – travels with the speed of light which is assumed by engineers as speed which makes “immediate” or “instantaneous” events.)

The current is defined by the size of the voltage and the resistance which the current overcomes (sees) on the way through the circuit from start (+) to end (-) of the source. This resistance is the sum of the resistance of the two resistors because, as mentioned above, the current passes through the two resistors and only through the two resistors not through anything else. Mister or Herr or Mister Herr Ohm says that the product of the current and the resistance must give the voltage. Therefore, U must be equal to I times the sum of the resistors R1 and R2 or U=(R1+R2)\*I.

Yes but we know the voltage, our source (assume an ideal battery) and we do NOT know the current.

Either way you look, Ohm's law must be in force. Therefore, from the previous equation U=(R1+R2)\*I, we can deduce that I=U/(R1+R2), i. e. we can look at the Ohm's law from the point of view of the current, not the voltage.

Yes, but we have just said that UR1=R1\*I and UR2=R2\*I and then we said that I=U/(R1+R2), so how about we apply our knowledge of what the current is (the third equation) to the first two equations. Or, simply said, to replace the value of the current of the first two equations with the value we found by the third equations:

UR1=R1\*I, I=U/(R1+R2) => UR1= R1 \* U/(R1+R2)

and

UR2=R2\*I, I=U/(R1+R2) => UR2= R2 \* U/(R1+R2)

Shall we reshuffle these equations a bit:

UR1= R1 \* U/(R1+R2) → **UR1= U\*R1/(R1+R2)**

UR2= R2 \* U/(R1+R2) → **UR2= U\*R2/(R1+R2)**

Ain't that funny: THE VOLTAGE ACROSS ANY OF THE RESISTORS IS A FRACTION OF THE GENERAL SOURCE VOLTAGE. THE COEFFICIENT OF THIS PROPORTIONALITY IS DEFINED BY THE RESISTORS ONLY. SO, IF YOU HAVE RESISTORS, YOU CAN MAKE ANY VOLTAGE OF A LESSER VALUE THEN A PREDEFINED VOLTAGE. AIN'T THAT NICE?

We can also reshuffle the equations a bit more to get:

UR1/U= R1/(R1+R2)

UR2/U= R2/(R1+R2)

THE PROPORTION OF ANY OF THE VOLTAGES ACROSS THE CORRESPONDING RESISTOR AND THE GENERAL VOLTAGE IS THE SAME AS THE RESISTANCE OF THIS RESISTOR OVER THE GENERAL RESISTANCE (THE SUM OF THE TWO RESISTORS).

Assume we want to build a voltage divider. We know the source voltage Uin and we know the voltage we want to get Uout. Uin is the U of the above schematic and Uout can be any of the UR1 and UR2, shall we take UR2 as Uout.

R1

+

+

I

R2

Uin

Uout

-

-

FIGURE 2: VOLTAGE DIVIDER

The signs of the output are the same as the signs of the input and this can be proven by following the direction of the current or simply by knowing the closer to the plus we are, the more positive the voltage towards points closer to the minus and vice versa. i. e. more positives points are towards the upper of the circuit (towards the plus) and more negative – towards the minus. The voltage is spread across the circuit and no other voltage can come from nowhere.

So, taking into consideration the equations which we derived above and mainly UR2= U\*R2/(R1+R2), we substitute as per the agreement above and get:

**Uout= Uin\*R2/(R1+R2)**

The circuit is invariant on the sign of the voltage. If the signs of the input are changed, then the current will fly from R2 first and then through R1 and similar analysis can be done to see that the value of Uout is the same. Instead of simple analysis, we can just realise that when the voltage is reversed, R2 becomes R1 and R1 becomes R2. Therefore, we can take the formula for UR1 (UR1= U\*R1/(R1+R2)) and to substitute R1 for R2: UR2= U\*R2/(R2+R1) which is exactly equal to the formula for UR2 which we derived without change of the signs of the input voltage: UR2= U\*R2/(R1+R2) which shows that the value of the output voltage does not change with a change of the direction of the input voltage.

HOWEVER, the sign (direction) of the output voltage changes and this can be proven the same way like the derivation of the sign of the output voltage before the change – by following the current which goes from plus to R2 and makes the lower point of the diagram more positive then the upper point.

THE ABOVE ANALYSIS OF THE CHANGE OF THE SIGN (DIRECTION) OF THE INPUT VOLTAGE WHICH LEADS TO A CHANGE OF ONLY THE DIRECTION OF THE OUTPUT VOLTAGE AND NOT THE VALUE MEANS THAT THE VOLTAGE DIVIDER WORKS PERFECTLY OK WITH ALTERNATING VOLTAGE AS AN INPUT AND GIVES ALTERNATING VOLTAGE AT THE OUTPUT WITH A SIGN AT ANY GIVEN TIME DEFINED BY THE SIGN OF THE INPUT VOLTAGE AT THAT SAME TIME AND A VALUE DEFINED BY THE RATIO OF THE CORRESPONDING RESISTOR AND THE SUM OF THE TWO RESISTORS.

Howdy. I ain't been writing in months. And this is why books are written so badly. They write them quickly and don't explain anything. Quick buck.

I have to do the same not because of the quick buck – quick or slow, I ain't gonna get any – but because I've got lots of other things to do, it ain't the book only.

## **Current Divider**

So a current divider circuit (although this ain't the name – I am making it up) is pretty similar to the voltage divider and you have to do it yourselves, although I will also do a lot.

Remember, there is a duality between voltage and current. One can be either similar or the opposite of the other as depends on the point.

R2

R1

-

+

I2

I1

I

U

FIGURE 3: CURRENT DIVIDER

Voltage U is applied on two resistors connected in parallel. As far as there is voltage, there would be current. Current I starts to fly through the circuitry. Because the resistors are connected in parallel, the voltage U is applied across each of the two resistors as in case they were disconnected from the voltage source with voltage U, whilst the other one was connected to another ideal source of voltage with a value of U, identical source to the first one.

Therefore U is across R1, thus there must be a current through R1. Shall we call this current I1?

Obviously, as per Mister Ohm, who says the voltage across a resistor is equal to the resistance times the value of the current, therefore:

U=R1 x I1

Therefore,

I1=U/R1

U is also applied across R2, just the same way as U is applied across R1. Therefore, we can do exactly the same analysis.

U=R2 x I2

Therefore,

I2=U/R2

As simple as these two resistors, we have just divided a current I into two currents I1 and I2.

Before we continue, a resistor question:

What happens as far as the current I is concerned when two resistors are in parallel to one another? In other words, there may be cases where we are not interested in what happens in the resistor branches but we are interested only in the main current and voltage. This is called a closed approach of the black enclosure: we ain't in the current and voltage elsewhere throughout the circuitry, we are interested only in a given point of the circuitry to, say, choose a part or find out whether a given part works properly or whatever. When musicians play the saxophone, they ain't interested how to play a still guitar. Even more, when the saxophonist plays, the said plays only the music for the saxophone and ain't interested at all what the guitarist plays. Not always but true in most cases.

So, how much will the current I “SEE” when I passes through the circuit and looks at the two resistors before passing through them? Mr. Kirchhoff of Germany says when a given current is divided into two or more currents, the value of the current is equal to the values of all currents. Therefore,

I=I1 + I2 =>

I= U/R1 + U/R2 (I1 and I2 are no longer in the equation) =>

We have a formula only with U, I (what we are interested in) and R1 and R2 which we can't eliminate.

Take U up front:

I=U\*(1/R1 + 1/R2) =>

I=U\*[R2/(R1\*R2) + R1/(R2\*R1)] =>

I=U\*(R2 + R1)/(R1\*R2) =>

I=U\*(R1+R2)/(R1\*R2) => (move to the other side)

(R1\*R2)/(R1+R2) \* I = U => (revers)

U=(R1\*R2)/(R1+R2) \* I

So, the voltage is equal to some coefficient times the current. The coefficient is a constant because the resistance of the resistors is constant. In case we name the coefficient K, then

U=K\*I

Now, pay attention in this trick: Instead of saying the Ohms law as “Voltage equals Resistance times Current” we can say the opposite: In case a given voltage is equal to a given value times current, therefore this value is resistance. I.e.: “Voltage equals (Resistance ONLY) times Current”. I.e.: Anything which times current gives voltage is a resistance or equivalent thereof.

Therefore, K is some kinda resistance. We can therefore choose another character, say R and call K – R:

R=K =>

R=(R1\*R2)/(R1+R2)

So, R and K are the same thing: equivalent resistance of the sub-circuit made of the parallel resistors.

So, when we connect two resisters in parallel we get a resistance defined by the two. And here is how it is defined: Do you remember the formula: I=U\*(1/R1 + 1/R2) from a few lines up? Thus:

I\*[1/(1/R1 + 1/R2)]=U =>

U=[1/(1/R1 + 1/R2)]\*I =>

(R1\*R2)/(R1+R2)=1/(1/R1 + 1/R2) =>

R=1/(1/R1 + 1/R2)

When R1=0, then 1/R1=infinity, then 1/(1/R1 + 1/R2) equals 1(infinity + something) => equals 1/(infinity (or more infinity when you will)) => equals 0. SAME FOR R2=0 BECAUSE THE PLACE AND POSITION OF THE TWO THEREOF ARE THE SAME IN THE EQUATION.

Therefore, when one of the two resistors is zero, the parallel circuit has zero resistance. Physically, when one of the resistors is a wire shunt (zero resistance), then all current will pass through the shunt wire and none through the resistor. THE CURRENT AIN'T CRAZY TO PASS THROUGH RESISTANCE WHEN CAN SKIP ANY.

When R1 is not zero but something close to zero, then the current through the other resistor is small. As we increase the resistance of R, the current through R2 increases. Physically, there ain't no shunt no more and the higher the R1 the less current gets shunted (sucked) through the low resistance and the more current passes through R2. This can be seen from the formula: when R1 goes from low to high, 1/R1 goes from high to low, thus 1/(1/R1 + 1/R2) goes from low to high too.

And when R1 is infinity, then 1/R1=0:

R=1/(1/R1 + 1/R2) =>

R=1/(0 + 1/R2) =>

R=1/(1/R2) =>

R=R2

Physically, when one of the resistors is take out (infinity resistance – insulator – air), then no current passes through infinity resistance and all the current passes through the other resistor R2. THE CURRENT AIN'T CRAZY TO PASS THROUGH WHERE AIN'T POSSIBLE TO PASS BUT WOULD RATHER PASS THROUGH SOME KINDA RESISTANCE THAN THROUGH INFINITY RESISTANCE.

Therefore, when a resistor is in parallel to another resistor, by varying the value of one of the resistors we vary the value of the overall resistance between the value of zero and the maximum value of the other resistance, for example, in case R2 is a non variable resistor and R1 is a variable one (a potentiometer) which can be varied from 0 to a value much higher than the value of R2 (practically infinity as compared to the value of R2), the overall resistance of the parallel resistor sub-circuit can be varied from 0 to R2.

## **Current and Voltage Dividers**

Now, what happens when there is a combination of a parallel and sequence resistor sub-circuits.

U1

R1

I

U2

I21

U

I22

R21

R22

FIGURE: COMBINATIONAL (SEQUENTIAL PARALLEL) CIRCUIT

R21 and R22 can be evaluated to be an equivalent resistor R2 as we have already done so, and thus U2 can be calculated. The circuit R1-R2 becomes a voltage divider and, therefore,

R2=R21+R22 (R2 is not a physical resistor but a physical resistance on the basis of which a logical resistor can be assumed)

I=U/(R1+R2)=U/{R1+[R21\*R22/(R21+R22)]}

U2=U\*R2/(R1+R2)=U\*[R21\*R22/(R21+R22)]/{R1+[R21\*R22/(R21+R22)]}

I21=U2/R21={U\*[R21\*R22/(R21+R22)]/{R1+[R21\*R22/(R21+R22)]}}/R21

I22=U2/R22={U\*[R21\*R22/(R21+R22)]/{R1+[R21\*R22/(R21+R22)]}}/R22

So, only by using the physically existing material objects U, R1, R21 and R22 we have derived every single current which may fly all over the circuit and all potential (voltages) all over around.

As simple as it looks, this is the analysis used in 90% of electronic circuits. Again: one does not need to know neither mathematics nor physics (except extremely basic versions thereof) and one can do electronics much better than the best professor in Mathematico-Physics or Physico-Mathematics.

Computers don't need even the basics of these.

This is the beauty of electronics and computers. Even donkeys and jackasses can do them.

## **Capacitors and Capacitance**

I, same as you, ain't got no patience to get to the real electronics faster. However, there is one more non-electronics but rather electrical component which must be mentioned before to get started with the electronics. This component is electrical and NOT an electronic one but is largely used in electronics. The components is called capacitor.

It was probably previously mentioned (it may have been so long ago, no one remembers) a capacitor is similar to a pot put in the middle of a water stream via a viaduct. So, water ushers in a pipe, the pipe is cut, there is a pot thereafter the cut and then there is another pipe through which the water continuous. Assume the water has been stopped for years and there is no water in the said system. Then, the valve gets switched to an open position and the water gets to run free through the first pipe. What happens then? The water reaches the pot and can't jump over it in order to continue through the second pipe. THUS the water MUST go into the pot first and starts to get accumulated into the pot. Then THE ACCUMULATION (the amount) of water climbs up and up and up in the pot until it reaches the level of the pot where the second pipe and continues to go through the second pipe. (If the pipes have the same diameter (or the second pipe has a larger diameter) and if there is a lower or no counter-pressure in the second pipe and if the resistance of the second pipe on the water stream is negligible, then no water would be spilled.)

So, there was water ACCUMULATION in the pot which took a certain TIME DELAY and only then the water continued through. So, we introduced a TIME DELAY in the viaduct by using an ACCUMULATOR (a pot).

If the water was passing in alternating fashion (left to right and then quickly switching right to left), THERE MAY HAVE BEEN WAVES ON THE WATER CURRENT DUE TO FAST ALTERNATION. Thus, because of these water waves, the water may have jumped over the pot and thus skipped the time delay needed for accumulation. Therefore, alternating current can jump over the accumulator and there will not be any time delay. THE HIGHER THE FREQUENCY OF ALTERNATION OF THE WATER CURRENT, THE HIGHER THE WAVE, THE EASIER THE JUMP!

However, if we were to put a resistance in any of the pipe, say, in pipe number one, then the wave would have been slowed down and the water would have jumped over the pot with a greater difficulty, i. e. some water will get into the pot. Therefore, the introduction of resistance and accumulator slows down the alternating current but still the higher the frequency of alternation the easier to jump over the pot despite of the resistance.

So, the pot was named an accumulator because the pot accumulates water from the system. A CAPACITOR IS A POT ON THE ELECTRICAL CURRENT STREAM. It collects the electrical current inside of its own the same way as the pot collects water. The same principals apply except one: the electrical current is considered (theoretically) to get spread with the speed of light (almost infinitely high speed) – therefore, without a resistor, the capacitor will became full almost immediately.

With a resistor in series, there will be time delay in case of a direct current. There will not be a time delay in case of the alternating current and the higher the frequency the more current passes through.

THEREFORE: A RESISTOR AND A CAPACITOR CAN INTRODUCE **A TIME DELAY** ON THE FLOW OF THE DIRECT ELECTRICAL CURRENT (**DC**) AS WELL AS **RESPOND DIFFERENTLY TO** ALTERNATING ELECTRICAL CURRENTS **(AC) WITH DIFFERENT FREQUENCIES.**

The second of the two important features of a capacitor allows for introduction of a FREQUENCY DEPENDENT RESISTANCE largely referred to by the name of the components of which it is made – and RC network. HOWEVER, I WILL BE HAPPY IF Y’ALL REMEMBER THE TERM WHICH I TRY TO PUSH: **FREQUENCY DEPENDENT RESISTANCE**. This will make your learning process easier.

## **Frequencies of Electrical Currents and Voltages**

Also, the availability of a frequency dependent response circuitry means we will be able to differentiate and discriminate against currents with different frequencies, i . e. we will be able to introduce larger resistance on the path of currents with SOME frequency(ies) and small or almost no resistance on the path of currents with OTHER frequency(ies). Musicians, hello, anybody home, are y'all sleeping: WE CAN EASILY BUILT A FILTER WHICH CAN ALLOW ONLY SOME FREQUENCIES AND FILTER OTHERS, FOR EXAMPLE, WE CAN FILTER NOISE!

There is another feature of the capacitor: the voltage “passes” (builds) BEFORE the current passes. In the pot system from before, a TIME DELAY was needed before the water went through the second pipe. While the water was being accumulated in the pot, there was no current in the second pipe (therefore no current through the whole system) but there was a water PRESSURE build-up inside the pot.

The same with the capacitor: when the DC current is switched on, the DC current starts to build “pressure” (VOLTAGE) inside the capacitor. The voltage will keep rising in time and will eventually reach the voltage applied on the capacitor. In case of a lack of resistor and availability of a perfect voltage source this process will happen almost immediately but in case of a resistance before the capacitor, the time delay needed for the capacitor to become full of current (VOLTAGE) will delay the process of VOLTAGE INCREASE and there will be a slow increase of the voltage from 0V to the amount of the applied voltage. Thus, voltage and therefore power supply can be delayed and gradually applied on a given electrical system thus protecting the system.

This feature of capacitors is rather important because this helps to control the electrical current in time.

It has been the dream and the heavy work of millions of electrical/electronics engineers to CONTROL the electrical current with the ease with which, say, a miller can control the water current//pressure. Once full control has been established, electricity can be put into work. The more control the more work and, importantly, the MORE PRECISE AND ACCURATE work and job.

Here is a bit better representation of a capacitor by a use of a simple hydro-mechanical system similar to the toilet flush: Assume you have a system where there is a tank with an entry pipe on the top and an exit pipe at the bottom and a mechanical system with a floater which goes up with accumulation of water and eventually may close the exit pipe.

Water

Tap Valve

Tank with a Floater

FIGURE: REPRESENTATION OF CAPACITOR BY WATER TANK WITH A FLOATER VALVE

The tap valve is a RESISTOR which allows only so much water to pass through and resist to more. The water is the electrical current and the tank with the floater is the capacitor. The pressure of the water in the city water supply system is the voltage.

The pressure of the city water supply system pushes a water current through the tap valve and the amount of this water current depends on how much the tap is turned towards “On” position.

The tap is CLOSED at the beginning and there is no water at all in the whole system. Then an operator turns the tap towards “On” and stops at a given point in between “On” and “Off” positions BUT A TINY LITTLE BIT AFTER “OFF” so there is a little bit of water running through the tap. The water starts to usher through, passes the tank and goes through the exit pipe and leaks on the ground. This is just a tiny bit of leakage, not the real operation of the system. Then the operator turns the tap in the middle between “On” and “Off” position. Lots of water passes through the tap and goes running through the entry pipe. Then the water goes into the tank. PART OF THE TANK WATER CONTINUES THROUGH THE EXIT PIPE AND GOES OUT TO THE GROUND. Other part stays in the tank and starts to build up pressure. This simultaneous run of water to the ground and rise of water in the tank continues for a while. Then the rising tank water pushes the floater towards the entry pipe. At a given moment, the floater will almost touch the entry pipe but the stronger pressure of the city water supply system, though reduced by the tap, keeps pushing the floater down and the entry pipe is not fully closed which, therefore, leads to pushing more water into the tank and, therefore, to more and more “TANK PRESSURE BUILD UP” which will lead to the floater to block the entry pipe and thus the water current through the entry pipe will stop.

In this example, there is no valve on the exit pipe which is close-able by the same floater. It is possible, however, to make one with a simple lever connected to the floater and controlled thereby, and a closing rubber valve. In case of existence of such an exit pipe valve, then once the tank is full and the inside built-up pressure is high enough to close the two valves by acting on the floater, then the valves will remain closed theoretically forever because, theoretically, there ain't no place where the water (the pressure) to leak out.

Take into account how the water was running at the beginning and when the pressure of the tank became equal to the pressure of the supply (through the tap) the water current stopped but the pressure remained in the tank.

A capacitor is a simple electrical component which:

1. Allows AC to pass through but does not allow DC to pass through.
2. At the beginning DC changes from zero to a given value. When a current changes, therefore it is AC. Therefore, DC can be considered AC at the moment of the switch and shortly thereafter.
3. Allows the current to pass but DELAYS the voltage build up across itself.
4. Resists differently to AC's with different frequencies. The higher the frequencies the lower the resistance – the easier for the currents to pass through the capacitor.

All of the above are a consequence of the capacitor being an INERT component – reacts slowly to electrical changes.

How can a capacitor be explained physically: Capacitors depend on the electrical properties on these substances and materials which are known to be INSULATORS and do NOT **NORMALLY** conduct electricity. However, the important word here is NORMALLY. A physical property of all non-conductors is these non-conductors will eventually start to conduct when STRONG voltage is applied above a given value and this value is different for every substance and material.

In other words, a donkey will eventually pass over a bridge when pushed stronger. The police also relies on this effect and interrogates and sometimes may even torture a prisoner to get a confession out which confession the prisoner does not want to give at the beginning.

Along with this effect, an opposite effect can be observed: some materials will start conducting at the beginning and then, after some time has passed for these materials to be re-arranged in certain ways, they will stop conducting.

This is like a free soccer match or rock concert where the door keepers may allow people to enter but only until a given limit is met which depends on the CAPACITY of the stadium. Only so many thousand people will rush in, and then the gate is closed and no others can get in. The gates exert pressure against the people who want to get in but ain't allowed.

Some substances, called electrolytes, being liquids, will naturally allow current to pass through them (same as water allows) but, WITH THE CURRENT PASSING THROUGH THEM, THE ORGANISATION OF THESE MATERIALS CHANGES AND THEY START TO RESIST MORE AND MORE TO THE PASSING CURRENT UNTIL THEY GET ORGANISED IN SUCH A WAY AS TO DISALLOW ANY CURRENT TO PASS THROUGH THEM. However, it takes them a given period to get organised. THE IMPORTANT THINK IS THE ELECTRIC CURRENT THROUGH THESE MATERIALS IS THE REASON WHY THEY GET RESHUFFLED AS TO DISALLOW THIS CAUSE.

This is like an invading army which is extremely successful at the beginning but the other army gets to re-organise and re-group and then the resistance of the defending army becomes stronger and stronger until, at a given point, the defending army manages to stop the invading army entirely.

A good point of these effects (break through after a while and get to resist after a while) is: WHATEVER HAPPENS AT THE END IT HAPPENS **AFTER A WHILE** AND NOT IMMEDIATELY.

So, effect number one: a weaker army may be able to invade a stronger army after persisting for a while. Effect number two: a stronger army which has invaded a weaker army may be overcome by the weaker army in a while mainly when the weaker army gets organised.

So, something happens with the electrolytes when current passes through and they allow this current to pass through at the beginning because they have not known the current will be passing AND because THEY ARE SLOW and can't get regrouped immediately alike the strong insulators (such as rubber) can.

The chemists will explain this slowed reaction of the materials with effect such as ionisation and polarisation as well as regrouping of the ions and polarised molecules.

Now, it is important to remember the inertness of the reaction (the slowed reaction) of these materials to electric current.

The inertness will explain why they allow DC for a given time only and they don't thereafter. The inertness also explains why AC can pass: the materials want to stop the current which goes one way but they ain't got enough time because the direction of the current changes and the materials start to get to regroup to stop the “other” current (the one which flows in the opposite direction), however, by the time they get to do something, the current directions changes again, etcetera.

However, the materials may not be so fast as to stop the direction-switching current BUT may be fast enough to put some resistance against the current regardless the current switches – in other words, the current ain't switching fast enough as to avoid any (or any significant) resistance.

THEREFORE, CAPACITORS REACT WITH PUTTING A DIFFERENT AMOUNT OF RESISTANCE TO CURRENTS WITH DIFFERENT FREQUENCIES. THE HIGHER THE FREQUENCIES OF THE CURRENTS, THE EASIER FOR THE CURRENTS TO PASS THROUGH THE CAPACITORS BECAUSE THE LOWER THE RESISTANCE EXERTED BY THE MATERIALS AT HIGHER FREQUENCIES.

R

I

U

C

FIGURE: RC NETWORK

See the RC network: Assume the voltage U is 0. Therefore the current I is 0 too. At a given moment, the voltage goes from 0 to a given value. What happens? The capacitor cannot put any resistance at the beginning. The capacitor is like a simple copper conductor and allows all current to pass at the very beginning. I. e. the capacitor is like being shunted at the very beginning.

Since the capacitor allows all current to pass through itself at the very beginning, the current I which flies through the whole circuit (network) will pass through the resistor R and see the resistance which R puts against the current but ain't gonna see no resistance from the capacitor C and fly through it like a car through the divided highways of Germany (autobahns) which ain't got no limits much to the dismay of the US government.

Therefore the current at the beginning will have a value of:

I=U/R

as per Mr. Ohm : another ingenious German engineer and scientist.

However, the capacitor ain't as stupid as you may think. SLOWLY BUT SURELY, the capacitor will start to put resistance against the current. This resistance increases as the time progresses. Shall we call the resistance which capacitor puts at a given (and at ANY given) point of time Xc (or you may wish to put a number after Xc which says at which numbered point of time this resistance is to be present – Xc1, Xc2, Xc3, etcetera. You may wish to call the resistance at the very beginning Xc0. Therefore, Xc0=0 for every capacitor!).

With the resistance Xc being present and non-zero, the mathematical description of this circuit (the formula) for current and voltage will be:

I=U/(R+Xc)

This is because the current passes through the circuit and sees resistance with a value R Ohms from the resistor also called R and then it sees another resistance with a value of Xc Ohms from the capacitor called C. Therefore, the capacitor and the resistor add the resistance of each to the resistance to the other in order for each of them to contribute to the overall resistance with a value of

Rall=R+Xc

the addition of the values of the resistance of each of the components in a given sequence. (DO YOU REMEMBER THE RESISTORS IN SEQUENCE TO EACH OTHER ADD THEIR RESISTANCE? AIN'T A BIG DEAL IN CASE YOU DO NOT BECAUSE IT'S PRETTY MUCH OBVIOUS AND EASY TO DERIVE. It may be a good reason to remember some things, though, like nerds who just study to re-cite a given thing and ain't putting no sense in what they are talking about but just repeat what they have memorised like parrots. (Please, do not insult the nerds.)

However, remember nerd-i-ness can be good because it ain't necessary to always re-invent the wheel either.

What happens next? As the period after the initial switching-on of the power supply (the voltage U) progresses, the capacitor puts higher and higher and higher resistance, I. e. Xc becomes bigger and bigger and bigger, and, eventually, Xc becomes huge and huger and huger and, theoretically, in a long while, becomes infinitely enormous and then it is like breaking the circuit, like cutting the copper cables with a pair of scissors – no current flies at all. So, in a long while:

Xc=Infinity

and

I=0

The analysis made here is called a TRANSITIONAL ANALYSIS in time domain. I would call it a TIME TRANSITIONAL ANALYSIS IN TIME DOMAIN. The first TIME word is because we analyse the electrical circuit as far as the time is concerned and not as far as the space is concerned. We do NOT look at where the current passes through inside of the capacitor, whether through the central axis or a bit to the left or a bit to the right or all of these physical paths inside the component or, even, outside.

The second term TIME DOMAIN is because we analyse what happens with the circuitry in the progress of the time. Again: UNLIKE THE RESISTOR, WITH THE **PROGRESSING TIME**, THE CAPACITOR CHANGES ITS STRUCTURE AND, MOST IMPORTANTLY, THE CAPACITOR CHANGES THE VALUE OF THE RESISTANCE WHICH THE CAPACITOR PUTS OUT AND WHICH RESISTANCE **HAS NOT EXISTED** BEFORE THE CURRENT STARTED TO FLY THROUGH THE CAPACITOR.

(I. e.) The resistance of the capacitor is zero at the beginning and starts to accrue after the current starts to pass ALIKE A BANK ACCOUNT WHICH HAS 0 PROFIT DOLLARS BEFORE A BUSINESS IS STARTED AND THEN GETS TO ACCRUE THE PROFIT DOLLARS WITH THE BUSINESS CONTINUOUSLY BEING DONE PROVIDED NO ONE WITHDRAWS MONEY FROM THIS ACCOUNT. At the end, this business gets all the money in the world and then the business stops because there ain't no more money for anyone to do any business with this business. Something like the US Military Aerospace industry. Companies like Boeing, Pratt and Whitney, Gromming, Lockheed Martin, Bombardier, etcetera.

The question is whether this transiently changing resistance Xc of the capacitor C can be calculated and expressed with numbers. 1 Ohm in 1 second, 3 Ohms in 2 seconds, etcetera. THE ANSWER IS YES!

Xc changes in time in a strictly mathematically defined way, called exponential function of time.

Except on time, Xc DOES DEPEND ON THE SIZE OF THE CAPACITOR obviously. It ain't the same to force gas a pipe into one small propane bottle as compared with forcing gas in the home burners' tanks of 12 million happy, shiny New Yorkers.

Do you need to know this formula? No. You ain't never be dealing with the transitional behaviour of a capacitor even if you design your own power supplies for your own amplifiers. However, remember the transitional behaviour is very important in many different projects. Sparking of the car spark plug for example. Important, eh?

What happens when AC voltage U (U=Uac) is applied on the RC network. Kinda the same. The capacitor C reacts to a given AC current with a given resistance which depends of the frequency (and, obviously, on the size of the capacitor) and TAKE AS INDEPENDENT OF HOW LONG HAS PASSED AFTER THE SWITCH OF THE POWER SUPPLY ON. In theory, there will be some dependence on this same time-after-switch progression. I. e. WHEN AC VOLTAGE WITH A VALUE Uac AND CERTAIN WAY OF BEHAVIOUR IS APPLIED TO THE CIRCUIT, THERE WILL BE SOME WHILE TO PASS BEFORE THE CAPACITOR CAN RESPOND WITH A GIVEN STEADY RESISTANCE OF Xc WHICH DO NOT CHANGE NO MORE REGARDLESS ON HOW LONG IT HAS BEEN SINCE THE CIRCUIT WAS SWITCHED ON. (OF COURSE, THE BEHAVIOUR OF Uac MUST NOT CHANGE.)

So, when an alternative voltage Uac is applied, the capacitor will be wobbling for a tiny while with the value of the resistance the capacitor is to establish in the near future and then the capacitor will be able to firmly, steadily and sustainably be able to put the steady-state value of Xc Ohms. And what does this firm and state and sustained value depend on? On the size of the capacitor and on the FREQUENCY(IES) of Uac.

Assume Uac is a sine voltage. Sine voltages alternate by following a sine functions. Sine functions are mathematically defined. (KNOW: EVERY ALTERNATING FUNCTION WHICH REPEATS A GIVEN BEHAVIOUR MANY TIMES ONE AFTER ANOTHER WITH EXACTLY THE SAME PERIODS OF PERFORMANCE OF THIS BEHAVIOUR **CAN BE** REPRESENTED AS A SUM OF SINE FUNCTIONS. Therefore, when we learn how a given circuit responds to a sine voltage/sine current we will be able to know how this circuit responds to EVERY repetitive voltage/current with stable and pre-defined period of repetition!)

So, when Uac is applied to the circuit, and AC current (I=Iac) starts to fly AND AFTER SOME TIME HAS PASSED FOR THE CAPACITOR TO REALISE WHAT THE BEHAVIOUR OF THE CURRENT IS, the capacitor goes into **stable AC response** and responds to the stable AC current Iac with a stable resistance Xac.

Therefore:

Iac=Uac/(R+Xac)

is applicable in this case too because the AC current alternates through the resistor R with resistance R Ohms and through the capacitor C which makes a resistance Xc Ohms as a response to this alternating current Iac (which current Iac is a sine current with a given frequency of sine alternation fac).

So, what is this resistance in numbers:

Here is what it is:

Xc=1/(2πfC)

So, the **bigger the CAPACITANCE** (MEANS SIZE FOR A GIVEN TYPE OF MATERIAL) capacitor, the **smaller the resistance**,

and

the **higher the frequency** of alternation of the sine current, **the lower the resistance**.

REMEMBER, THE **FIRST ANALYSIS** WHICH WE HAVE JUST DONE WAS THE **TRANSIENT REGIME** OF OPERATION OF A CAPACITOR WHEN SUBJECTED TO **DIRECT CURRENT**.

The second analysis which we have NOT done but only mentioned briefly was **TRANSIENT REGIME** OF OPERATION OF A CAPACITOR WHEN SUBJECTED TO **ALTERNATING** **CURRENT.** We just said it takes a while not only to react to each alternation but to reach the moment when the capacitor will start to react **steadily** to each of this alternations. We had previously mentioned :when the current alternates, the capacitor ain't got no time to react because the current changes value and direction. E! WHEN THE **FIRST SHOT** OF ALTERNATING CURRENT (**THE FIRST WAVE**) WITH A GIVEN VALUE(S) AND DIRECTION GETS RUSHED IN, THE RESPONSE IS DIFFERENT WHEN THE **1000000TH** CURRENT (**WAVE**) WITH THE SAME VALUE(S) AND DIRECTION GETS GOING BECAUSE OF THE REPETITION OF THE SAME CURRENT BEHAVIOUR OVER A SHORT PERIOD.

The third analysis was how the capacitor reacts to an **AC** current after one gazillion periods (I. e. not in transitional but in a **steady regime of operation**). Or, in case you prefer, this is analysis on how capacitor performs when AC current has been applied for a FEW, say, DAYS OR MONTHS OR YEARS.

The fourth analysis which we have made was a **steady regime** of operation when **DC** current tries to get through the capacitor. This was the easiest. We said it ain't gonna get through and the circuit looks like been cut with scissors.

Forget the second analysis for now. This is rather complicated and may become clearer in a while. For now, know a little bit ONLY of the first and the fourth analysis. They ain't so important. The only important analysis is the third: **long term steady** reaction of capacitors to AC currents. Capacitor is a fuckin' frequency dependent resistor whose resistance changes with the frequency of the current passing through it.

The second analysis analyses the transient regime of the capacitor shortly after a given change of the input. It can be very well explained with the performance of a reactive engine after start up. The engine would start burning only a bit of fuel/oxygen mixture to allow for the metals to slowly warm up. Then, after a while, when the metals are warm, more and more mixture will be burned until a given output is reached when the rocket is released. (In some cases may be the opposite way: thrust is provided slowly to avoid a jump and then the metals are cooled with liquid nitrogen). As a gross generalisation, metals do NOT like quick temperature changes.

Capacitor is passive element. Capacitor only uses the voltage and the current which are given to it. Capacitor does NOT TAKE ANY voltage or current from somewhere else in order to apply it anywhere else.

Capacitor is a linear component. Whatever changes of the electrical parameters in time arise (one parameter (current) may change due to another (voltage) because of the physical properties of the capacitor) THESE CHANGES ARE CARRIED OUT LINEARLY IN THE TIME DOMAIN.

Capacitors are called reactive components. They use the reactive energy accumulated in them to perform whatever need be. Same as reactive engines who do not act on the air (in a way the propellers do) but they do something else: they simply burn fuel and because the gases expand, the expansion generates force which does not push the rocket up but, rather, pushes the air backwards and the air pushes another air which pushes another, etcetera, and because the air is material and has some resistance the reaction of the material (the reaction of the air) acts (or reacts) on the rocket and pushes the rocket up. In other words, the rocket pushes the air backwards in order for the air to be able to push the rocket upwards and thus the stability of the system is maintained: no one loses. Who loses energy then? The energy for the rocket to fly must come from somewhere. The fuel loses.

The most important application of capacitors in music and in all other fields of expertise is in the RC filters, I. e. certain frequencies of the sound can be filtered by the use of simple RC circuits.

Here is a simple RC filter. The analysis is in steady regime.

R

U

Uout

I

C

FIG.: SIMPLE RC FILTER

We can put an alternating voltage signal U through the RC Filter. Assume this is the output of a microphone. An alternating current I passes through. The resistor has a constant resistance which does not vary and cannot be changed (ignore changes due to temperature (temperature is the strongest irritant to resistors but, in most cases, the change of the resistance due to temperature is negligible) and ageing (ditto)). The capacitor has a reactive resistance Xc which is different for different frequencies of the input alternating voltage signal.

Therefore, we have a simple voltage divider with two resistances: R and Xc. Therefore, the output voltage Uout will be:

Uout=U Xc/(R+Xc)

Mathematical analysis of this formula can be carried out and shown what happens with the multiplier Xc/(R+Xc) with changes of Xc in all directions. This mathematical analysis is rather simple and studied in high school. It is also linear.

However, it is MORE IMPORTANT (professors, modelfuckers) to conduct an ELECTRICAL/ELECTRONICS/SIGNAL (CALL IT AS YOU WANT) ANALYSIS. The real name is ELECTRICAL because there ain't no such thing such as electronics as far as ANALYSIS IS CONCERNS. It's all electrical analysis. Electronics is something which engineers at another level of engineering has decided to call. ELECTRONICS IS ELECTRICAL. NO ONE CAN FUCK THE LAWS OF OHM AND KIRCHHOFF. NO ONE CAN FUCK THE LAWS OF ELECTRICITY NO DIFFERENCE WHAT ONE MAY INVENT. SO, ELECTRONICS MUST CONFORM TO THE LAWS OF ELECTRICITY (I. E. MUST BE ABLE TO BE ANALYSED BY THE ELECTRICAL PRINCIPLES) OTHERWISE IT AIN'T REAL. THIS IS FOR STAR TREK THE NEW GENERATION.

So, here is a simple analysis: It's been done before and here. We just need to repeat what happens with the Xc, I. e. we must know our components. They are real, they ain't no just pictures of dicks and pussies.

As said: capacitor conducts alternating currents with higher frequencies EASIER then alternating currents with lower frequencies. So, THE HIGHER THE FREQUENCY (F) THE LOWER THE RESISTANCE Xc. AND THIS IS OUR PREREQUISITE.

SO CURRENTS WITH HIGH FREQUENCIES WILL BE SHUNTED (SHORTED) BY C BACK TO THE SOURCE U WHEREAS CURRENTS WITH LOW FREQUENCIES WILL BE STRONGER RESISTED BY C AND AS C RESISTS THESE, THE Uout OUTPUT WILL BE HIGHER (REMEMBER, WHEN THE RESISTANCE RESISTS A CURRENT, THE RESISTANCE PRODUCES VOLTAGE).

The input voltage tries to drive current through the RC filter from one end to another and return it back to itself (back to source). However, the R and C do NOT want to allow so but have nothing to do. They resist but are overcome. They continue to resist with no surrender and as they continue to do so, the generate a voltage across each of the components which voltage is to try to fuck (stop) the current but, in case the current stops, then the resistance and the resistance voltages stop, then there ain't no resistance and therefore the source would be able to put the current through but then the components would try to resist and stop the current then stop to resist (there ain't no nothing to resist to), then the source would start again... etcetera endlessly. HOWEVER, BECAUSE THERE AIN'T NO TIME DELAY IN THE SYSTEM THE DESCRIBED PROCESS WOULD HAVE THE CHANGES INSTANTANEOUSLY AND UNDETECTABLY i.e. THERE AIN'T GONNA BE NO CHANGES BUT AN ANALOGUE EQUILIBRIUM INSTEAD which means there will be one level of alternating current and one level of resistive voltages AND THE SUM OF THESE RESISTIVE VOLTAGES (Ur AND Uxc) WHICH ARE ACROSS THE R AND C WILL BE ALWAYS EQUAL TO THE FRONT VOLTAGE U, i. e. U=Ur+Uxc.

HOW COME? This cannot be true. In case U=Ur+Uxc then there ain't gonna be no current. True. And not true. It is explained the same way with ANALOGUE EQUILIBRIUM. In order to have Ur and Uxc we must have current I otherwise we ain't gonna have the current I and thus we ain't gonna have Ur and Uxc HOWEVER the source U will continue to push current I through and there ain't no nothing to do to stop the source, so resistance will get going and thus Ur and Uxc will appear and stop the current and again the source U will start it and then stop, etcetera. BECAUSE THERE IS NO TIME DELAY, THESE PROCESSES WILL TAKE PLACE IMMEDIATELY AND CHANGES WILL NOT BE OBSERVED BUT, RATHER, THE ANALOGUE EQUILIBRIUM WILL ESTABLISH THESE PHYSICAL ACTIONS (ALL VOLTAGES AND CURRENTS, THESE ARE).

If you so prefer, you may assume the input voltage would be slightly higher by a negligible value than the sum of Ur and Uxc, say by one electron volt and will not be able to put extra current but just keep the system up and running. This, generally, is NOT true but is a good explanation and understanding as long as it doesn't lead to misunderstanding and doesn't mislead the understanding. BEST, TRY TO THINK THE PRINCIPLE OF ANALOGUE EQUILIBRIUM OR ANALOGUE EQUALISATION OF PARAMETERS. See the world around, try to apply it elsewhere. For example, to explain light.

So, the high frequency alternating currents will be shunted and low frequency alternating currents will generate a voltage Uout which we can further use (say amplify and play though the speakers). And what happens to the zero frequency? This is certain. NO DIRECT CURRENT CAN PASS THROUGH THE CAPACITOR UNDER NO CIRCUMSTANCES (with the exception of transient current). THE CAPACITOR IS ALIKE A SWITCH WHICH DISCONNECTS THE CIRCUIT FOR THE DIRECT CURRENT. The direct current can be accepted as an alternating current with zero frequency of alternation, i. e. does not alternate, i. e. direct current. This is the only thing 100% certain of the capacitors and 100% stable. (The breaking voltage of the capacitor is disregarded the same as a lightning which can jump over the light switch in the room is disregarded. These are not normal working conditions. The capacitor will eventually break under high voltage and blow up. Then, it is not known what happens. The electrodes are supposed to be disconnected and the circuit broken after a blow up. But the electrodes may be “welded” elsewhere due to the blow up. Kinda unpredictable explosion.) Just this: NO DIRECT CURRENT CAN PASS THROUGH A CAPACITOR!)

Assume we can vary the frequency of the voice in the microphone perfectly. Then low frequencies will play loudly (with negligible attenuation). High frequencies will play more quietly. Higherer frequencies, even more quietly. Highererer, even morere. And so on and so forth. Higher then a given frequency will be so quiet, no one can hear it!

In case we are to put a voice (many sine voltages with different frequencies put together at the front U), then the parts of the voice which are high pitch will either not be heard or heard very quietly as compared to the low (bass and baritone) parts of the voice.

SO, WE HAVE A LOW PASS FILTER, YOU FUCKERS! Your voices will sound nice and low not like the voice of Steven Tylor of Aerosmith which voice is so high even dogs can't hear this Bostonian scum.

Now what happens when the places of the C and R of the low pass filter are changed? A HIGH PASS FILTER. The high pitch voice components will pass and the bass/baritone ones will either be attenuated or filtered out beyond a possibility to hear them. Steven Tyler will be rejoiced.

The analysis is pretty much the same and the end result is the opposite.

C

U

R

Uout

I

FIG.: HIGH PASS FILTER

THE MOST OBVIOUS AND IMPORTANT THING OF THIS CIRCUIT IS NO DIRECT CURRENT (0 FREQUENCY ALTERNATING) CAN PASS FROM INPUT TO OUTPUT, I. E. CANNOT FLY THROUGH THE CIRCUIT!

So, the mathematics is simple: Uout=U R/(R+Xc). Now, even the mathematics is easy to do: Xc is under the line of the multiplier R/(R+Xc) => The higher the Xc the lower the multiplier R/(R+Xc). Then the output voltage Uout is lower. The prerequisite says Xc is higher when the frequency of the alternating current passing through C is lower. Hence the bass/baritone frequencies will result in higher Xc thus Uout will be lower. This can be said to be because THE SUM of Ur and Uxc MUST ALWAYS BE EQUAL TO THE INPUT U. It is assumed U (the input) cannot be influenced neither by the frequency of the own signal, nor by the values of the components in the circuitry (almost ideal source of voltage with very low output impedance, which principle will be mentioned in a long while). This assumption is true in the low pass filter too.

ELECTRICALLY: The capacitor does not allow low frequency currents coming from the source to pass easily and resist thus puts a voltage across C which affects the output as per the Kirchhoff law which says the sum of the voltages across the capacitor and resistor MUST ALWAYS BE EQUAL TO THE ENCLOSING VOLTAGE, IN THIS CASE THE SOURCE U.

Fuck Kirchhoff’s law, though. Always use simple CURRENT explanation. When not possible, use a simple voltage explanation. AIN'T NO WAY THE TWO OF THEM NOT TO EXPLAIN WHAT HAPPENS. This means these two WILL explain everything which happens in the sense. Otherwise, you are building an alien space ship.

So, The input from the microphone (source) voltage U will pass current I through the circuitry, which will definitely be AC (alternating current) because, even in case U tries to push DC (direct current) U will not be able to do so because C will stop DC for sure. So, either there is AC or the circuit is disconnected.

C likes high frequency AC's and they pass without any problem. C doesn't like AC's with low frequencies and they pass with a difficulty, thus creating a voltage across the capacitor Uxc. The currents which pass easily will be big and close to their original value without attenuation while the currents which pass with a difficulty will be lower and more attenuated as compared to their original values. Then the resistor will resist to the easily passing currents through the capacitor as well as to the more difficult to pass through the capacitor currents. The bigger the current the more pressure (voltage) is built after the resistance of the resistor which resistance doesn't change. This is the Ohm's law. Voltage equals Current multiplied by Resistance. The bigger the current the bigger the voltage at the same resistance. Thus the easily passing through the capacitor high frequency currents will produce higher output voltage as opposed to the more difficult to pass low frequency currents. (Remember this is when we compare currents with the same amplitude and just different frequencies).

Therefore, when a combined signal with all kinda frequencies is applied as an input voltage (for example a human voice from a microphone signal), then the bass/baritone will be attenuated or will not be heard at all and the high pass will be less attenuated or almost not attenuated at all. And this is a high pass filter.

THERE HAS BEEN SOMETHING STRANGE IN THESE EXPLANATIONS. The impedance of the capacitor is Xc=1/2πfC. This means, for a given frequency, the resistance depends ONLY on C. Then why do the engineers say the cut off frequency (the frequency where the filter is said to start filtering from) depends of the product RC?

To answer this question, one must realise what CUT OFF FREQUENCY is. This term ain't much electrical but, rather, a designer's help. The designers have decided to evaluate filters without thinking so much on how they work but looking at them almost as a separate electrical component. Thus, they have decided to pin point a percentage of attenuation after which the filter is considered to “filter” the frequencies and before which is considered not to filter although there is a decrease, which, for simplicity is not taken into consideration.

Here it is simply said:

Say, we have a low pass filter which allows the bass/baritone frequencies to pass and filters (“washes out”) the high frequencies. Assume we put DIFFERENT input voltages U (U1, U2, U3, …) each of them with a different frequency (f1, f2, f3, …) where the frequencies are numbered from lower to higher: f1<f2<f3... Assume the voltage U1 with a frequency f1 passes OK, U2 with f2 is slightly attenuated but still OK, U3 with f3 is a bit more attenuated but not so bad, U4 with f4 a bit more then f3, U5 with f5 more, U6 with f6 more … and U25 looks really attenuated a lot U50 with f50 can't be heard even by a conductor. Then which one is the voltage frequency after which the filter can be said to do the job? In case we ACCEPT this to f50, then someone may think f49 is OK but U49 with f49 is so quiet so one can barely hear and the conductor gets mad and starts to blame the engineers for the failed Christmas concert of the Vienna Philharmony! As you know, the principle is to always blame the guitar manufacturer, the pick is worn, the electrical got a silence glitch, the string has not been missed by the pick, etcetera.

So, because the voltage at the output decreases with the increase of the frequency of the input voltage with the amplitude of the input voltage kept the same, A GIVEN PERCENTAGE OF THE RATIO BETWEEN THE AMPLITUDE OF THE OUTPUT VOLTAGE AND INPUT VOLTAGE HAS BEEN **SELECTED BY THE ENGINEERS**. Remember the words SELECTED BY THE ENGINEERS. This means it ain't real. Someone has decided to select a given percentage and this is it.

So, the engineers have been looking at the Uout/U ratio. At low frequencies around zero, this ratio is almost 1. At huge frequencies, this ratio decreases tremendously. At infinite frequency this ratio is 0, i. e. which means there ain't no output voltage. So, a given ratio (a given decrease of the output voltage with the increase of the input voltage's frequency) was selected to be the ratio whose frequency is called to be the cut off frequency. This ratio is 3dB.

So, when someone tells you a given filter filters at 16kHz or has a cut off frequency of 16kHz, do not expect you will be unable to hear a sound with, say 16.5kHz.

When a tape recorder is rated to work between 100Hz and 16kHz, do not expect you will not hear 17, 18 even 20 kHz. You will but not so clearly, somewhat attenuated.

However, when a modern active (built around active components) analogue filter OR A DIGITAL FILTER is rated at 16kHz do not expect to hear 20kHz at all. Modern filters have be designed to almost not attenuate any frequency before the cut off frequency and to attenuate all, even these very close to the cut off frequency. How do they do it? It would take a while to explain a bit of electronics and the basic principles of automation (cybernetics) mainly control systems with and without a feedback as well as digital control systems with and without feedback in order to explain how a filter can be made to cut sharply frequencies after the cut off frequency. It ain't difficult though, it just takes a while.

So, the capacitor ain't affected nor influenced by the resistor. The resistor ain't neither affected nor influenced by the resistor. The capacitance C of the capacitor does not change neither does the resistance R of the resistor change. The only thing which changes is the resistance of the capacitor Xc and this is it. THINK OF THE RESISTOR AS A DUMB “PASSIVE AMPLIFIER”. Passive amplifiers are not possible, however, the sense of this presumption is to say the resistor is there just to put the output voltage out.

The same words for the cut off frequency can be said for the high pass filter just the other way around. However, the cut off frequency of the high pass filter is defined the same way. This is the frequency at which the output voltages decrease 3DB as compared to the input voltages as the frequencies of the input voltages goes LOWER and the amplitudes are the same.

A very important application of the high pass passive filter is to be put before the loudspeakers or headphones to block the DC component of the overall current applied through the speakers/headphones because even a tiny DC current may damage either the rest of the components or the speakers/headphones' coils. The speakers/headphones' coils have very tiny resistance (DC resistance, real resistance) which is determined by the diameter and the length of the wound copper wire of the coils of the speakers/headphones. Thus, the coils will act as short circuit connectors and will, probably, easily burn. Therefore the capacitor has to be calculated to withstand the maximum voltage possible to be provided by the amplifier and a lot more so the capacitor doesn't blow up and damage the expensive speakers. These days, the low tech device called speaker is much more expensive than the high tech device called amplifier. The power transistors at the output are priced at less than $1 each and the rest of the single electronic components are priced a few cents. The operating amplifier IC's are priced at less than $1 too. Quality loudspeakers (especially high power ones) may reach several hundreds of dollars, believe it or not.

Here is a good point for a lyrical detour from the topic. It is extremely inexpensive to build a loudspeaker. Just wound copper wire at a few cents and cardboard. A tiny bit of inexpensive metal to put these as well as a magnet. All of these can either be built by simple and inexpensive machines where accuracy and precision are not important or even by hand. They sell them for hundreds of dollars. And this is why there are not large volumes of speakers manufactured in the US or they will disappear very soon. People would rather get inexpensive speakers built elsewhere which have parameters either the same or pretty close to the ones built elsewhere. So, there is only one way to go: sell extremely inexpensively AT LOW PROFIT. The other way is to close the factory. Believe it or not, the US and UK manufacturers prefer to close the factories. They believe they would be able to invest their money elsewhere at a higher profit than to maintain a factory at a low profit. Yes but where? Financial. Yes but how can the financial be profitable? Money is just paper for ass wiping when not backed by product to be purchased with this money. For example, why do I need US dollars? They are so weak and keep going down as compared to the Euro. What would I do with this kinda money? You will get something in the US. What? Ain't no nothing to get. Plus, no one wants to get money which keep dropping in value against other products due to inflation at an interest rate where the profit or the interest rate are so tiny they can't cover the devaluation. Also, people work for gold and want gold, not paper. THEY WANT SOMETHING STABLE WHICH TO BE EXCHANGEABLE FOR GOODS **EVERYWHERE IN THE WORLD**, NOT IN THE US ONLY. No one knows what will happen with the US next few days not to mention next year. May stop existing at all. The only thing one can do with US currency is to purchase gold which is in abundance in the US and store or export the gold elsewhere to exchange for another currency. May not make money BUT DEFINITELY AIN'T GONNA LOOSE.

An interesting question would be whether it is possible to make the filtration better, I. e., in case of a high pass filter, to make the frequencies before the cut off frequency more attenuated and the frequencies after to remain untouched and the other way around in case of a low pass filter. Yes. This is possible by putting many filters one after another. This is called cascading. However, one must pay attention:

R1

R2

C1

C2

FIG.: Multiple Filters

It is normal for most people to say: “This is it. We know how to analyse one filter, we will sure analyse two just by applying the same analysis twice.”. Simple BUT wrong. Can't do. This is because R2 and C2 (which are in sequence each to other) are, as a whole, NOW connected in parallel to C1. In other words, C1 ain`t alone no more. R2C2 channel of the pipe will allow current to flow through it and God knows what happens. Not only God. It is not difficult to calculate and analyse applying the simple methods as before. However, it is easier to explain it electrically: The new big circuit is not made out of two independent circuits but, rather, the two circuits are intermixed and affect one another. Take a look: We still have kinda voltage divider but this voltage divider is composed by R1 as first impedance and X0 as a second impedance where X0 is the parallel connection of C1 on one side and R2C2 on the other which R2C2 is the serial connection of R2 and C2. Look how simpler to understand this is when I redraw the figure:

R1

R2

C1

Uin

U0

C2

Uout

FIG: Multiple Filters Redrawn

Now, the connected C1R2C2 are the second impedance X0 of the voltage divider made by R1 on one hand and X0 on the other. Therefore:

The output voltage of R1X0 voltage divider is U0:

U0=Uin X0/(R1+X0)

This U0 is at the beginning of R2C2 network. U0 “enters” R2C2 and is divided by R2C2 and Uout is the result of this division. Give the names X1 and X2 of the impedances (reactive resistances) of C1 and C2. Then:

Uout=U0 X2/(R2+X2)

Substitute U0:

Uout=Uin X0/(R1+X0) X2(R2+X2)

Sounds familiar? This is what you might have thought BUT X1 is replaced by X0. This is how the simple math proves the simple electrical: C1 ain't single any more. The new “C1” is made by C1, R2 and C2. I. e. the new “X1” is X0. This is because R2C2 INFLUENCES C1.

Simpler math. Name the impedance which is a result of the sequential connection of R2 and C2 X02. Remember the serial connection principle from before:

X02=R2+X2

Also, do you remember the principle of parallel connection of resistors or impedances or mixed: resistor and impedances?:

X0=X1 || X02

X0=X1 X02 / (X1+X02)

Time to use the values of:

X1=1/2πfC1

X2=1/2πfC2

Therefore:

X02=R2+1/2πfC2

X0=1/2πfC1 (R2+1/2πfC2) / (1/2πfC1+R2+1/2πfC2)

And:

Uout=Uin {[1/2πfC1 (R2+1/2πfC2) / (1/2πfC1+R2+1/2πfC2)] / [R+1/2πfC1 (R2+1/2πfC2) / (1/2πfC1+R2+1/2πfC2)]} {1/2πfC2/(R2+1/2πfC2)}

Go figure.

So, what does a contractor do when the job is difficult? The first thing is to think: “Can I not use some power tools?” Yes, you can.

In our case we ask “Can I not use some power tools to eliminate the influence between the two circuits?” Yes, you can. You have to use a power tool which takes power from the power supply in order to make a huge its own input impedance HUGE and its own output impedance TINY! Then, when you insert this tool in between the two filters, the first filter will see a huge impedance at its output and will think the circuit is DISCONNECTED there and will not be affected by the second filter BECAUSE THE CIRCUIT IS DISCONNECTED. The second filter will see the tiny impedance at its input and will think there is an ideal power source connected to the front and hence will not have any influence of whatever is before this ideal power source unless the power source depends on whatever is before it and it does not because of the huge input impedance of the power tool which DISCONNECTS the rest of the circuitry before it AS FAR AS THE INFLUENCES ARE CONCERNED.

## **The Buffer Idea**

This magic power tool is called a BUFFER or buffer amplifier although the buffer does NOT amplify but is rather an amplifier with a gain of 1. THE ONLY THING THE BUFFER DOES IS TO PROVIDE A HUGE INPUT IMPEDANCE AT ITS FRONT AND A TINY INPUT IMPEDANCE AT ITS OUTPUT AND TO TAKE THE VOLTAGE OF ITS INPUT AND PROVIDE THE VOLTAGE ON ITS OUTPUT REGARDLESS OF WHAT THE CIRCUITS BEFORE AND AFTER THE BUFFER ARE. Hence the buffer is sometimes called a voltage follower or just a follower.

BUFFER

FIG.: Buffered Multiple Filter

Now, we are talking. Now, we have a simple addition of filters each of them performing the same way as on its own. Neat, eh!

Now, the more filters we put, the better the filtration. The number of filters will determine the “order” of filtration or the order of the filter as a term and will give a better filtration of the unwanted frequency and (some exceptions apply) a better preservation of the wanted frequencies.

So, why not putting 1 gazillion of buffers, capacitors and resistors and this is it. Because buffers are electronic devices and can be made out of semi conductor or tubes (valves). Tubes are huge and slow but almost noiseless. Transistors are tiny but noisy. Eventually, transistors (inside op amps) are used as well as a tricky circuitry of the filters which would boost the order of filtration are used. These can be combined with amplification to save extra circuitry. It is important to know: circuitry better be saved whenever possible NOT BECAUSE OF THE PRICE (THESE DAYS) BUT BECAUSE OF THE NOISE EXTRA ELECTRONIC CIRCUITRY INTRODUCES.

Enough filtration. I fucked up but not so great. I went too far. Too complicated for now. Hence, I didn't mention filter parameters (come from automation) such as overshooting, etcetera.

Enough capacitors. We spent so long on these dumb devices. We should have rather concentrated on simple electronics then go back to the flux capacitor of “Back to the Future”. Have I mentioned this, I would like to just say a very important application of capacitor is to use it as a simple accumulator of voltage. Just like a battery, a capacitor can be charged and then the energy can be preserved in the capacitor for to be used in a while until the capacitor gets discharged the same way as the battery. A huge and major application of this is the so called switching power supply: Instead of using transformers, connect a capacitor to a rectified voltage (or to the positive wave or only to one of the waves of the AC) of the mains. Wait for a while to get charged. Then take this charged capacitor and bring it somewhere else and connect it there. Now, you have a DC voltage power source (a battery). The vehicles which “bring” the capacitor to the mains and then “bring” it back to where DC is needed are called simple and simply transistors which operate in switching (digital mode) and are used as simple switches of electrical circuits. The switching supply circuits are easy, simple, tiny and inexpensive as opposed to the transformers. So, why do they use transformers, then? Because the switched capacitors introduce noise. This switching noise can be moved away from the audible noise BUT the self noise of the transistors cannot.

**Electronics makes noise. Sorry. The electronics takes power from the power supply and makes not only good things with this but also bad. One of the bad things is noise.**

## **Basic Safety**

Another principle of electrical equipment is safety. Transformers, especially the toroidal, are considered to be extremely safe for humans, sparks and animals. Switching power supplies, not.

The principle of safety is:

**Ain't a transformer, ain't safe.**

Also, one side of the transformer can be grounded as well as the mains as well as the enclosure of the equipment. Once everything is grounded, one must only touch only one power line to get screwed. Otherwise more. Also, once the “ground” of the equipment to which the enclosure is connected is also connected to the ground of the mains (the real ground), ain`t no nothing to be afraid of: you touch the real ground, the one you walk on. Assume there is a problem with your equipment and a huge voltage line from inside touches the enclosure from within (something gets loose or broken). Then, in case NOT grounded, the potential of the enclosure will have a huge voltage difference with the potential of the real ground on which you stay. Then you will connect these two potentials. You are conductive. The RUBBER SHOE SOLES ARE NOT. So, in case, you wear shoes with rubber soles, you may be OK. BUT otherwise (or in case you touch ground with other parts of the body (GUESS WHAT PARTS IN THE WORST CASE)) then you close the circuit between two different potentials. What does this mean? Electric current will pass through you. In case you touch the enclosure in such a way as the enclosure doesn`t get released when your fists are tightened (I. e. holding a handle(s)), then, when the electric current passes through you, it will make your muscles contract and you may NOT be able to release the handles and the current will keep on running unless you cannot disconnect the other part of the circuit (wherever you touch ground) by jumping in the air or moving at least temporarily to be able to release the handle.

So, another principle of safety is:

**Ain`t grounded, ain`t safe.**

Kinda similar to the US Air Force! (Each pilot must pay a dollar for this compliment!)

How can this be? What`s goin' on with this ground? This is because the ground is very conductive although you may think it is not. There is a lot of water, water molecules, metals, metal atoms, etcetera in the ground. So, in case I connect a cable to one of the outputs of a generator and dig this cable very deep in the ground and I pull another wire from the generator to you and touch you, I may be able to fry you. Sounds like a new weapon for the US Army and, mainly, Navy.

On the other hand, in case you lean to a metal poll stuck very deep in the ground and I touch this metal poll with the power cord, nothing will happen to you. Just sparks will fly. This is because I touch the metal poll which touches deep in the ground then the generator grounded cable touches deep in the ground then the generator non grounded cable touches the poll and thus the generator is SHORTED before you and not after.

The ground safety idea can be thought this way:

When I stay on the ground or lay or touch the ground, I can touch anything I want AS LONG AS this thing is electrically connected with deep underground. Then NO DIFFERENCE WHAT HAPPENS AROUND, THE POTENTIAL OF THIS THING IS THE SAME AS THE POTENTIAL OF THE GROUND AND AIN'T NO WAY A CURRENT CAN PASS THROUGH!

In case you are driving your pickup truck through your farm and there is a lightning and the lightning hits your pickup, DO NOT EXIT DURING OR SHORTLY AFTER THE LIGHTNING because the potential of your metal (it will soon be plastic) truck is different than the potential of the ground and when you put one food on the ground while you touch the truck, you may fry because current may pass though you. ALSO, lightning is a big fuckin' voltage. This shit may ionise the air in your truck as well as fuck knows what other materials which normally may be isolators and when you touch the ground these ionised molecules will discharge through you towards the ground. So, stay in the truck OR (big OR because it ain't safe to stay inside always) jump simultaneously as far away as possible. You must NOT be touching the truck while landing.

This is particularly applicable to Texas because: there are huge open fields and people usually drive pickups through and they usually ware Western boots with leather soles. Expensive and nice BUT ain't much electrically safe either. Who gives a fuck as long as one can actually get a fuck with this nice pair of boots!

One more thing: the same way the two low pass filters were put one after another, any combination of low pass and high pass filters can be done and thus a band pass filter can be designed.

Combination of filters is very popular as well as any other circuitry put one after another. The first circuit would have input voltage of Uin1 and output voltage of Uout1. The second: Uin2 and Uout2. The third Uin3 and Uout3. Each circuit would change the voltage from Uin to Uout by multiplying this voltage by a given coefficient K. Thus Uout1=K1Uin1, Uout2=K2Uin2 and Uout3=K3Uin3. However, note: THE OUTPUT VOLTAGE OF EACH CIRCUIT (except the last one) IS THE INPUT VOLTAGE OF THE NEXT CIRCUIT (except the first one where the input is the signal (the voltage we would like to perform something upon)). Therefore Uout3=K3Uout2. Substitute Uout2, therefore Uout3=K3K2Uout1. Substitute Uout1, therefore Uout3=K3K2K1Uin1. Yes, but Uin1 is the input voltage of the whole circuit made out of three sub circuits put one after the other, I. e. Uin1 is the signal of the whole circuit. Also, Uout3 is the output of the whole circuit made out of three sub circuits put one after the other. Thus Uin1 can be also named Uin. Uout3 can be also named Uout. Therefore, Uout=K1K2K3Uin. The product K1K2K3 can be named K. Therefore, K=K1K2K3.

**Therefore, when putting circuits one after another, the resulting circuit can be thought of being one circuit wit COEFFICIENT EQUAL TO THE PRODUCT OF ALL COEFFICIENTS OF ALL SEPARATE CIRCUITS (sub circuits) ONLY WHEN THERE IS NO INTERACTION BETWEEN ANY TWO SUB CIRCUITS (I. E. WHEN THERE IS BUFFERING BETWEEN EACH TWO CIRCUITS.**

Thus, the fore said principle of putting circuits one after another and having the resulting coefficient to be a product of the coefficient of each circuit is true ONLY for the buffered filter and not for the non buffered filter. The non buffered filter is known as a passive filter because the said is built by passive components ONLY (resistors, capacitors and coils). The disadvantage of this is loss of signal and difficult calculation and design. Loss of signal means the signal at the end will be less than the input signal. The signal will be attenuated (divided) as well as the unwanted portion of the signal (the filtered portion). However, the filtered portion is supposed to be attenuated much more. The advantage is lack of active components, therefore lack of self induced noise. Rock and roll ain't noise pollution.

Passive filters are usually not used because of their complexity. The electronics has advanced a lot and the self induced noise has been overcome to a great deal of extend in the frequency range of interest (audible range). The engineers are no one slaves. They do the easy job.

Passive filters however are preferable in huge frequencies where the electronic components may not perform well as for example TV. I wish to believe there are smart computer aided design systems which will do the design just by giving input and output although the number of combinations of components and their interconnections is huge. The fuckin' military uses these shits hence I hate passive filters. The rule of thumb in engineering is: whatever the military uses, one should use the opposite. I ain't never seen so much green and stupid as in the military engineering. The pacifists too. Doesn't know the system here.

Ideally, all non reservist military must be killed. However, the problem is they are also human beings who went into the army ONLY BECAUSE THEY WERE FORCED TO DO SO. Some were forced by their stupidity. Most were forced by the society (they went in the military for a hat full of dollars, however, it sometimes happens they went there for a fistful of dollars). Some were forced by the state because of a conscription law. Others were forced by their dicks and pussies: they went there to get a pussy(ies). Now women even go to the military more and more. Some of them for a lotta big dick. These who went there for pussy/dick are the least bad. So, because it ain't good to kill them, try to find a way to kick them asses.

Another disadvantage of passive filters with MANY components would be each of them (mainly coils) would pick up one heel of electromagnetic noise so abundant around these days. Some noise is out of audible range, other is in. The 50/60Hz mains noise remains one hell of the problem. This is why, when you get plastic enclosure distortions and amplifiers and wires with plastic or rubber jacks and you go to the basement where your laundry machine and drier is and plug your gear, the noise may as well be stronger than the guitar.

## **Introduction to Basic Electronics**

FINALLY A POSSIBILITY TO START WITH ELECTRONICS. At the beginning there was tubes/valves. They are still around mainly because of the same problem: noise of solid state (mainly silicon) based electronics. But as we started, first things first. Why is it called electronics on the first place? Because it's got something to do with electrons, I guess. You guess right. Electricity is a simple dumb flow of electrons (electron energy) through a conductor. Electronics deals with BEHAVIOUR (not only simple flow) of electrons (energy) in SPECIFIC, KINDA STRANGE CIRCUMSTANCES. These may as well be some kinda level of material development and existence which is at the barrier of conduct / doesn't conduct. i.e. under certain circumstances a given material may, under other, may not conduct. WHERE THERE IS HESITATION, THERE MAY BE A POSSIBILITY FOR CONTROL. This is why some employers want to have dumb employees, so they control them easier. Must not think, must only follow orders. Sounds like the US/Canadian society. This is why, when Europeans come over here, they think everyone is as stupid and as dumb as in the army. In Europe, people are encouraged to think and to always try to look for better ways of doing things as well as to always innovate and improve and, possibly, invent. THIS IS THE MAIN REASON WHY THE US WAS SHUT DOWN BY GERMANY AND JAPAN IN WORLD WAR 2. Because the dumb red necks used to go pray to Jesus on Sundays and dig coal all day every other day with an exception of Saturday afternoon. When the US got fucked badly by Germany and Japan the masterminds of their theories, policies and politics realised they can keep the illusion which they have kept in order to keep the dumb red necks under control by the exertion of which they would keep making them money which means they ain't gonna work and have a much better standard. This standard without work (even with) was going to be fucked up badly and the dumb red necks would become German/Jap slaves WITHOUT THE ILLUSION of being free which was lied upon them by their hidden masterminds overloads who started to play a different tune when realised they were to lose everything they have stolen from the people. So, for a short period of time US started to perform then kept the momentum for a while and is now loosing again. Canada too. God bless Detroit otherwise them morons would be in the Stone Age again. This is what they have done with the society. They are the political (hidden or not) mentors.

So, electronics is something which deals with side effect of electricity. But does it break the laws of electricity (physics). NO! The laws of electricity/physics CANNOT be broken. So, remember: the laws of Ohm and Kirchhoff FULLY APPLY TO ELECTRONICS regardless of how it may look at the first glance.

So how did this start? Electrical was getting more and more powerful in the society at the end of the 19th century. Some people claim Edison recorded some kinda strange flow of current effect when trying to make a simple light bulb (trying to find the materials for it). I think people say so because of the old British American competition of who's got bigger which was very strong in the Queen Victoria era when Britain owned most of the world and US was emerging as a nice place to be which it was not but as compared with the wild stingy British capitalism of the time looked like a free country, hence some of the illusions.

So, most likely, the Edison recorded but not explained and not thought over effect either didn't exist or Edison was so dumb not to realise the said effect is hell more important than the light bulb. However, as typical for the US, Edison wanted to make a quick buck (no wonder the scum was a Brazilian slum dog, although Brazil performed better than the US at the time). In the best case, made just a mistake. Mistakes happen.

The truth most likely is them Brits invented Electronics and the first tube/valve and the US lied as well as Edison in order to prove themselves stronger than the Brits and keep them propaganda over the slaves white and black. They also did so because, at the time, it was very popular to come to the US for a few years, find gold and then go back to Britain to be a real human not a dumb slave of the local capitalist or feudalist or any combination thereof. Britain and mainly London was the desired destination then and the US was a nasty bad and dirty place where it is only worth to go for a few years to dig gold and other natural resources then to export them to Britain and get pounds of gold. Hence the stupid archaic British currency is called pounds. This is because 1 Pound Sterling was 1 weight pound of STERLING gold (not the one mixed with copper). 1 Pound was a salary for one or many years.

So some Brit was playing with electrical currents and decided to find out what happens when electrical currents pass through isolators. One of the most interesting isolators which is abundant around is air. Also, the Brit was probably interested in why there is lightning. How come electricity passes through air? O, you say, sometimes air is isolator sometimes, in some circumstances a conductor. This is exactly what them Brits were looking for in order to be able to CONTROL the electric currents like one was able to control water currents. The needed to be able to stop the current when they want and to start it when they want as well as to PUT ONLY CERTAIN AMOUNT OF CURRENT AS PER THEIR NEEDS WITHOUT ANY LOSS OF NEITHER VOLTAGE NOR CURRENT IN THIS CONTROL MECHANISM. Last but not least, them Brits wanted to control the flow of the current, I. e. to allow current to flow in one direction only over the conductor. THEY WANTED A VALVE LIKE THE VALVES WHICH STOP THE WATER OR AIR IN ONE DIRECTION (THE DIRECTION CLOSES THE VALVE ON ITS OWN DUE TO PUSHING ON THE VALVE) BUT NOT TO BE ABLE TO STOP THE WATER IN THE OTHER DIRECTION. This kinda directional valve would have many application as for example allowing only one of the waves of the AC current to pass and the other to be shut down. This is because the US decided to choose AC over DC and fucked the world up again as they usually do. The movie “Prestige” shows one of the main ingenious reasons for this: DC long lasting potentials without change can cause sparking. Where? Were they going to stick DC wires up them asses? THIS IS ONLY WHEN THE DIFFERENT POTENTIALS ARE TOO CLOSE TO EACH OTHER IN ORDER TO BREAK (IONISE) THE ISOLATING AND INSOLATING AIR, YOU MORONS. EVEN WHEN IT RAINS. CALCULATE THE ELECTRICAL STABILITY OF THE AIR IN THE WORST CASE. Don't be so dumb to believe someone may stick a wire in Moscow River (Thames at the time) and burn the White Gambling House in Washington, DC. Personally, I believe Edison was a fuckin' idiot. Dumb Brazilian short sighted bastardo.

The Brit was mainly interested of what happens with electricity through air and gas. So, the True Brit put some electrodes in a beer bottle (very traditional) after having drunk the beer first and started to use the prerequisite the Brit have from conversation with the posh electrical elite at the time. Colleagues manufacturers who make hangers in Hollywood. Richard Dreyfuss and Nick Nolte. Pure geniuses. Mainly the wife there.

Most likely, the smart Brit put one electrode to be very tiny in area and the other huge. Look how simple and mechanical the thinking of the Brit was. This is a typical simple Red Neck American thinking which is usually rejected in Europe (sometimes to a dangerous proportion) BUT NOT FOR THE PURPOSES OF ENGINEERING and not in Germany. Germans are Red Necks. Hence the war. The funny thing is to look at the wars from an independent prospective: 2 red necks one against the other and a third red neck former imperial slave fucking independently and a bunch of mean evil Brits who carpet bomb all over the place and kill German women and children. The German women complain they were raped by the Red Army and did not complain they were slaughtered by the Brits. So, never fuck a German girl. Eat'em, instead.

Obviously, in case of a tiny source of water (garden hose) and a huge amount of water (back yard) and in case of pressure from tiny (hose) to large (yard) the water from the hose will be within the range of the yard. The hose is the source and the yard is the target. Can`t miss it. What happens the other way around? In case of a sprinkler system which covers the whole yard. How probable is to hit the hose? With how much water as a percentage of the overall amount of water used? Negligible in case at all.

So, most likely, this is how the good ol' Brit started. Then the “professionals” came. It is important to ridicule them because they ain't done nothing. THEY JUST FOUND SIMPLE MATERIALS IN ORDER TO IMPROVE THE IDEA. This ain't invention. This ain't engineering either. This ain't logic. It is just simple physics and material use. It's “trying to get the best out of the nature”. So, they have found some materials who can easily emit electrons (transfer electrical energy) and other materials who can do so with a great difficulty. Also, they have found some nice gases which can be ionised more easily or with a greater difficulty, as depends on the needs.

So, take a bottle of beer, put some gas in OR TAKE THE GAS OUT TO CREATE VACUUM. Cut the bottom of the bottle. Put some electrodes of special metals in the bottom hole as well as in the neck hole. Put the whole bottle with electrodes in VACUUM environment (room or furnace) to suck the air out. When done, keep the bottle in the vacuum room and seal the bottom and the neck with hot pliers but keep the electrodes in. The molten glass will seal the holes and will also nicely melt around the electrodes preventing air to enter around them. Now you have a vacuum tube/valve.

Most likely, following some Greek words, the engineers have decided to call one of the electrodes anode and the other one cathode. I always forget which one was which. It all sounds Greek anyways. I can check with the Internet but I am not happy to do it. What difference does this make? One must know the PRINCIPLES not the terms and names. This ain't Shakespearian Theatrical. It's simple and basic. USE YOUR BRAINS. THINK. DO NOT JUST LEARN TERMS LIKE PARROTS. I think, the electrode which can easily EMIT electrons is called anode and the electrode which can easily RECEIVE electrons but can't emit them easily is called cathode. It would have been nice to have called the emitter and receiver but morons are morons. OK. For y'all, I checked with Wikipedia. I thought it WRONG. CATHODE EMITS ELECTRONS, ANODE RECEIVES THEM. Fuckin' Greek. They don't know how to talk. Monkey people.

When y'all read Wikipedia for anode and cathode, go to the section which says what these are in VACUUM TUBES/VALVES. There is one hell of the confusion there. Every one calls whatever they want whatever they want based on the application. Better don't use them terms.

So, the Brits had the vacuum tube. What to do with it. Stick it up the Queen's ass? Considering the size this may be a useful application. Big and hot!

However, there are other more important yet less interesting applications.

+

Receiver (collector) of electrons

I

External source of electrical voltage U

U

Flow of electrons

-

Emitter of electrons

FIG.: VACUUM TUBE/VALVE

Apply voltage from an **external** DC source. Connect the negative to the emitter (cathode) of electrons of the vacuum tube/valve AND the positive to the receiver (collector) of electrons of the vacuum tube/valve. THERE WILL BE A FLOW OF ELECTRONS THROUGH THE VACUUM, I. E. THROUGH THE NOTHINGNESS. As mentioned earlier, this flow makes an electric current which, contrary to any logic, has been decided to be noted with an arrow in a direction against the flow of the electrons, largely referred to as “THE OTHER WAY AROUND”.

REMEMBER, THE ELECTRONS FLOW PHYSICALLY FROM NEGATIVE TO POSITIVE ONLY AND NOT THE OTHER WAY AROUND. Some people have decided to use a notation to say the “electrical current” flows from positive to negative. This is very confusing when physical explanation is made and when mixed up with the electrical depiction. DISREGARD THE ELECTRICAL NOTATION FOR NOW. TAKE ONLY THE FLOW OF ELECTRONS! ALWAYS FROM – TO +.

So, electrons (energy) flow through the vacuum. They hit the collector (anode) and continue to the positive of the external power supply thus closing the circuit. What's vacuum. Notha. Nothingness. Ain't no nothing to conduct, true but ain't no nothing to stop the electrons either. Thus they simply fly like a NASA rocket in the open space. The rocket get accelerated in the Earth atmosphere by the reactive jet engines and crosses through the stratosphere with some inertia. When the rocket exits the stratosphere and is in the open space (in vacuum) the rocket does not need no engines. The inertia, acquired by the rocket fly through the atmosphere and stratosphere keeps a pushin' the rocket and there ain't no nothing to stop it. Kinda like your car. When you press the accelerator to pay the engine for its work with some gas, the car accelerates until it reaches a given speed of 75 miles per hour when you ease off of the gas pedal. In case you release the accelerator fully, THE CAR AIN'T STOPPIN'. The inertia keeps it in motion for a while. However, due to friction and air resistance, the car will eventually stop. Ain't no friction in a jet engine. There is air resistance though. Hence, in the atmosphere, the rocket would eventually stop. HOWEVER, AIN'T NO ATMOSPHERE IN SPACE. AIN'T NO AIR. AIN'T NO NOTHING. Kinda like an unemployed in Texas. So, ain't no nothing to stop this. So the rocket will keep flying.

Not only ain't no notha to stop electrons in vacuum but the tube has ELECTRIC FIELD which pushes them out of their original location (negatively charged emitter cathode) towards their destination (positively charged collector anode). Like Mexicans across the border. The difference of the potentials of existence in Texas and Mexico pushes them Mexicans away from Mexico and into Texas. And BECAUSE THERE AIN'T NO BORDER BETWEEN MEXICO AND TEXAS, THERE AIN'T NOTHA TO STOP'EM. Mexico is a cathode (this is why they are Catholics) and Texas is the anode (largely referred in the North to as the anus of the US) and the border line is vacuum. Can be crossed the other way around but NO ONE IS STUPID TO DO IT. (Occasional transitions to see friends and get something for less money excluded.)

Some tubes have gas in it and can be used for specific purposes, for example radiation detection but we better stick to the vacuum ones, the real McCoy.

OK. So electrons flow. What's the big deal? They fly through a piece of copper too. Why am I supposed to read shit electronics? BECAUSE, WHEN YOU REVERSE THE EXTERNAL VOLTAGE SOURCE CONNECTIONS TO THE TUBE AND PUT THE POSITIVE TO THE EMITTER AND THE NEGATIVE TO THE COLLECTOR CURRENT AIN'T FLYING AS OPPOSED TO A PIECE OF COPPER WHERE, NO DIFFERENCE HOW ONE TURNS IT, CURRENT FLIES THE SAME STRENGTH AND WAY JUST. And this simple thing is the ingeniousness of electronics. The same thing (vacuum tube) is A CONDUCTOR IN ONE DIRECTION AND AN ISOLATOR IN THE OTHER. Hence them Brits decided to call it a VALVE. No other shit could do it at the time. This is a directional conductor/isolator.

Does this defy the laws of physics and electricity? HELL, NO! Does the electricity deal with conductors? Yes. Does the electricity deal with resistance? Yes. Does the electricity deal with isolators? Yes (isolators are conductors with huge, theoretically infinite, resistance).

Assume, there is a fuckin' minimum wage train dispatcher, drunk like a skunk but ain't so drunk not to be able to do certain things, like most Texans: “Drinks but never gets drunk!” Send a dollar you lousy fuckers for this compliment. Call this looser John or Ivan or George or anything. Now, give John a piece of wire and a piece of rubber (real rubber, not a condom). Make a simple electrical system with a battery and two cables. Connect one end of each cable to each of the battery knobs. Give the other ends to John. Shout: “John, put the copper between the cables.” John does it. What do you have now? A simple electrical connection. A simple short connection. How does this defy electrical principles? It does not. Now, reverse the polarity of the cables (whichever's been attached to the positive, goes to the negative and whichever's been attached to negative, goes to positive) and shout: “John, put the rubber between the cables.” John does it. Now, you have a disconnected electric circuit because the rubber piece is an insulator. How does this defy electrical principles? It does not. So this is what the vacuum tube does for you. It's a John. It changes copper and rubber as depends on the direction of the electrical current through it.

THIS VACUUM TUBE IS CALLED A DIODE. INITIALLY, IT WAS CALLED VALVE. THEN OTHER VACUUM TUBES APPEARED AND THE ENGINEERS STARTED TO COUNT THE PINS LIKE A SHEPHERD WHO COUNTS THE LEGS OF ALL SHEEP AND THEN DIVIDES BY FOUR TO FIND THE COUNT OF THE SHEEP. SO, THE ENGINEERS CALLED THE VALVE A DIODE BECAUSE THE VALVE HAD TWO PINS (ANODE AND CATHODE) AS OPPOSED TO ANOTHER VACUUM TUBE WHICH HAD THREE PINS (GUESS HOW IT WAS CALLED).

What is the importance of this electronic directional dispatcher called valve or diode? TREMENDOUS! The first way to control this beast called electrical current! At least only the direction. NOT the AMOUNT of current yet. So, why do I need this shit?

In case of DC ONLY world, one needs it to parallel batteries as mentioned earlier. Thus when you have a few 12V batteries, you can put all of them with diodes and you do not have to wake up eversooften and replace the discharged battery with a fresh one. So, why do I not parallel them without a diode? BECAUSE, you will discharge each into another very quickly because batteries are supposed to be as close to ideal voltage sources as possible and have as tiny inner impedance (resistance) as possible. This means, in case you connect a 24V battery to a 12V battery you will discharge the 24V battery to 12V almost immediately. In case these batteries are not chargeable, you would lose a lotta power. Even when they are and they reach 12V, you will have two sources connected in parallel and each of them has a very tiny inner resistance. Thus, in case one of the voltages goes slightly off, current will fly and one of the battery will get discharged. When you add the capacitive effect and the INERTIA OF THE DISCHARGE they will keep bouncing and discharging one into another and there ain't no notha to keep the system stable and independent of glitches. (BTW, this is why capacitors and coils are called inert components, because they deal with inertia and do not react immediately to electrical changes but, rather, take a while during which they accumulate energy for future use or just to keep it).

Here it is:

D1

+

U1

+

+

U2

D2

Uout

-

-

FIG.: Parallel DC Voltage Sources

The electrical sign for a diode is a triangle with a line. The electrical current (not the flow of electrons) flies in the direction of the arrow made by the triangle. The current cannot fly in the opposite direction and pass through the line.

Assume U1 is greater than U2 (U1>U2). Then current will try to flow from the + of U1 through D1 and then through D2 and the + of U2 and then through the inner resistance of U2 source then will reach the negative of U1, then through the inner resistance of U1 back to the positive of U1 to close the connection. HOWEVER, THIS AIN'T GONNA HAPPEN BECAUSE D2 DOESN'T ALLOW CURRENT TO FLOW IN AN OPPOSITE DIRECTION THROUGH IT.

Similar is applicable when U2 is greater than U1 (U2>U1) but now D1 blocks the current.

Therefore, whatever the DC voltages U1 and U2 are no current will fly from one to the other. All the current will fly only through the load which is connected to Uout (not shown). Assume a resistor is connected between the + and the – of the Uout.

In case U1>U2, then the potential of the common point after D1 and after D2 will be equal to U1. Why? Because D1 is just a piece of copper when the current flies through the diode in the direction which the diode allows. So, when U1>U2 current can fly in direction through D1 but no current shall fly towards U2. D2 is a piece of rubber and doesn't allow current to fly in this direction. Yes BUT D2 is also a piece of wire when current flows in the right direction for D2. YES BUT CURRENT CAN'T FLY IN THIS DIRECTION BECAUSE U1 IS BIGGER. So, U1 makes the wires on the two sides of D2 look like rubber for the currents which may wish to fly in the direction in which D2 allows and D2 makes itself look like a piece of rubber for the opposite direction currents which definitely do want to fly but D2 does not allow them.

So, when U1 is greater than U2 this is like the positive of U2's is connected to the circuit not through copper cable but through a piece of rubber (rope) which means it is disconnected from the system.

Similar is the situation when U2 is greater than U1 just, now, U1 is out.

Therefore, whatever the case, the greater of the two voltages will be used to provide current to fly through the load. Also, there is NO interaction whatsoever between U1 and U2.

What when U1=U2. Theoretically, the two sources will provide equal currents through the load, each of them ½ of the overall current “consumed” by the load (which the resistor load allows to fly through it by using the simple Ohm's law: I=U/R, where U=U1=U2 in this case (just to use a simple notification U instead of Ux or Ui or U1 or U2, this is why I wrote U which means it is the two because they are equal IN VALUE: the number 5 is 5, regardless whether one uses Arab numbers (5) or Latin number notification (V) or writes it with a word: five). PRACTICALLY, IT IS ALMOST IMPOSSIBLE FOR THESE TWO TO BE EQUAL AND EVEN A NEGLIGIBLE DIFFERENCE WOULD DRIVE HUGE CURRENTS BECAUSE OF THE NEGLIGIBLE INNER RESISTANCES OF EACH OF THE SOURCES.

Y'all happy now, I got you an application. Case you have a few batteries in your pickups and, obviously, you can't connect them in series because your pickup takes 12V and each battery is 12V and when you put them in series you will get 24V which may burn your fuses and starter and alternator (must charge a higher voltage barrier which 's gotta be overcome by the alternator), so your only choice is to connect them in parallel and your BEST choice is to hook two diodes each of them rated for the maximum current allowed to be provided by the battery which may as well be 200A for 5 seconds and 60A continuously. These kinda diodes may as well prove to be bigger than your pickups. Try to look at your car/truck spec and see how much maximum current your car/truck takes during normal operation and how much maximum current your car/truck starter takes to start the engine AND FOR HOW LONG BEFORE YOU BURN IT. Then look up on the internet at the site of your local electronic component supplier and look how big and expensive such a diode is. Remember you need two. But this is just the precaution. BECAUSE YOU CANNOT USE THIS SCHEMATIC DURING DRIVING OF THE VEHICLE BECAUSE THE ALTERNATOR CAN'T CHARGE THE BATTERIES. Remember D1 and D2 do not allow currents in opposite direction which means, in case there is something in the load which can generate voltage (alternator) this will not be able to pass current through the batteries, I. e. the batteries will not be charged. So, why do we not connect the alternator to the two batteries directly, with a separate wire? Because then you will parallel the batteries. This is what we are trying to avoid. Then why do we not connect the alternator either to one or to the other battery and switch which battery will be charged? This you can do! Then why do we not get another alternator for another $100 and spend another few dollars and hook it to the system and then each battery will have an independent alternator and the two alternators will be able to provide power also to the whole car independently, without affecting one another on the same principle: “the greater one is used”. This you can do!

Yes, but why do we need two batteries and two alternators? This y'all learn when you come to the Northern States in the winter (which means after the oil in Texas gets depleted).

You can also use this double battery system when the car is not run (camping, etcetera).

Another incredibly and, probably the most, important application of the diodes is AC to DC conversion. Diodes have been used since they have been invented until today (more than 100 years) for rectification of AC and making it DC (better stick it in the rectum of Edison). Diodes will have continued to be used for this purpose forever. Do NOT be fooled when someone tells you there are IC's for this purpose. INSIDE THE IC'S THERE ARE DIODES TO DO THIS JOB.

Will we always need to use AC to DC conversion for power supply? Probably NOT. How come? Because, very soon, I hereby predict the US government will introduce DC power supply to all houses or will make a law or a policy so houses be built with built in AC to DC conversion, transparent to the user. Is this good. Hell yes. No more transformers, no more 60Hz noise (not as strong), miniature equipment, safer. AC may stay for some things (hopefully not). So why have they not done it. It was expensive in the past before China came around. The US companies used to work with law efficiency due to the desire for high profit and the extremely high prices of “Made in USA”. The US government used to refuse to control them because of the Western Ideologists and string controllers who were afraid the people of the US will follow the Soviet Union. By not controlling them, there were a possibility people still to erupt BECAUSE OF THE HIGH PRICES. The US government solved this problem BRILLIANTLY by electing the economy intellectual Ronald Reagan who allowed China and thus, driven by the mentors, Ronnie fucked the US industry in order to make a quick buck for the puppet masters. Thatcher was sucking Ronald Reagan's cock and did the same in the UK. So did Canada and Australia. Western Europe followed somewhat reluctantly. Germany fought very strongly and is still fighting, however, only in Berlin. The Chinese Army is in Berlin looking for Adolph Stevens. Eastern Europe and the Soviet Union resisted and won against the Chinese Influenza but lost to Kurt Vonnegut, I. e. Ronald Reagan fucked them all and they won all battles but, out of stupidity, surrendered to the Chinese as ordered by their American mentor. However, the US government is unable to do anything against the Chinese Empire now and just try to delay the total, unconditional surrender of the US Empire and the world to the Chinese.

In order to make a few dollars to a few, the US government did not control the industry being afraid from an invented, artificial thread which consisted a very limited possibility for the US to switch to socialism in the future and thus protect themselves but destroy the few buck a few had made. To try to protect them economy from high prices and to continue to serve the few, the US government destroyed the US industry by allowing China. Now, they may see there is no way to stop China, however, they believe the Chinese will be as stupid as the Japs and equalise the salaries with these of the US or at least very close, so the US companies can start manufacture again (in case they still can) but, in case of so, China ain't gonna exist, so the Chinese will keep the salaries and the costs of the industry so law as to always be able to sell everything the US needs to the US and there ain't no way to stabilise the system because the population of China is not only bigger but tremendously bigger by a multiplier of 54 than the population of the US.

So, with a few Texans, just like Travis, Ronald Reagan destroyed the US and the whole world unlike Travis. The funny thing is some countries made a monument of Ronald Reagan. Good idea, though. One day will lift it up by the neck!

Texans are known as people who shakes their big sticks and cannot see the important things but, instead, like drakes (cocks) jump against anyone who tells them they are morons instead of selecting these who tell them so the least. (This is because it is impossible to exist such a human being who will not consider the Texans to be morons.) Well, guess what, them Texans have been barking against a wrong tree.

Back to the USA (sorry, AC/DC) and the DC in houses. The US government will do so not because they take care of the stupid morons who call themselves people and are, practically, with the intellectual level of a pig (sorry to have insulted the pigs), they do not. Not only they don't care of them but they want to slave drive them even more. However, there are all kinda companies in the US. There will be some who will pull some strings with (or of) the US president and convince the said Emperor of how good it is to sell 100 000 000 devices with a huge marginal (as a percentage) profit per unit. Hell yes will “Hail to the Chief” say. SO, IN THIS CASE THE GOAL IS GOOD BUT THE MEANS USED DO NOT JUSTIFY IT. But it is better to have DC under the Chinese rule than not having rule at all, many of people I saw fall as I've been driving to the jungle with the snakes rattle and the monkeys scream and I say “Drive on.”

## **The Graetz Circuit**

The AC/DC converter is known as the bridge.

+ -

1 2

I+

C

D1

D2

A

Uac

Uout

RL

B

D3

D4

I-

- +

1 2

D

FIG.: THE BRIDGE: AC TO DC CONVERTER

One must always think of what happens with the applied voltage, I. e. to follow the schematic from input to output first. Obviously, when there is an AC, one must think what happens during the two waves, positive and negative. The positive wave of Uac (case 1) tries to through current I+ as every voltage would do. The current “starts rollin'” at the upper left point of the schematic 1+ and would work its ass off in order to reach the lower left point of the schematic 1- and the continue the journey INSIDE the power source Uac until it reaches the upper left point of the schematic 1+ where the current started thus passing through a close circuit IN CASE SUCH EXISTS. We don't know yet. We are gonna follow the path of the current and figure this out.

So, I+ starts from point 1+ (upper left point of the schematic) and continues until it sees two paths in a fork and starts thinking which one to choose, whether to pass through diode D1 or through diode D2. I+ doesn't need to think longer to find out D2 does not allow the current I+ to pass through it. D2 looks like a wall on the road. So I+ takes the correct decision to pass through the allowing D1. Then there is another fork: point A. Will I+ take the road down through diode D2 or will it go through the load RL? Well D2 doesn't allow I+ to pass through it. Kinda one way street in New York. So, ain't much choice, eh? The current came from Europe and thought North America is different but is, now, realising the current shouldn't have left Europe at all. So I+ goes through the load RL, than exits the load RL at point B. NOW THIS IS THE ONLY TRICKY POINT. Where will I+ go after point B? Will it take D4 or D2. The current starts to hesitate mainly when the current realises the two diodes are open for the current to go through. Well, the current started from point 1+. AS THE CURRENT PASSED THROUGH MANY OBJECTS SUCH AS WIRES, DIODES LOAD, THE CURRENT HAS EITHER MADE SOME VOLTAGE OR NOTHING AT ALL. As Ohm says, when a current passes through a resistor or resistance (being active or reactive), the current makes a voltage across this resistance. So, when the current starts from a point with a potential of 60V and the current passes through a resistor, the current will create a voltage across this resistance which voltage can be calculated by the Ohm's law. Say the voltage across the resistor is 20V. So, does this mean the potential of the point which has 60V already will increase? NO! This point is kept stable BY THE POWER SUPPLY AND THE SCHEMATIC. The current cannot fight against the power supply because the power supply is active and the schematic is passive: the power supply created this current and ordered this current to do something and the current follows the orders strictly. There is nothing around to generate another current. So, the first point will remain stable at 60V. What happens next? What does this voltage drop across the resistor do? IT DOES NOT CHANGE THE POTENTIAL OF THE UPPER POINT (kept by the power supply and the schematic) BUT IT CHANGES THE POTENTIAL OF THE POINT AFTER THE RESISTOR TO A LOWER VALUE OF THE POINT BEFORE. This is true when operating in regime of constant voltage as opposed to the regime of constant current, means with voltage supply not with current supply, means with voltage source not with current source.

SO, THE POTENTIAL ANALYSIS SHOWED: AS THE CURRENT GOES, THE CURRENT MAKES MESS AND MAKES THE POTENTIALS OF THE POINTS AFTER EVERY PASSIVE COMPONENT IT PASSES DECREASE IN VALUE AS COMPARED WITH WHAT THESE VALUES WOULD HAVE BEEN HAD THERE BEEN A DIRECT WIRE CONNECTION WITH THE RELEVANT POINT OF THE POWER SUPPLY.

In other words, in case of a wire to deliver the 60V AFTER the resistor, the point after the resistor would have the same potential of 60V. BUT, THERE ISN'T SUCH WIRE. THEREFORE THE CURRENT WILL MAKE THE POTENTIAL OF THE POINT AFTER THE RESISTOR 40V. THE ENGINEERS SAY THERE IS A 20V VOLTAGE DROP DUE TO (THEY SAY ACROSS) THE RESISTOR. THUS, THE POINT BEFORE THE RESISTOR HAS A POTENTIAL OF 60V, THEN THE CURRENT WITH A KNOWN VALUE (defined by power supply AND schematics) passes through the resistor with a known value and makes a voltage of 20V across the resistor (voltage drop) and thus makes the point after the resistor to have a potential of 40V. THE POWER SUPPLY ENSURES THE POINT BEFORE HAS A POTENTIAL OF 60V BECAUSE OF ITS LOW INTERNAL IMPEDANCE (CAN'T HAVE A VOLTAGE DIVIDER DUE TO BUILT IN IMPEDANCE). THE INTERNAL RESISTANCE/IMPEDANCE POINT WILL BE CLEAR IN A WHILE BUT THE IMPORTANT THING IS: A VOLTAGE POWER SUPPLY WILL WORK ITS ASS OFF IN ORDER TO ENSURE THE VOLTAGE PROVIDED AT ITS OUTPUT DOES NOT CHANGE NO DIFFERENCE WHAT HAPPENS WITH THE LOAD. In other words, no difference what power appliances you plug in, the mains voltage will always be 110V, 60 Hz in North America, 240V, 50 Hz in the UK and 220V, 50Hz in the rest of the world much to the dismay of anyone who belongs to this world

SO MANY WORDS JUST TO SAY, at point B, the current cannot take it up the hill through D2 because of a higher potential after D2 but has got only one choice: to go through D4 and then to point 1-, lower left of the schematics, then goes inside the power supply to get “accelerated” up to the point 1+ (upper left) and then pushed again into the system.

OK. What happens with the negative wave? The negative wave is depicted by case 2. Negative voltage wave is applied to the bridge. The current I- starts from point 2+ (bottom left) and tries to get goin'. Gets to point D and sees the fork which has 2 ways: either through D3 or D4. D4 does not allow for the current to pass through it, so the current I- passes through D3 to reach the same point A. At this point A there is another fork: either through D1 or through the load RL. The idea to pass through D1 sounds extremely attractive to I- BECAUSE THERE IS A NEGATIVE POTENTIAL OF THE POWER SUPPLY APPLIED ON THE OTHER SIDE OF D1 (POINT C IS CONNECTED TO D1 AS WELL AS TO THE POWER SUPPLY DIRECTLY: COPPER WIRE). I- would be happy to take this short cut and skip the load RL. However, D1 does NOT allow I- to pass through it and I- is forced to go through the load and then to come to point B same as I+ has previously done. Now the tricky point again. I- hesitates where to go on the fork of point B. Whether to take the route to D4 back to where it came from skipping the power supply and circulating in a loop as in case I- has been induced there OR ether to take D2. The potential of point D is higher than the potential of point B because I- has started from point D (copper wire directly connected to 2+, the now positive of the power supply). So, the higher potential of point D than point B does not allow I- to pass through D4 ALTHOUGH D4's direction allows it. D4 may allow whatever D4 wants but D4 is just a simple diode and not the boss there. The boss is always the dumbest one: the power supply! So, again, I- ain't got no choice to go nowhere else except through D2, then, through point C and the, through the copper wire, to the negative point of the power supply: point 2- which is the upper right point of the schematic, then through the extremely low inner resistance (impedance) of the power source back to the positive point of the power supply 2+ where the current started. We've got a circuit! Works.

Works but what happens? I kinda lost you with so many explanations. What happens is kinda important. THE TWO CURRENTS I+ AND I- PASSED EXACTLY THE SAME WAY AND DIRECTION AFTER POINT A AND BEFORE POINT B. SO, REGARDLESS OF THE DIRECTION OF THE VOLTAGE WAVE (POSITIVE OR NEGATIVE), THE GENERATED BY EITHER WAVE CURRENT WILL EVENTUALLY PASS THE SAME DIRECTION BETWEEN THE POINTS A AND B: **FROM A TO BE AND NEVER FROM B TO A**!!! AND THIS IS DIRECT CURRENT NOW! IT DOES NOT ALTERNATE ONCE IN ONE DIRECTION THEN IN THE OPPOSITE! IT GOES THE SAME DIRECTION AS IN CASE OF A DC VOLTAGE POWER SUPPLY DIRECTLY ATTACHED TO THE LOAD RESISTOR RL!

Now read this again. Once done, read it again. Once ready, NOTE: I have used the words WAY and DIRECTION. I have not used the word SHAPE! The voltage Uout will NOT be the same as a DC voltage source AS FAR AS THE SHAPE IS CONCERNED! A DC voltage source will have a steady voltage, say 9V (like in a 9V battery) which will never change and will always be 9V (unless the battery starts runnin' out of juice). In our case, this is what happens to the voltages Uac and Uout:

Assume the applied voltage Uac from an external power supply comes from the mains. Could be anything, though.

Positive wave: Uac starts from 0V to increase to say 150V. When it reaches a peak (called an AMPLITUDE) of 150V, Uac starts fallin' down to 0V in order to become a negative wave after crossing the 0V. Uout DOES EXACTLY THE SAME!

Negative wave: Uac starts from 0V to decrease to say -150V. When it reaches a bottom (called an AMPLITUDE) of -150V, Uac starts going up to 0V in order to become a positive wave after crossing the 0V. Uout DOES THE OPPOSITE BECAUSE THE BRIDGE CHANGES IT! How does the bridge change this? You said the bridge rectifies current not voltage. Yes, but our source is a voltage source. Ain't no current without voltage from the voltage source. Can't change the direction of the current without changin' the direction of the voltage. This can be seen on the schematic HOWEVER remember once again: a diode (ideal) is a short connection in one direction and an OPEN circuit in the other. The direction depends ONLY on the diode's internal design. It is indicated on any diode what the direction is. So, in order to follow the schematic easier, one can short or take diodes out for each wave and it will be easier seen what happens with the voltage. So, for the positive wave, D1 and D4 are short circuit (copper) and D2 and D3 are open circuit (rubber), same as having air instead. This means point A is connected with a copper wire to point 1+ (the positive of the power supply during the positive wave) because D1 is alike a copper wire for the positive wave. Same as D4, which means 1- is connected to the negative of the power supply (the positive of the power supply during the positive wave). This is like the power supply is directly connected to the load. For the negative wave, D2 and D3 are like short, D1 and D4 like open. Therefore, point A is connected to 2+ and point B to 2-, I. e. point A is connected to the positive **DURING THE NEGATIVE WAVE** 2+ (the lower left point) and B is connected to the negative **DURING THE NEGATIVE WAVE** 2- (the upper left point).

This is like John is sitting there and drinking and watching the generator. Assume the generator gives a sine AC BUT very slowly (the positive and the negative waves come in turn, each of them every 10 seconds). John has been instructed to watch the generator monitor and, when the wave is positive to stick the cables one way to the load. AS THE WAVE TURNS NEGATIVE, JOHN REVERSES THE PLACES WHERE JOHN STUCK THE WIRES BEFORE. In other words, during the 10 seconds of the positive wave, John kept the red wire connected to the red input of the load and the black wire to the black input and, as the wave turned negative, John quickly detached the wires and attached the red wire to the black input of the load and the black wire to the red input.

So, Uout starts from 0V to increase to 150V. When it reaches a peak (called an AMPLITUDE) of 150V, Uout starts fallin' down to 0V in order to repeat this again during the next positive wave, then again after the followin' negative wave, then again after the followin' positive wave, etcetera for ever.

Here are simple badly drawn graphics of Uac and Uout:

Uac

Uout

FIG.: Uac and Uout

The rectified voltage Uout looks like tits and/or female asses.

Now the question is how it is possible for one to use such voltage instead of the never changing DC voltage of a battery. This is because there is a way to make it almost as good. All we need to do is to put a big capacitor rated for voltages above the RMS of the voltage we would like to make look like a battery. Remember the RC passive low pass filter? Remember we have said when R=0, ALL FREQUENCIES WILL BE FILTERED EXCEPT FREQUENCY 0 WHICH IS THE PERFECT DC? So, this is the solution. We will make an RC filter without R (R=0) which is ONLY A CAPACITOR across the load! Problem solved? In most any case YES! However, the inner resistance of the source (transformer after mains) as well as the tiny resistance of the diodes (when in SHORT position (current passes in the direction which the diode allows)) as well as the tiny resistance of the copper tracks, wires and cables, as well as the tiny resistance of the contacts and soldering points, all added together, will make a bit of ripples on the DC voltage after the capacitor which we wanted to be perfect.

Also, in case of big load (not very big resistance of RL) the load will drain huge current out of the capacitor when the voltage drops below the RMS value (below what the capacitor is supposed to KEEP). This current will make the capacitor voltage get lower progressively, similar to draining a battery. (The more power we take from a battery the lower the voltage of the battery gets, hence people measure the voltage of their car battery and, in case it is around 12V with some load (lights on), then the battery is considered charged, otherwise they refresh the charge to start the car the next day.)

Then, when the voltage Uout grows above its RMS value, the capacitor will start charging again.

Then discharging, then charging, then discharging, then charging, then discharging, then charging, etcetera. THIS RESULTS INTO RIPPLES.

## **Power Supply Filtering Capacitor**

So our DC voltage will have ripples. So what? Notha in most cases, HOWEVER in music, this ripples would proliferate throughout the whole equipment and lead to 60Hz noise in the loudspeakers. You may wish to add a few harmonics too. And these are in the audible range and can't be filtered. One has to advise the bass guitar players not to play 60Hz notes in the US and not to play 50Hz notes in Europe so the engineers can filter the 50/60Hz from the overall sound!

The engineers have found several ways to reduce this effect as well as the effect of the 50/60Hz electromagnetic noise picked up by musical and electronic equipment and successfully delivered to the loudspeaker.

And here is the ingenious circuit with one thick capacitor in parallel to the load (the bigger the capacitor the better the filtration the less the discharge when current is drained out of it):

A

RL

B

FIG. CAPACITOR AS A POWER SUPPLY FILTER

The capacitor is in parallel to the load between points A and B.

I think enough is enough for now. However, you may ask yourself a question: Why do we need transformers, then? This can be plugged directly to the mains and here is AC to DC. This is possible but ain't safe. The transformers ain't safe either, however, they are the safest alternative possible. The safest transformers are the toroid transformers where the coils ain't twisted isolated copper wire over wire over wire but are lined around a short cylinder instead with isolation between the cylinder and the coils and the coils are covered with thicker lacquer isolation. The primary and secondary coils are away one from another. The probability for the isolation of a coil wire to burn and to touch another wire with burned isolation between primary and secondary coil is decreased. As described, the problem with transformers is when a naked wire of the primary coil touches a naked wire of the secondary thus transferring power from the mains to the secondary directly (no longer a transformer but a direct Galvanic connection) and since one side of each of the coils may as well be grounded, we will be transferring the mains directly over our circuit and God knows what happens next!

They sell transformerless 5V USB chargers these days but I ain't much too sure how legal they are in North America. AS A RULE OF THUMB, ANYTHING TRANSFORMERLESS IS MUCH MORE DANGEROUS THAN TRANSFORMERFUL!

Usually, all equipment is built with transformer power supplies and none (except specialised) uses a toroid transformer. This is the only approved way in North America and most or all of the world mainly the UK. Toroid transformers are much bigger (the size of a football (American)) and extremely expensive.

Another way to build a very safe yet very low efficiency power supply is by converting AC electricity to light and then light to DC electricity. Simple, ingenious (I've made it), top quality and pretty useless due to the low efficiency and huge power losses! The idea is simple. You plug a light bulb in the mains. Put the bulb in metallic enclosure with ventilating holes. Put photovoltaic element(s) as well as mirrors around the bulb in such a way as to make sure all light is reflected onto the photovoltaic elements. Off you go! Hot, eh? Extremely. Most of the energy will be dissipated as heat due to the way of work of the light bulb! NO GALVANIC CONNECTION BETWEEN THE EQUIPMENT AND THE POWER SUPPLY, THOUGH. Low power only! You can touch even with your dick the equipment wherever you want to stick it, in the worst case you may have a few volts. Good for your wife/girlfriend!

A very important thing to note is the impossibility to GROUND the DC voltage output and thus the load to the power source ground. There is always one diode between the DC voltage output/load and the power source ground.

Another important thing is the size even of the standard transformers. Most of you would say they are not so big and mounted in a monolithic enclosure with the plug (these plug adapters like for cell phones, MP3/4 players, etcetera). This is because these are very low power supplies. Try to get to 1A or higher at 5V or higher. Then the plug adapters become big and heavy. And, in North America: expensive. Not a good idea for higher than 5W output.

So far, I have been looking at diodes from signal (analogue logic) and digital applications (digital logic) point of view. Pretty much the same as in silicon diodes. However, an important disadvantage of the tubes is: it ain’t very easy for an electron to break away from the cathode. Sometimes, the voltage to be rectified is very low. The valve designers has overcome this problem by heating the cathode until it becomes unstable and electrons can break easily. Electrons may even break and float in the vacuum so even a tiny electrical field (voltage applied on the two electrodes) would run a current when in the correct direction.

Obviously, one wouldn’t assume they burned coal in the tube, so the only practical way to warm up the cathode is by driving electrical current through. ASSUME TO BE DIFFERENT ELECTRICAL CURRENT ONLY THROUGH THE CATHODE NOT THE ONE WHICH GOES THROUGH THE TUBE. Ideally, one would like to have a saturation of electrons in the vacuum tube before voltage is applied, so the tube looks as much as short connection in the correct direction as possible.

## **Powering The Tube**

So, how can we drive two currents through the cathode? The simplest way is with two different power supplies:

In case one is to put 2 transformers to the mains, they look like two separate power supplies not interconnected to each other just like two different adapters plugged to the mains, say an adapter for the distortion and an adapter for a guitar amplifier. In case ONLY one output of the **secondary** coil of each transformers are connected, still, there is no interaction between the two. Neither the secondary coil voltages or currents interact nor the primary. So, these two transformers will look like totally independent power supplies. In case we connect one of them to the cathode (each output to each side of the cathode string), all of the power the transformer can give would go through this cathode string warming it up just like a heating element of an electric heater or an electric stove. However, the transformer may be powerful enough to burn the cathode. Or, in case of many cathodes in parallel, when one burns, the current through each of the rest will increase and may burn one more, then increase more and burn one more, then increase more, etcetera. In order to provide a certain amount of current only, a resistor can be put in series with the transformer’s secondary.

The rest of the electronics/electrical in the circuitry can be powered by the other transformer’s secondary. Thus the signal will not have any electrical interaction with the cathode heating. More, instead of two transformers one may have two secondary coils on a single transformer. This is kinda the same as to have two transformers. Again: in transformers, there is no electric interaction whatsoever between any of the coils. So, assume they are two different transformers for simplicity.

V1

Uacdcs

V

R

Uacp

V2

V3

FIG.: POWERING THE TUBE

The power to the tube (the heat) is provided by applying voltage Uacp (U AC Power) applied between points V3 and V2 through a resistor R. Point V is a point where the two power supply systems meet (it is not important they meet through the resistor R or whatever other components, it is important they meet). The good news is the two power supply systems meet in ONE POINT ONLY! Therefore, there will not be any electrical interaction between them. There may be whatever voltage drops across the cathode (literally across) but they will affect only the cathode, i. e. they will be spread throughout the cathode (INSIDE) only and there will not be any potential difference between the anode and cathode. Thus, there will be free electrons floating in the tube OR there will be electrons just waiting for a tiny anode-cathode potential difference in order to start flying OR a combination thereof.

So, with the Uacp applied only, nothing happens. The tube gets warmed up and nicely glows in the dark. Looks kinda beautiful too. One can warm up hands in the winter coming home after playing with the snow. Looks magical. Please, each and every one of you, go ask some guys in pawn shops or shops for old electronics to show you how an old TV looks inside. This can be seen through the punched cardboard cover, they don’t need to open the lid: the cover MUST be punched like a practice target, otherwise there ain’t gonna be no aeration to bring the room temperature to the equipment and, with so much power inside converted into heat by the tubes (cathodes) the equipment will melt like a Chrysler engine without water/antifreeze.

The TV programs all over the world became so stupid, it is better to look at the tube electronics inside the TV rather than to watch the TV programs.

In case you want to warm up, place your hands near the cover and enjoy. Just make sure water ain’t dropping inside or over the cardboard cover. In the best case, the cover will be broken (most likely where the wood screws are) in the worst, you will be propelled like an RPG. REMEMBER, NO DIFFERENCE WHETHER YOU WORK WITH TINY SIGNALS OR HUGE SIGNALS, JUST POWERING THE TUBES TAKES A NUCLEAR POWER STATION!

Resistor R may not be necessary in the power circuit of the tube. Mainly when the resistance of the cathode is large enough. However, in case of a short, all current will go through one tube and the others ain’t gonna get no current. In case of a large differences in the resistance of the cathodes, large current can be drawn through the lower resistances. The power supply may lack the necessary output power to maintain the desired power voltage Uacp and thus the voltage will drop and may drop to levels impossible to power some of the tubes.

Anyways, once powered up, we may forget of the power circuit to the valves and to consider only the signal circuit (Uacdcs in this case (U AC DC Signal)). Hence we can draw only these points V and V1 on the schematics. The power is standard for each tube and cannot be changed for different schematics. The application of the signal part of a tube is totally up to the designer.

## **Analysis**

**Basically, there are a few important basic type of analysis to be considered when designing a circuit or figuring out how a circuit works.**

* 1. **Potential Analysis**
  2. **Current Analysis**
  3. **Potential and Current Analysis in Time Domain**
  4. **Potential and Current Analysis in Frequency Domain**
  5. **Schematics Analysis (Resistor, Capacitor, Coil Level): Active components are broken into the three basic electrical components. Schematic level view is used for this analysis: Voltage Dividers, Current Dividers, Filters, etcetera.**
  6. **Feedback Analysis: Although part of the Schematics Analysis, special attention needs to be paid on the feedback circuitries. STRENGTH OF FEEDBACK is one important parameter to be considered.**
  7. **Power Analysis**
  8. **Instrumentation Analysis**

## **ADDENDUM**

**Microphone Preamplifier**

**By Steven Stanley Bayes**

+

-

5 to 30V

+

-

1kΩ

1kΩ

+

10µF

1µF

330nF

+

-

10K

120K

39K

10K

0 to 100K

100Ω

10µF

56pF

Microphone

It is assumed the output of a standard AC to DC adapter is totally galvanically independent from any other power supply of any other device which is supposed to be true assuming the adapter is just a transformer with a rectifying bridge on the secondary and a capacitor.

Then +/- DC power supply voltage is supplied through a switch to an electrolytic and ceramic decoupling capacitors in parallel to each other with values of 10µF and 1µF. Then, there is an LED to indicated power on after the switch. Then a simple voltage divider to divide the input voltage into two and to give a middle point between the two voltages. Then there is an operational amplifier connected to the power supply almost directly (through the LED). Hence, it may be wise to put the LED with the resistors although there would not be a perfect voltage division of the adapter output.

The LED takes 1 to 1.2V voltage. The rest would power the operational amplifier which buffers the middle voltage (middle point) and provides a LOCAL “ground” only for the preamplifier circuit.

Ideally, this local ground should not be connected to anything outside the circuit but, in this case, it would be connected through the output of the preamplifier to the input of the amplifier (PC Sound Card).

Any current which starts from the positive pin of the power supply will go through the LED and the circuitry and then go through the output of the operational amplifier and through the very low (almost zero) output resistance of the operational amplifier to the pin of the operational amplifier which is connected to the negative pin of the power supply. The operational amplifier, itself, does not add any burden to the circuitry because of its almost zero output impedance. In this connection, the operational amplifier is an almost perfect power supply additive because of its almost zero output impedance. Of course, the ideality (how ideal) the power supply is) depends on the ideality of the DC power supply source (the AC to DC adapter). After all, the adapter powers this part of the circuitry. The operational amplifier just ensures an almost zero impedance return path to the negative rail (pin) of the adapter.

Any “negative” current which starts from the ground, ground is the output of the operational amplifier, will go through the circuitry and return through the circuitry to the negative pin of the power supply. The operational amplifier acts as an almost ideal positive power supply to the connected circuitry with ground as a positive output and the negative pin of the power supply as a negative output. The operational amplifier in this connection is an almost ideal power supply because of its almost zero output impedance. Of course, the ideality (how ideal) the power supply is) depends on the ideality of the DC power supply source (the AC to DC adapter). After all, the adapter powers the operational amplifier which, in turns, powers the rest of this part of the circuitry. In case this part of the circuitry wants to suck a lot of power, it will suck it from the operational amplifier which, however, does not generate power and needs to suck the necessary power from the adapter in order to be able to provide it at its output.

Thus, I say this operational amplifier does nothing except BUFFERS THE GROUND!

It is not necessary to compensate this operational amplifier for the front bias voltage (currents) because, since the gain is 1, there will be a very negligible offset of the middle point at the output of this operational amplifier which will only lead to different size of the “positive” (upper) half of the divided power supply voltage and the “negative” (lower) one. As long as the signal voltage of the circuitry doesn’t go high and low near the power supply rails, this asymmetry of the two half voltages will not create any problem.

The ground buffer provides a very low output impedance which means the ground rail will not pick up electromagnetic noise but the operational amplifier self noise will be present on the ground rail which should not be a problem.

The microphone will typically have 0 to 10µV (standardly 5µV) output. The internal resistance of the microphone is unknown but is supposed to be low for coil microphones. The microphone would pick up a lot of noise, hence a resistor with a relatively low value is advisable to be put in parallel (or the negative input resistor of a negating operational amplifier circuit).

In this case, a 10kΩ resistor is put in parallel to the microphone, followed by a positive operational amplifier circuit. (A passive band pass filter of 50Hz to 20kHz may come handy after the microphone and before the operating amplifier, hence a negatively connected operating amplifier without a potentiometer would come handy since a band pass filter can easily be arranged around it.)

A capacitor of 330nF may be put after the microphone and before the resistor in parallel in order to introduce a high pass filter with 50Hz cut off frequency.

Here comes the positive operational amplifier circuit, the gain of which is 1 + the ratio of impedances of the feedback track and the “negative input of the operational amplifier to ground” track. There is a 120KΩ resistor in the feedback track. There is a 10KΩ resistor and a 0 to 100KΩ potentiometer in the “negative input of the operational amplifier to ground” track.

Thus, when the potentiometer is at position 0Ω, the gain is:

1+120000/10000=13

and

when the potentiometer is at the 100KΩ position, the gain is:

1+120000/(100000+10000)=1+120000/110000=1+1.1=2.1

So, this amplifier will always amplify with a gain of minimum 2, maximum 13 as depends on the position of the potentiometer.

A disc (ceramic) capacitor of 56pF can be added in the feedback circuit of the operating amplifier to introduce an “imperfect” low pass filter with a cut off frequency of 25KHz. The filter is imperfect because, even at infinitely high frequencies, when the capacitor shunts the feedback resistor and gives a feedback impedance of 0, the gain of the circuit will be 1 and not 0, i. e. the operational amplifier will act as a buffer with output connected to the negative input. The impossibility to bring the filtered signal to 0 is one of the disadvantages of the positively connected operational amplifier. The huge input impedance is its main quality which is not used in this case because of the resistor parallel to the microphone. However, in case this resistor is removed, then the huge input impedance will prevent loss of signal. In case the resistor is changed with another one, the operational amplifier circuit will be invariant to the value of the new resistor parallel to the microphone. (In case installed the 330nF capacitor must also be changed accordingly). Again: huge input impedance of the circuit after the microphone is extremely highly desirable because of the very miniscule microphone voltage, however, the 50/60Hz noise as well as other electromagnetic noise in the audible range (such as car/truck/motorcycle electromagnetic noise generated by the coil + switch + distributor spark generation and alternator power supply). Even incandescent lights generate an audible electromagnetic noise. Power lines too and people whose houses are near a distribution line are exposed to the said and not only their high performance audio equipment may have problems but the electromagnetic noise at levels near the distribution lines may be dangerous for their health.

After the operational amplifier circuit, a large (largest possible) ceramic or equivalent (not polarised) capacitor is somewhat welcome to filter the DC component. The danger is this capacitor may filter parts of the audible range as depends on the input resistor of the circuit after the pre amplifier (usually an audio amplifier of a PC Sound card). It is assumed the circuit after the microphone should have a passive high pass filter with the capacitor up front but it is always good not to rely on anyone.

Another good reason for this capacitor is to prevent any significant DC to enter the circuit after the pre amplifier such as the output of the amplifier voltage in a case of latch up or the power supply voltage in case of malfunction of the pre amplifier.

The problem with separate pre amplifier and amplifier with different power supply is there is not much of a way to logically protect the amplifier because the input level of the amplifier are not known because there are very many amplifier manufacturers and their amplifiers have different power supply voltages, gain and input impedances. Hence, the only possible way seems to be the passive way. A capacitor in series to the output may lead to filtration of the audio range but will protect the amplifier from high DC. A resistor in series will protect the input of the circuit at the output of the pre amplifier (usually an audio amplifier of a PC card) from very high AC currents. The problem is this resistor must have a very low value because of the unknown input impedance of the amplifier which, when too low, may lead for the resistor to introduce a voltage divider with the input impedance and thus loss of signal.

Most likely, in order to decrease the significant reflection of the electromagnetic noise on the microphone and the pre amplifier, some manufacturers have put a very low value resistor in parallel to the input of their audio PC card. Some sources cite a value of 1KΩ which is a shame from the electronics theory point of view but a necessity from the practice point of view. I, personally, consider even 10KΩ incredibly low input resistance but there is nothing to do but conform to the standards of the manufacturers. Most of the PC audio card manufacturers have been cited to put 10 or 20KΩ resistor on their microphone input.

To make the pre amplifier as universal as possible, a resistor of 100Ω has been put in series to the output. Even at the lowest cited input impedance of the circuit after the preamplifier, there will be a 100Ω + 1KΩ voltage divider with a transfer ratio of 91% and 9% loss of signal.

The protection which this resistor offers is not very much. The resistor would limit a 12V power supply to be able to provide maximum of 120mA to the circuit after the preamplifier which is not so great help but still may do some job. Alternatively, a 1KΩ resistor may be put instead which will lead to as high as 50% signal loss but will definitely ensure the necessary protection of 1.2mA input current.

Most of the manufacturers and probably all protect their equipment by resistors in series to the input for generally used supply voltages of 1.5 to 24V.

The idea of input protection is to ensure the input current is limited by a resistor when the input of the equipment becomes higher than the power supply of the equipment. Most manufacturers may decide to put a pair of diodes from input to the power supply rails with a resistor before but the diodes introduce a signal nonlinearity and may prove not to be the best choice for most analogue applications. It is, however, a must to put this resistor and diodes protection for digital signals exchanged between equipment with different power supplies. A problem there may appear at huge speed signals due to the created low pass RC filters between a resistor and the parasitic capacitors of the diodes. Deterioration of the shape of the digital signals may appear. Also, in addition to the diodes, the standard CMOS circuit, whose input is protected, would have a parasitic input capacitance. An input parasitic capacitance of a bipolar transistor as well as a silicon diode would be around 5pF. The thinner gate of modern CMOS would decrease the parasitic input capacitance yet become easier to be damaged.

As a gross generalisation, maximal input currents of around 1mA are not considered to be dangerous for the silicon.

Anyways, once the pre amplifier circuit is built, one may wish to tweak the two resistors: the one in parallel with the microphone (input) (with the capacitor in series) as well as the one in series to the output (the protection one).

Instead of putting just a 1KΩ protection resistor, one may put a voltage divider with at least 1KΩ resistor and a potentiometer to ground. Then, the gain of the amplifier must be higher to be followed by attenuation. Amplification and then attenuation is possible when the supply voltage is much higher than the maximum signal required at the output of the pre amplifier.

Avery standard approach to providing a middle point (ground) is to use a resistor and a Zener diode across the power supply. However, this is when the power supply voltage is, at least APPROXIMATELY known. Otherwise, a switch and a few Zener diodes may be used with most conveniently selected values to be around the middle of the most used power supply. However, the user is supposed to switch them as depends on the power supply voltage used and, most importantly, the switch will act as an antenna for the electromagnetic noise, which may not be a great deal of a problem since the switch is grounded but it very much depends on the ground path. Here is a simple depiction to replace the voltage divider at the power supply:

DC Power Supply

R=1KΩ

+

-

+

-

I

I2

I1

I2b

I2a

I2c

I2d

The selected Zener diode provides a voltage defined by the internal structure of the Zener diode which cannot be changed by an increase and decrease of the current which passes through the Zener diode.

Assume, a Zener diode with a maintained voltage of 5.6V is selected. Assume the power supply provides approximately +/-12VDC. No difference what the current through the resistor and the Zener diode, the Zener diode will always maintain 5.6V across itself. The Zener diode has an incredibly small internal resistance. In case the Zener diode was to be put across the DC voltage power supply, then the Zener diode will:

1. Try to force the power supply to go down to the Zener voltage (5.6V in this example). However, an ideal power source would not agree with the Zener diode. The power source will put as much current as possible to maintain the power supply voltage (12VDC in this example) and the Zener diode will “open” as much as possible to enforce the Zener voltage. The fight between the power supply and the voltage will continue until a burnout either of the source or of the Zener diode.
2. The same can be explained with: The Zener appears to be a short across the power supply because of its incredibly low input resistance. Short leads to a burnout either of the source or of the short connector.

To prevent a burnout, a resistor is put in sequence to the Zener diode. The voltage across the resistor will be the voltage of the power source minus the voltage across the Zener diode as per Kirchhoff’s law. In this example, the voltage across the resistor will be 12-5.6=6.4V. The resistor is then calculated to the resistor provides the necessary good current through the Zener diode with which the Zener diode is able to maintain the Zener voltage. Zener diodes usually allow for a huge range of currents to be applied. Assume, our Zener allows for 6.4mA to be applied through. Therefore, our resistor is 6.4V/6.4mA=1KΩ as per the Ohm’s law. The power dissipated by our Zener diode is 5.6Vx6.4mA=35.84mW~36mW.

It is important to note, ideal power sources have limited capabilities of providing limited currents while maintaining the signposted voltage. For example, there are 12VDC power supplies rated at 300mA (300mAx12V=3.6W) which will provide between, say, 16V and 12V for currents between 0 and 300mA (non regulated AC to DC adapters). One must ensure the whole circuit does not consume more than the maximum specified current. One must, therefore, ensure the resistor and Zener diode parallel branch does not consume all of the allowed current and not to leave any current for the rest of the circuit which is being attempted to be power supplied. In this example, the resistor and Zener diode parallel branch must NOT consume 300mA and must NOT consume more current than the (maximum power supply current – maximum current needed by the rest of the circuitry). In other words, in case the rest of the circuitry needs 100mA to operate properly, the zener diode and resistor branch must not consume more than 200mA hence the resistor has to be calculated to limit the current through itself and the Zener diode to 200mA.

The switch switches to a given Zener diode in order to provide a “ground” point somewhere in the middle of the power supply voltage. For example, a 5.6V Zener is to be selected by the switch for 12VDC power supplies, a 3.3V Zener diode is to be selected by the switch for 6VDC power supplies, a 7.5V Zener diode is to be selected by the switch for 15VDC power supplies, etcetera.

Yes but the resistor value is the same. Does one have to have a single pole double throw switch and also switch to a different resistor for each of the Zener diodes? No, because the Zener diodes have a huge tolerance of currents which pass through them while they are able to maintain the Zener voltage. IDEALLY, a Zener diode maintains the Zener diode voltage for all currents from 0 to infinity. Practically, there is a very tiny minimal current required to be passed through the Zener diode in order to maintain the Zener diode voltage and a very huge current where the Zener voltage is significantly off the rated Zener voltage. Some assume the Zener diode does maintain the rated voltage all the way up to the maximum current of the voltage at which the Zener diode will dissipate maximal power=maximal current x Zener voltage.

In this example: The resistor is 1kΩ. The power supplies are 6V, 12V, 15V with Zener diodes rated at 3.3V, 6V, 7.5V accordingly. Therefore, the 3.3V Zener diode will see (6V-3.3V)/1kΩ=2.7mA current and 2.7mAx3.3V=8.91mW power dissipation. The 5.6V Zener diode was calculated before. Therefore, the 7.5V Zener diode will see (15V-7.5V)/1kΩ=7.5mA current and 7.5mAx7.5V=56.25mW power dissipation. Obviously, since the resistor is the same and the power supply voltage increases (therefore its approximate half also increases), the current increases but the current through the resistor is the same as the current through the Zener diode and this current, as it has just been said, increases but the voltage value of the Zener also increases because it is the other half of the increasing power supply voltage and when one half of something increases the other half increases too since one of the halfs is almost equal to the other. So the current through the Zener diode increases and the rated voltage requirement increases, therefore the power increases too.

PAY ATTENTION: BECAUSE THE CURRENT AND THE VOLTAGE ARE MULTIPLIED IN ORDER TO OBTAIN THE RESULTING POWER, THE CURRENT INCREASE WILL BE MULTIPLIED BY THE VOLTAGE INCREASE TO GIVE A MUCH HIGHER, NON LINEAR INCREASE OF THE POWER, IN OTHER WORDS, THE POWER INCREASES BY THE POWER OF TWO.

“The power increases by the power of two” is an interesting sentence. The first power is the power dissipated by the Zener diode and the second power is the power level which is put in mathematics when one says ex equals y in power of 2. Although you can see the connection here, to use a physical parameter in mathematics is wrong and stupid. Mathematics is independent of physics and is higher in the hierarchy of sciences. The highest in the world! MATHEMATICS IS USED FOR LOGIC, AND LOGIC DOES NOT MEAN DIGITAL LOGIC, AND NOT FOR PHYSICS. There is elementary logic and there is complicated logic. There is analogue and digital logic. THERE IS NOT SUCH A THING AS COMMON SENSE. Therefore, the expression “The most common thing we lack is a common sense” is true one way and the other.

What happens with the current through the rest of the circuitry? The current starts from the positive of the power DC Voltage supply. (Part of the current goes through the resistor and Zener diode parallel branch. The rest goes through the circuitry. Then it goes to ground (the point above the Zener diode. Then it passes through the Zener diode. THIS MEANS THERE WILL BE MORE CURRENT THROUGH THE ZENER DIODE AND OUR CALCULATIONS FOR POWER AND CURRENT THROUGH THE ZENER DIODE ARE WRONG. WE MUST TAKE THE CURRENT WHICH GOES THROUGH THE REST OF THE CIRCUITRY AND THEN RETURNS AND PASSES THROUGH THE ZENER DIODE AND ADD THIS CURRENT TO THE CURRENT OF THE RESISTOR ZENER DIODE BRANCH.

The “negative” current starts from the “ground” goes through the circuitry and returns to the negative point of the power supply. THIS MEANS THERE WILL BE LESS CURRENT THROUGH THE ZENER DIODE (THE NEGATIVE CURRENT IS TAKEN AWAY FROM THE ZENER DIODE BY THE CIRCUITRY OR PART THEREOF) AND OUR CALCULATIONS FOR POWER AND CURRENT THROUGH THE ZENER DIODE ARE WRONG. WE MUST TAKE THE “NEGATIVE” CURRENT WHICH GOES THROUGH THE REST OF THE CIRCUITRY AND THEN RETURNS TO THE NEGATIVE POINT OF THE POWER SUPPLY AND SUBTRACT THIS CURRENT TO THE CURRENT OF THE RESISTOR ZENER DIODE BRANCH.

IN CASE OF A SYMMETRICAL CIRCUIT WHERE THE “POSITIVE” CURRENT AND THE NEGATIVE CURRENT ARE EQUAL, OUR CALCULATION IS RIGHT. OTHERWISE, THE DIFFERENCE OF THE TWO CURRENTS MUST BE ADDED TO THE BRANCH CURRENT (THE ZENER DIODE AND RESISTOR PARALLEL BRANCH). Even unsubstantial differences may have a substantial effect over the power dissipation of the Zener diode because of the multiplication factor of current multiplied by voltage in the power calculation.

This potential (voltage) stabilisation is amazing and miraculous. I still can’t believe it. An asymmetrical branch of a Zener diode and a resistor introduce symmetry in another asymmetrical or symmetrical circuitry! Just because and because it stabilises the potential of one point!

Stabilisation of one point is enough in this case! Virtually, the Zener diode makes the resistor look like another Zener diode! This is because: the potential of the positive pin of the DC power supply source (adapter) is stable (assume ideal voltage source) and the potential of the negative pin of the DC power supply source (adapter) is stable too (assume ideal voltage source) AND, MOST IMPORTANTLY, the potential of the middle point is stable because of the wonderful work of the Zener. Indifferently of the power (current) consumption elsewhere in the circuit, the potentials of these three points will always be stable!

Simply: Assume an ideal DC Voltage Source (an ideal adapter) which gives voltage of 12V. Current I starts from the positive rail and reaches the point where there is a fork one side of which goes to resistor R, the other to part of the circuitry. The current I gets divided into two currents: I1 goes to the circuitry and I2 goes to the resistor. I2 passes through the resistor and creates a voltage across the resistor with a value of I2R. After the resistor, the current I2 reaches the ground point where it gets divided into two currents: I2a goes to part of the circuitry and I2b continues towards the Zener diode. I2b meets the returning I1 and they add to make I2c=I2b+I1. I2c passes through the Zener diode and goes towards the negative rail but meets the returning I2a and they add to each other to make I2d=I2c+I2a. I2d goes to the negative power supply.

What goes up must come down and ONLY what goes up. In other words, the current which started at the positive rail of the power source (adapter) must return to the negative rail and ONLY this current and no other else. So, I2d must be equal to I. Is this really true?

We said: I gets divided into I1 and I2. Therefore, I=I1+I2 or I2=I-I1. We said I2 gets divided into I2a and I2b. Therefore, I2=I2a+I2b. Therefore, I2b=I2-I2a but I2=I-I1, therefore I2b=I-I1-I2a. We said I2c=I2b+I1, substitute I2b and therefore I2c=I-I1-I2a+I1. O, o, we have +I1-I1 which cancels itself out and, therefore, I2c=I-I2a. We said I2d=I2c+I2a. Substitute I2c and, therefore, I2d=I-I2a+I2a. O, o, we have -I2a and +I2a. I2a cancels itself out. I2d=I. I goes out, I2d=I comes in. Garbage out, garbage in.

Zener diodes are incredibly inexpensive, almost for free. They are tiny in size and easy to work with. Are the operational amplifiers expensive? No. They are less inexpensive than the Zener diodes and the difference gets tinier. Operational amplifiers were expensive in the past. Extremely expensive when they first appeared. Nowadays, a Zener diode would cost $0.05 and a dual operational amplifier would cost $0.25. In applications where 2 operational amplifiers are used, it may be considered each of them to cost $0.125, just 71/2 cents more than a Zener diode. A saving of 7.5 cents is not much of a saving. Is there any advantage of the operational amplifier ground buffer as opposed to the Zener diode middle point provision? No. There is an advantage of being able to use any power supply between 5V and 30V DC without switching of different Zener diodes but the operational amplifiers have more complex structure as opposed to the simple Zener diodes hence the reliability of the Zener diode is higher. The internal impedance is negligible in the two devices. Since no accuracy of the ground point is necessary (to be exactly between the two rails), than accuracy considerations are not applicable. Where accuracy is needed, one must consider the Zener voltage even in most accurate Zener diodes (1% or less error) will change with aging. So will the operational amplifier but the changes will not affect the performance as much and the accuracy will mainly depend on the accuracy of the two resistors which can be extremely accurate (0.001%) and the change of this accuracy with aging will be much less than the changes with the accuracy of the Zener diode. In addition, the formula of the middle point (R2/(R1+R2)), a voltage divider formula will allow for partial minimisation of the aging. In case R1 and R2 change with equal amount and different direction, than the change will cancel itself out as far as the sum R1+R2 is concerned and will remain only at R2. In case of equal amounts, same direction, there are differences in the divided and the divider. In case of different amounts, combination of these consideration. The exact formula of the effect of aging may be simply derived when adding a value with an unknown sign deltaR1 to R1 and deltaR2 to R2. Then the formula (R2+deltaR2)/(R1+deltaR1+R2+deltaR2) can be analysed and chewed for hours and hours. German engineers do so. So have I. Hence the hate!

On the serious side, Instrumentation is pretty useless as a part of engineering and suck the brains out of the students and make them crazy and to lose the ability to see the obvious. However, also on the serious side, when accuracy comes to play and it does, here and there, than the engineers must either get a pro Instrumentationalist or grab themselves by the dicks.

Even some super pro musicians call for incredible accuracy as far as the nonlinearity error is concern. They probably wash their ears with antibiotics because it is not believed for such tiny nonlinearity to be detectable by a human ear. However, I am happy they demand high quality anyways. They push technology forward!

There are some interesting things to be considered: One of them is when the microphone is a perfect or a very good voltage source, than the availability or size of the parallel resistor will NOT affect the voltage and the strength of the signal. In case the microphone is a current source (which it is: a membrane and a coil), then the size of the resistor is important! The bigger, the better but the bigger, the more noise! Another thing to consider is very bad. Operational amplifiers cannot drive capacitive loads with above certain capacitance. This may become an issue mainly with the operational amplifier at the output after which a huge capacitor of 10µF is placed although followed by a relatively high input impedance (10 or 20 kΩ typical) of the amplifier thereafter. In case of a problem a transistor built buffer (common collector) may be placed after the operational amplifier or a transistor can be put directly at the output of the operational amplifier BEFORE the feedback (this is a standard way for buffering the operational amplifier’s output when high current is necessary).

+

Input Voltage

+

-

RL (LOAD)

The NPN transistor (any would do, depends mainly on what current one wants to get out of the transistor) is powered by the same power supply as the operational amplifier and, most importantly, is in the feedback of the operational amplifier, which feedback takes care of the correct work of the transistor and, therefore, no extra components are necessary. The transistor is connected in a common collector circuit with “part of the operational amplifier” as the emitter feedback resistor Re. The funny thing is the operational amplifier circuit provides the feedback resistor for the common collector circuit (Re) and the feedback circuit of the common collector provides the feedback circuit of the operational amplifier. I would say the two circuits share the same feedback. One way or another, the transistor performs as a common collector buffer, a. k. a. emitter follower or repeating amplifier. The input impedance of these circuits is huge and the output impedance is tiny and all this is paid with a lack of gain, i. e. gain of 1. Hence the term repeating amplifier. It is repeating because the output voltage repeats what the input voltage does. It is an amplifier although it has a gain of 1 because the input impedance is huge (practically infinite) and the output impedance is tiny (practically zero). The input is similar to isolation and draws no current. The output is similar to a copper connection and can supply as much as the power supply can as long as the transistor doesn’t burn. (In common collector the two AC waves: positive and negative pass through the transistor with a temperature effect caused by the RMS value of the passing AC current).

In the circuit with the buffered operational amplifier:

Potential analysis: The operational amplifier will try to work its ass off in order for the voltages of the positive input and the negative input to be the same, i. e. the operational amplifier will make the voltage of the negative input to be the same as the voltage of the positive input.

Current analysis: The operational amplifier will throw some current Ibe through the base, emitter and load of the transistor and will open the transistor just as much as to allow collector emitter current Ice to flow from the power supply through the transistor and the load and along with the current through the base emitter junction Ibe will make the load current Il=Ice+Ibe. Ibe is much smaller than Ice and can be assumed IL=Ice. The transistor is open just as much as to allow for IL to maintain the current x load product to be the same as the input voltage. When the input voltage drops, the operational amplifier blows less current into the base emitter junction of the transistor. When voltage goes higher, more. When the load drops at the same input voltage, more current is injected in the base emitter junction, therefore the transistor gets more opened, therefore more current passes through emitter collector therefore Ice is higher, therefore IL is higher hence the voltage across the load gets maintained. When the impedance of the load becomes higher, less current is allowed by the transistor (under the order of the operational amplifier) hence the load (output) voltage gets maintained to be the same as the input voltage.

Schematics analysis (resistor, capacitor, coil): Simply, the transistor and the load form a voltage divider. The transistor is a resistor whose resistance is controlled by the current through the base emitter junction Ibe. This current, generated by the operational amplifier’s output, will change the value of the transistor’s resistance between collector and emitter Rce in order for the voltage of the negative input of the operational amplifier (same as the voltage of the load because they are short connected) to be the same as the voltage of the positive input which is the input voltage. Therefore, the circuit does exactly the same what a simple operational amplifier without a transistor would do BUT the load current is sucked from the power supply through the transistor and does not come from the operational amplifier, in other words, the operational amplifier does the potential job (potential maintenance) and the transistor does the current job (blows huge currents from power supply to and through the load). The problem of the circuit as such is the transistor is UNIDIRECTIONAL, current goes from + to – only and can’t go the other way. The good news is there is a solution to this.

Feedback point of view: The feedback will try to make the operating amplifier work its ass off so the output voltage is equal to the input voltage as all negative feedbacks do in a positive input connection of the operational amplifier (positive amplifier).

+

T1

Input Voltage

+

-

RL (LOAD)

T2

-

The span of this circuit is limited to the span of the power supply minus the maximum to rail” voltage of the operational amplifier. This circuit works in a similar way to the one already explained. During the positive way, the NPN transistor T1 conduct just as much current as to make the output voltage (which is input for the feedback) equal to the voltage applied to the positive input of the operational amplifier (the input voltage). The PNP transistor T2 is fully closed during the positive cycle because the base emitter current is attempted to be drawn in the opposite of opening direction. Explained with potentials, the potential of the base of T2 is more positive than the ground “applied” to the emitter through the load. Because T1 is fully closed and T2 opened just as much, current flies from ground through the load, cannot pass through T1, passes through T2 and goes to the negative rail of the power supply where the collector of T2 is connected. During the negative wave, the opposite happens. T2 is fully closed and T1 is opened just as much as to equalise the potential at the load (which is at the feedback) to the potential of the positive entrance of the operational amplifier which is the input voltage. The base emitter current of the T1 is adjusted properly. The potential at the base of T1 (the two bases are connected and this is the potential at the base of T2). The potential of the base of T1 drives a current through the base emitter junction of T1 and then through the load to ground. The same potential is also applied to the base of T2 as previously mentioned. This potential tries to drive a current through the base emitter junction of T2 but, since this potential is more positive than the potential of the emitter of T2 which, initially, is ground through the load. The attempt is unsuccessful because of the direction of the junction of the PNP transistor T2. Works like a diode in the opposite direction of the current. Therefore, T2 is fully closed and T1 is opened just as much. Thus current flies from the positive rail of T1 through the collector through the collector emitter of T1 through the load to ground.

The important word here is “initially”. This word was to be true in case the current travelled slowly. However, because the current travels instantaneously (with almost the speed of light) (and when assumed there isn’t any capacitance in the load) the current through the load would be equal to the potential of the load (which is the same as the potential of the two connected emitters of the two transistors which is the same as the potential of the feedback (these three are short connected) and is almost the same to the potential of the positive input of the operational amplifier which is connected to the input voltage and, therefore, the potential of the load is maintained by the operational amplifier to be almost the same as the input voltage. The operational amplifier MAINTAINS the voltage after the transistors to always be almost equal to the input voltage. In case of a perfect operational amplifier, these voltages would be exactly equal. The voltage at the output of the operational amplifier is equal to the voltage of the output (at the load) minus the base emitter voltage of the open transistor which is equal in the two transistors and is equal to 0.7V.

There is no requirement for transistors with matching parameters because the feedback system and the operational amplifier will always maintain the output voltage equal to the input (in case of perfect operational amplifier) regardless of the differences of the transistor. In other words, the operational amplifier would put a bit more or a bit less base emitter current through a given transistor as compared to the base emitter current through the same transistor were the transistors with exactly the same parameters and the only difference: one of them is NPN and the other PNP.

In case huge currents are necessary to fly through the collector emitter of the transistors, then the transistors best be separate as discrete components to be cooled more easily. Otherwise, the transistors may be purchased as an IC. Usually, the IC PNP and NPN transistors are matched to have almost the same parameters which is not necessary in this case.

In case of a capacitive load, huge current will fly through the load at the beginning to compensate for the initial “short” of the empty capacitor yet maintaining the voltage. This current would not be possible to be provided by the operational amplifier, hence the transistors are needed to “pick” the necessary current from the power supply.

Without the transistors, the operational amplifier would not have enough current to start to charge the capacitor and would not be able to lift up or push down the voltage of the output and would go “out of feedback balance”, i. e. would go to either negative or positive rail as depends on the direction of the input voltage. Based on how big the capacitance of the capacitive load (in parallel to the output of the schematics) is and how strong the operational amplifier is (usually 50mA max), the operational amplifier may be able to recover and to continue to repeat the input voltage at the output. In case of a very big capacitance in parallel to the output, the operation amplifier will go out of control and just change rails, in other words, during the positive wave of the input voltage, the operational amplifier will display maximum positive voltage at the output (almost power supply positive rail and, in case of perfect operational amplifier exactly the positive rail) and during the negative, the operational amplifier will display the negative rail (almost and exact when perfect). Thus, the operational amplifier will spin out of control either to positive or negative rail thus displaying a square voltage at the output.

It is important to mention, only the capacitance which is in parallel to the output of the whole circuit is problematic as per this explanation. The capacitance in series is not.

U2+

U1+

Rc1

T3

Input Voltage

T1

Rb

-

+

RL (LOAD)

R1

T2

T4

U1-

Rc2

U2-

R2

U1+

U2+

U2-

U1-

This is a schematics which I think I have just invented but I am not sure whether the circuit has not been invented before. This circuit uses a common emitter connection of the transistor(s) T1 and T2 and a common collector connection with the transistors T3 and T4 and the operational amplifier acts as a transistor stabiliser and source. In other words, the “analogue logic is carried out by the operational amplifier and the power as well as voltage conversion is carried out by T1, T2, T3 and T4. The most important application of this circuit is where the operational amplifier (whether buffered by power transistors in the feedback after the IC output or not) cannot provide the necessary output voltage because of the limitations of the maximum supply voltage of the operational amplifier. Hence, a separate power supply can be connected through resistors Rc1 and Rc2 to the collectors of T1 and T2 (common emitter) and without any resistors to the collectors of T3 and T4 (common collector). The beauty of this circuit as opposed to the standard common emitter or collector discrete transistor amplifier circuits is the feedback is after the transistors and therefore the output voltage does not depend on the transistor circuits but on the ability of the operational amplifier to maintain the voltage on the plus input to be equal to the voltage of the minus input, which ability is rather high. Also, the output impedance of the whole circuit with transistors before the feedback is much lower than the output impedance of a common collector amplifier built as a separate circuit and not related to the operational amplifier (i. e. positioned after the feedback).

Basically this whole circuit is a simple externally boosted operational amplifier. The output voltage can be bigger than the range of the operational amplifier but this is not a problem because this output voltage will be divided and the result of the division will be and must be within the range of the operational amplifier. Rb can be omitted physically, and, for simplicity, these explanations will be provided when Rb=0 is assumed. Thus the operational amplifier IC output pin will swing between -0.7 and +0.7 running T1 and T2 and depending on the voltage current characteristics of their base emitter junctions for control. Rb can be inserted in order to enlarge the control range and thus reduce the sensitivity of the control but the well feedbacked operational amplifier will be able to maintain the necessary base emitter voltage even without Rb because of the high level of precision of the control ability of the operational amplifier. As depends on the IC’s output pin voltage, one of the transistors (T1, T2) will go more open or more closed whilst the other one does the opposite: goes closer or more open. THE IMPORTANT THING TO NOTE IS THE EMITTERS OF T1 AND T2 ARE CONNECTED TO GROUND WHICH GIVES THE OPERATIONAL AMPLIFIER TO CONTROL THESE AS THE IC PIN OUTPUT VOLTAGE IS REFERENCED TO GROUND AND NOT TO U2+ NOR U2- WHICH VOLTAGES (U2+ AND U2-) THE OPERATIONAL AMPLIFIER MAY NOT BE ABLE TO ACHIEVE AT ALL. Operational amplifiers have a limit of the maximum supply voltage due to internal design limitations (unless the operational amplifier has been specifically designed to work under high supply voltage in which case, some parameters y have been sacrificed to have achieved this ability). For example, the iconic TL084 has been designed to be able to perform with maximum +/- 18V supply voltage (U1+=18V max and U1-=-18V min). TL)84 is not rail to rail amplifier and there isn’t a true rail to rail amplifier as far as I know although the companies would call them so because there is just a tiny bit more to go to become real to reel (real reel to reel). Usually, the operational amplifiers would go all the way down to negative but will be shy of a bit to reach the positive supply reel. TL084 can go from negative to positive -1.5V. In case of maximum power supply of +/-18V, TL084 would be able to go from -18 to + 16.5V at the IC output pin. When symmetry is needed, TL084 would be able to swing the output (to wave the dick on the beaches of Florida) from -16.5V to +16.5V. A perfect sine with an amplitude of 16.5V would have an RMS value of Amplitude \* 0.707 which, in this case, is approximately 12V. The square of this RMS value divided by the load resistance RL would give the maximum power a circuit with output of +/-16.5V in amplitude would be able to give even when no limitation of the maximum current exist. Thus, a 4Ω loudspeaker will suck twice as much power out of an amplifier with a given output voltage as an 8Ω loudspeaker ONLY IN CASE THE AMPLIFIER CAN PROVIDE THIS POWER, i. e. maintain the voltage while blowing a current with an RMS value of 12VRMS/4Ω =3A. An amplifier with a +/-16V output will then be able to provide a maximum of 36W RMS when connected to a 4Ω speaker. REMEMBER: THE AUDIO AMPLIFIER IS A VOLTAGE SOURCE NOT A CURRENT SOURCE. THE AUDIO AMPLIFIER GIVES A VOLTAGE AND TRIES TO DO THE BEST POSSIBLE TO MAINTAIN THIS VOLTAGE AT ANY CURRENT SUCKED OUT OF THE AUDIO AMPLIFIER TO THE MAXIMUM CURRENT POSSIBLE. I.E. AUDIO AMPLIFIER WORKS IN REGIME OF A MAINTAINED VOLTAGE NOT IN A REGIME OF A MAINTAINED CURRENT.

So, is there any way to have an amplifier with maximum amplitude +/- 16.5V to give more power when a load of 4Ω is connected? NO! There is only one way. Get more voltage. But the operational amplifier does not allow for more voltage. Then run the operational amplifier up to this voltage and build a circuit controlled within this range which can give more voltage because the circuit will be supplied by a higher voltage while only controlled by the lower voltage possible to be achieved by the operational amplifier. So, put, say +/-5V supply to the operational amplifier (which will be able to reach a symmetric output of +/-3.5V and then build a separate common emitter circuit which will be supplied by, say +/-60V and will run the loudspeaker. Or you may not have an operational amplifier at all. However, the circuit with an operational amplifier and a feedback after the power transistors has a lot of advantages previously discussed.

The common emitter connected T1 and T2 amplify and invert the signal of the operational amplifier and display this at their collectors which, in turn, drive the common collector followers T3 and T4 for which reason Rc1 and Rc2 must have such values as to allow the necessary current to fly through the base emitter junctions of T3 and T4. T3 and T4 do the opposite “ground : supply” consideration: while T1 and T2 take one signal, reference this signal to ground and split (“uncombine”) the signal to provide two outputs at their collectors, T3 and T4 take these two outputs as their inputs, reference these to U2+/- (T3 to U2+, T4 to U2-) and combine them again into one output which goes to RL.

The output voltage at RL will be much higher than the operational amplifier can handle. This means, there will be periods when the operational amplifier will go in saturation and will not be able to provide control and the same will happen to the output. This is why, the R2, R1 arranged feedback divides this output voltage to bring the input voltage coming from the output through the feedback in a size possible to be handled by the operational amplifier. When ground is applied to the negative input, the operational amplifier will do such as to have 0V on the positive (virtual ground). Thus a current of Uin/R1 will fly through R1 which can go nowhere but through R2, thus the output must be adjusted by the IC in such a way as to allow this same current to fly through R2. But one of the ends of R2 is connected to the positive pin (virtual 0V) which has 0V because the negative is connected to ground and the operational amplifier does nothing else but adjusting the output to make the two inputs equal. The other end of R2 is connected to the output Uout. Therefore Uout must be adjusted by the operational amplifier to be:

Uout/R2=Uin/R1

In order to have the current fly through, or to “suck” the whole current to the output.

Rewrite the formula:

Uout/Uin=R2/R1 which is:

Uout=Uin R2/R1

So, the output is equal to the input multiplied by a coefficient R2/R1 which coefficient is the gain G=R2/R1. NOTE: BECAUSE OF THE R2, R1 FEEDBACK Rc1/2 DO NOT HAVE ANYTHING TO DO WITH THE GAIN.

Will the operational amplifier be able to adjust the output this way? Assume the input Uin is positive, then the current flies from Uin through R1 to the positive pin (virtual ground), then cannot go nowhere else except through R2 and then continues to the output to pass through RL in part and through T4 to negative power supply U2- and then through the U2 power supply to the common ground between U2 U1 and Uin which must exist otherwise voltages will fly all over the place without any reference with each other.

In order for this current to be able to fly, the operational amplifier must adjust the output voltage to be negative and with a certain value. Because the operational amplifier is feedbacked, the operational amplifier will be able to provide the value of this voltage for sure as long as the feedback is stabilising and not generating feedback, means negative and not positive. This is the ONLY condition for feedbacked systems (the only qualitative (logical) condition, not quantitative (amount of how good the feedback is)). (This can easily be explained but not now.)

So, do we have a positive or a negative feedback? The only thing which can say so is the signs of the input and the output. In case the signs are the same, we have a positive feedback, otherwise, we have a negative.

Yes, but the feedback goes to the positive pin, this means positive?!? In most cases, yes but, not in this case. The output of the IC is INVERTED by the common emitter then REPEATED (not inverted) by the common collector. Therefore, the output of the schematic is inverted as compared to the output of the IC. Assume, we follow the standard procedures and put the feedback to negative. Then the IC will invert Uin the same way as the standard inverting operational amplifier circuitry does. Then the common emitter will invert again. Therefore Uout will have the same sign as Uin. Now, assume we connect the feedback to the positive pin (as shown). Then the IC does NOT invert the signal but the common emitter does, so the output Uout is opposite in sign to the input Uin which means we have a NEGATIVE (STABILISING) FEEDBACK although we connect to the positive pin. This is because we have an inverter immediately after the IC and before the point where the feedback is taken from.

Generally, this schematic is the SAME as the standard inverting amplifier as far as the logic of the way the schematic works is concerned, just there is an invertor at the end of the operational amplifier thus the feedback must go to the positive pin.

The same schematic may be connected to the equivalent way and logically the same as the standard non inverting amplifier, then point of R1 where Uin is applied now must be grounded and Uin must be applied at the positive pin. The derivation of the formula for the gain is the same as the derivation of the formula of the gain of the standard non inverting amplifier and the gain is: G=1+R2/R1

Any ingenious design? No. The circuit is the same as:

1. The standard amplifier, just the output is additionally inverted and more powerful and takes different power supply, yet has a SINGLE GENERAL FEEDBACK which gives the best parameters possible at the huge power output.
2. The standard amplifier with boosted output with common collectors, just the output is inverted and power is taken from a separate power source
3. The separately built circuitry by a standard operational amplifier, a separate common emitter and a separate common collector each of them with their own feedback wherever whatever necessary. (Common emitter does NOT require an AC FEEDBACK only DC. Common emitter is straight, non regulated amplifier.) The parameters of this circuitry will be worse.
4. Same as c) but with a general feedback as well as separate. Works OK but the parameters will not be as good as single general feedback. Mainly the speed of control as far as I can think. This is also because the straight gain will be lower which also leads to higher output impedance and lower input and is a fuckin’ waste of components and assembly.

Anyways much ado for notha. Also, much ado for notha. **I have not though carefully through this schematic, so you must.**

Another, unorthodox approach to creating a ground from a bipolar DC power supply, is just by the use of an operational amplifier without the divider.

+

-

6 to 30V

**DO NOT USE THIS SCHEMATICS!**

1µF

+

10µF

+

1KΩO

-

The virtual stabilisation of the operational amplifier is done by connecting a resistor in between the positive pin and the negative pin. The output would be the same as the positive input which is connected nowhere. In other words, the output would be the noise passed through a 1KΩ resistor which should be zero BUT DO NOT TRUST AND DO NOT USE THIS SCHEMATICS.

+

=

=

===

Microphone

-

=

=

===

+

=

=

===

-

=

=

===

R2

+

=

=

===

R1

R5

-

+

=

=

===

+

R3

P1

-

=

=

===

-

Rne1

R4

C1

R6

This schematic is the one I would chose. The schematic is largely referred to as an Instrumentation amplifier and comes is slightly different versions. This schematic should be used even when not necessary. There aren’t any disadvantages (except probably in some exotic applications where high speed or huge gain may be necessary). The only disadvantage in the past was the high price of the operational amplifiers which is no longer a problem. The schematics comes also in an IC.

The version which I have chosen has a slight systematic error which will be discussed and is not a problem in high gain applications.

I have decided to use an unorthodox approach and amplify the microphone signal much more than necessary and then attenuate it. One of the reasons is to virtually eliminate the systematic error (which can be compensated for by a schematic adjustment). Another, more important reason, is to take the potentiometer off of the feedback resistors of the operational amplifier thus to reduce the noise. The third reason is to ground one of the points of the potentiometer also to reduce noise. Previously, I did so by placing the potentiometer at the ground of the resistor which goes from ground to the negative point of the positively connected operational amplifier (buffer amplifier). This resistor is NOT directly the resistor which brings the output to the negative point but is used in the ratio to divide the output voltage in order to force the operational amplifier to provide a higher output voltage to equalise the positive and the negative input voltages, i. e. to force the buffer to amplify. This is kinda feedback resistor too because of the action performed on the output voltage to bring part thereof to the front of the schematics. Noise there would affect the performance of the whole circuit, the noise appears onto the input circuitry and will be amplified.

Thus, a passive voltage divider with a potentiometer to ground may solve the problem.

Here is how it works: The microphone may or may not be grounded. In this case, the microphone is not grounded. This may present a huge problem as far as the noise is concerned. However, this approach is very standard when the source is differential. True, there is no much of a point to use it on a microphone circuit but this may lead to a possibility to design a circuit without an internal ground and fully differential from start to end which will not bring a common point of power supply, source and pre amplifier at the input of the amplifier which is used after the preamplifier.

Ground is a common point which is used for reference. How this reference floats is not important as long as one measures a given signal against this reference. In case I have 1V jump of the ground and I measure 1mV between the ground and the signal line, I will still measure 1mV regardless of whether I have 1V noise on the ground or 3V. As long as the signal line is always 1mV higher than the ground, the measurement is OK. Therefore, we can allow the ground to have as much noise as there is and keep the signal line clean. The source will make sure the signal line keeps this 1mV higher than the ground. For this reason, one needs to ensure the ground is connected to the source. And, the ground is used as a reference for the electronics. And, the SAME ground is given to the equipment thereafter to use as a reference.

Therefore, the best solution is to ground the microphone, the electronics and the output. However, I have decided to try to make electronics which is as close as possible to a real microphone without electronics. Partly, because the amplifier (after the preamplifier) or the PC Audio Card or whatever equipment there is may expect to see a simple microphone and not an electrical, nor electronic system. This is very important in case the device where the microphone is plugged has a differential input which does not want to be connected to any point of the power supply of this device. To do so, one must be sure the power supplies of the amplifier and preamplifier are totally galvanically isolated, i. e. there is no common point in between the two. This is true in the general sense when there are two transformers for the two power supplies whose secondaries are not connected. This is one of the things the defenders of AC Power Distribution spell out. AC is convenient for transformers. Transformers do galvanically disconnect. Therefore, AC allows FULL galvanic disconnection and separate power supply for every piece of equipment all over the place. How often is this necessary?

Anyways, back to the circuit: The microphone is put into two buffers, each of them connected to each of the input and none of these operational amplifiers in a buffer connection is grounded, the two thereof are connected to +/-. The signal is not referenced to anything. It is just displayed at the outputs of the buffers the same as the signal would be displayed without the buffers AS LONG AS the signal is less than the power supply which is true for the microvolt signal coming out of the microphone.

The two buffers act as a “separator” of the signal. Each of them takes half of the signal. This, however, is not practically important. The most important feature of the two buffer input is the huge input impedance of the circuit. (Also the huge decrease of the common mode noise, i. e. huge Common Mode Rejection Ratio (CMRR) due to the differential (subtractive) principle of the circuit (the subtraction takes place after the buffers)). Irrelevant whether the microphone is a voltage or a current generator, a huge impedance will increase the sensitivity tremendously thus the rest of the circuit would be easier to design. Yet, the sensitivity to noise also increases. Not nice.

The two buffers are connected to the two inputs of a differentiator (subtractor). This is a simple operational amplifier connected in the two schematics simultaneously: positive and negative. Whatever is connected to the negative input resistor would be amplified by R2/R1 as a standard negatively connected operational amplifier would do. Whatever enters the positive input of the IC would be amplified by (1+R2/R1). And the “whatever” in this case is the output of one of the buffers multiplied by the divider ratio (the divider coefficient) R4/(R3+R4). Therefore, the output of this buffer would be multiplied by (1+R2/R1)R4/(R3+R4). However, 1+R2/R1=(R1+R2)/R1. Therefore, the amplification is (R1+R2)/R1 \* R4/(R3+R4). **IN CASE WE SELECT THE RESISTORS IN SUCH A WAY, SO R1+R2=R3+R4, THEN THE AMPLIFICATION WOULD BE R4/R1**. But, we want to have the same amplification on the two “channels”. Therefore, we want to select the resistors in such a way as to achieve R4/R1=R2/R1. This is only possible when: **R4=R2**. Can we introduce a new sign Rs which is equal to R2 and R4: Rs=R2 which in turn is equal to R4; Rs=R2=R4. Then, substitute in the requirement: R1+R2=R3+R4, and we get: R1+Rs=R3+Rs which is only possible when **R1=R3**!

Therefore, there is **NO SYSTEMATIC ERROR**! Once we meet these two conditions:

**1. R1=R3**

**2. R2=R4**

In case we call either R1 or R3 Rf, then Rf=R1=R3. When we substitute in the gain calculations, we get:

Gain of channel 1: R2/R1=Rs/Rf

Gain of channel 2: R4/R1=Rs/Rf

Therefore, the gain of the circuitry is: Rs/Rf. However, for this to be true, the resistor pairs must be VERY equal. Otherwise, the negative wave will be amplified differently than the positive. Sounds like nonlinearity. Musicians hate nonlinerity. Therefore, we must either call an Instrumentalist or we have to grab our dicks! In this case, the istrumentalism is simple. In other, not so simple. Thus, sound engineering is instrumentalism when quality gets goin’ but a tiny bit relaxed: In sound, engineering, one doesn’t give a shit on the accuracy of the gain. What for, I just turn a damn pot. Also, in sound engineering, one doesn’t give a shit on DC. What for, I’m gonna filter the DC out! However, in sound engineering, one cares a lot on: whatever the signal **SHAPE** coming from the mouth or the instrument is, the same **SHAPE** must come to the years of the listener. The only thing the musicians allow is the “volume”, i .e. the strength of the sound to be higher (usually) or lower than the original. This shouldn’t be allowed too. It ain’t real. True, it ain’t distorted as far as the shape is concerned but is distorted as far as the amplitude is concerned. Amplification is also distortion, just acts on the amplitude only!

Another important feature of this circuit which has been incredibly important many years ago and is no longer important but still good to have is the symmetry of the impedances which the input bias currents will see. These are the currents which enter the third operational amplifier (the differentiator (subtractor)) because the operational amplifier has a huge input resistance even without a feedback connection but this resistance at the entrances is not infinite. Hence tiny currents will be consumed from the previous stage (in this case OK because the previous stage is the output of the buffers). The problem appears when the symmetry of the circuitry is not perfect and the currents see different resistance before and after they enter the operational amplifier. The difference in the resistance leads to a voltage at the front. This voltage is negligible but not when amplified with a huge gain. And because no one can open the operational amplifier and tweak inside, the only thing to be done is to make sure the resistances which will be seen by the input currents are the same. (Some operational amplifiers allow for a compensation to be carried out. The manufacturers did not want to perform calibration of their products because of high labour cost. Hence, a decision has been made to use operational amplifiers which are as good as possible. The funny thing is some manufacturers (all) would prefer to get more expensive operational amplifiers to save the labour cost. This is nothing however as compared with how funny to sell crappy products just to save less than a dollar of labour.)

Anyways, in the case of the instrumentation amplifier, current which enters the differentiator at the negative point would see an equivalent resistance of R1||R2=R1R2(R1+R2) and the current which enters through the positive: R3||R4=R3R4(R3+R4). Thus the symmetry would depend on how much these parallels are the same as well as how symmetrical the operational input, i. e. how equal will these currents be.

A measure of the symmetry of the two input currents (which depends on the internal symmetry of the operational amplifier) is the so called “Bias Voltage” which is given in the spec sheet of the operating amplifier. Again: this may be a problem when DC voltages are measured or when huge gain is used. For example: TL084CN is a quad operational amplifier IC, each of the four operational amplifiers of which has 15mV input bias voltage. This voltage will be at the input and there ain’t much to do to compensate for. Assume an amplifier circuit with a gain of 1000. The bias voltage will make 15V at the output. This may as well be higher than the power supply and thus the output will be saturated. Therefore, for high gain AC applications, a different operational amplifier has to be selected with 1mV or less which will make 1VDC at the output which can easily be filtered.

The symmetry of the circuitry is yet another reason why a pot should not be put where the components of the operational amplifier are. Exception can be made for a switch which switches amongst many accurate resistors and this switch rather be multiple (single pole, double throw).

So, what was this with the systematic error? This is because it is possible and sometimes may be desirable to remove R4. This is because when R4 is removed, there isn’t any need to have a middle point. Also, to reduce power consumption in nano power devices. In case R4 is removed, the value of R3 has to be equivalent to R1||R2=R1R2(R1+R2) in case installed at all (can be shortened). This is not the problem, though.

The problem is the negative gain is (1+R2/R1) and the positive gain is R2/R1. Therefore, the positive gain is equal to the negative gain plus 1. This will introduce nonlinearity. However, when the gain is very high, say 1000, the difference of 1 is negligible. The percentage of the error introduced this way is (1/1000)\*100=0.1%. As compared even to the 1% resistors, the error is negligible. When 0.1% resistors are used, the error is acceptable. The error may become a bit too much when 0.01% resistors are used. In Germany!

Even with 0.01% resistors, a gain of 10000 may be possible with operational amplifiers with low bias thus the systematic error is reduced to 0.01%.

A passive voltage divider with a potentiometer to ground is placed after the differentiator (subtractor) buffered by a positively connected operational amplifier. There are no requirements for low bias for this amplifier, the requirement is for the differentiator (subtractor) and the buffers before.

In case R4 is not installed, the potentiometer may be connected to the negative point which may be connected to the “ground” input of the amplifier after the pre amplifier. Thus there will be a common point between the power supply of the preamplifier and the amplifier. In case the preamplifier is supplied by a battery or galvanically disconnected power supply (transformer) then there isn’t any problem. In case the power supplies are connected in some way, in what way they are connected is important to find out what happens.

The easiest way is to get power supply from the amplifier (PC) but this depends on the availability of such connections. Also, the PC would normally use a switching power supply as opposed to a linear one and switching power supplies are known to be very noisy, though not in the audible range. A big electrolytic capacitor across paralleled by a big ceramic capacitor are welcome.

I have always been dreaming of designing a circuit which:

* + 1. Amplifies differential signals (signals which cannot be grounded or better not be).
    2. Does not have any common point between the signal, the pre amplifier (the circuit) and the amplifier which follows. (I. e. the circuit looks like a microphone without this circuit to the devices connected after and looks like non existing to the microphone.)

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OA1

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Microphone

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R2

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R13

OA2

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R4

**Such circuits have been designed long time ago. The most important and useful, yet the simplest is the DIFFERENTIAL AMPLIFIER CIRCUIT built by two working transistors. Such circuits are sold as an IC. Just get one and all problems are solved. Get it if you can, this is.** Another schematic which passes through Australia when goes from LA to San Francisco, is the first part of the instrumentation amplifier. This is the first part of the instrumentation amplifier (with the resistors). There are two positively connected operational amplifiers in this circuit: OA1 and OA2. In the standard connection of each of them there should be a resistor from the positive pin to ground. Yes, but we do NOT have a ground, we do not have a middle point. Hence R13. In case R2=R4, the “middle” of R13 is supposed to play ground. So is the “middle” of the microphone. However, these are not connected. Not physically. Anyways, the operational amplifiers would work their asses off in order to ensure the voltage of the negative pin of each of them is equal to the voltage of the positive pin.

Therefore, the voltage across the resistor R13 will be the same as the microphone voltage. This voltage comes from the output of the operational amplifiers through the voltage dividers: R2 and ½ R13 as well as R4 and ½ R13. In case R2=R4 is selected, and the equal value is said to be R24, then the gain of OA1 is (1+R2/(R13/2)) and the gain of OA2 is (1+R2/(R13/2)). The gain of the whole circuit is the sum of the gain of the two half circuits:

G=Goa1+Goa2

Substitute R2 and R4 with R24=R2=R4, therefore:

G=1+2R24/R13 + 1+2R24/R13 = 2+ 4R24/R13 = 2(1+2R24/R13)

The important consideration is the reduction of the error due to non equal channels would be brought to reduction of the differences of two resistors only. Resistors with very equal values and low aging are easily available and not so expensive.

In case of a different bias of the operational amplifiers, there will be a DC component at the output which can be gotten rid of by the capacitor in the microphone input of the amplifier after the pre amplifier. The requirements on the operational amplifiers are relaxed.

Current path (current return path) check: No current shall be drawn from the microphone. OA1 and OA2 have infinite resistance. Currents will fly from the outputs of the operational amplifiers. OA1 will get a current from one of the rails of the power supply and get it through OA1, R2, R13, R4, output of OA2, through OA2 to the other rail of the power supply. OA2 will get a current from one of the rails of the power supply and get it through OA2, R4, R13, R2, output of OA1, through OA1 to the other rail of the power supply. Thus there will be a full current path.

To check the current path is one of the most important checks in positively connected operational amplifier design due to lack of operational amplifier virtual ground point and infinitely high input resistance. Logically, current cannot pass through an operational amplifier input. Physically is another story.

I haven’t thought very carefully over this schematic but I think this may work. To work or not to work is not very important because I haven’t invented this circuit and I cannot even lie I have. This circuit is the first half of one of the most well known circuits in the world: the so called Instrumentation Amplifier. There are two important variations of the Instrumentation Amplifier: with amplifiers at the front and with buffers at front. Most would use buffers at front to boost the input impedance. Buffers have a straight connection from output to negative input which gives them 100% feedback ratio and thus boosts the input impedance. In other words, whatever is displayed in the output will be present at the negative input and the operational amplifier will work in such a way as to provide such an output voltage to make the voltage difference between the negative and the positive pin 0. This is what the operational amplifier is designed to do. When you connect the output to the negative input, the voltage of the output which is the same as the voltage of the negative input (they are connected) must be equal to the voltage of the positive input. THERE IS NO OTHER WAY TO EQUALISE THE INPUT PIN VOLTAGES. THIS IS THE ONLY WAY THE OPERATIONAL AMPLIFIER CAN GO.

Think of the 100% number this way: In buffer mode, all the operational amplifier does is to repeat the input voltage and nothing else. This is done by the feedback which brings the output to the input as well as by the operational amplifier as a component which is in the straight track of the circuit. In amplifier mode, the operational amplifier does something more than just pushing voltage backwards: the operational amplifier, as a component connected in a circuit, amplifies. We pay with loss of input impedance in order to have amplification and yet high input impedance. When we do not have amplification we get a huge input impedance but there isn’t amplification.

Theoretically, one does not need power to amplify. One needs power only when one drives load. Theoretically, the losses in the operational amplifier are 0. There is power loss at the load only. Also, theoretically, there is no power loss at the source. So, the operational amplifier has been designed to amplify THEORETICALLY without power and only to take power from the power supply and give it to the load when the load so desires (consumes). Amplification is logical, not physical. When the word amplification is used, most often the word is referred to VOLTAGE AMPLIFICATION. These considerations also apply to current amplification BUT, obviously, do NOT apply to power amplification unless we talk power amplification without power consumption which is not very useful but, in theory, even so is possible.

It is important to note: PRACTICALLY the operational amplifier always consumes power for the internal operation of the operational amplifier being only amplification without power consumption at the output. Also, THE MORE THE OPERATIONAL AMPLIFIER CONSUMES THE BETTER AND THE FASTER THE WORK OF THE OPERATIONAL AMPLIFIER! Hence, for most applications, the more the better is OK. Better consume more power but have a better performance. In battery powered application, tough!

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OA1

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Microphone

Uo1

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R2

Uo

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Ui

R13

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OA2

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Ui1

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Uo2

Uai1

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Ui2

R4

Uai2

The schematic is rather misleading, although very simple. The misleading comes from the crossing paths of the two operational amplifier circuitries. The easiest mathematical (with a slight combination with physical) analysis is when it is assumed all voltages are positive to some imaginary ground which is far more negative than the most negative possible voltage, i. e. more negative than the negative power supply rail. This is physically OK because we can call any point a reference (a ground) point from – infinity to + infinity and perform our analysis and this analysis must work for all points. However, in case the analysis works for one, the analysis will work for all because the voltages and currents do nothing else but may change signs ACCORDINGLY with any change of reference. The word ACCORDINGLY is very important here. This means whatever changes, something else will change too to maintain the balance. Balance must be maintained not only because we have arbitrarily chosen a point but also because of the Kirchhoff’s laws: all voltages as well as all currents get neutralised. Move the point as you wish. All voltages as well as all currents will continue to neutralise. The same applies in regards to the values of the voltages and currents.

In the schematic, except from the assumption all voltages are more positive than the reference point (imaginary ground), values have been assumed as Ui1>Ui2, therefore Ua1>Ua2 and Uo1>Uo2. Also, remember the only and most important point of the analysis (another than Kirchhoff’s and Ohm’s laws bit of physics (electronics) in the mathematics): When an operational amplifier is connected with a negative feedback THE VOLTAGE OF THE POSITIVE PIN AND THE VOLTAGE OF THE NEGATIVE PIN ARE EQUAL AND THERE IS NO CONNECTION BETWEEN THESE TWO. True for an IDEAL operational amplifier. Ideal operational amplifiers have infinitely high input impedance, infinitely low output impedance, infinitely high internal gain and are infinitely fast.

So, the input voltages are called Ui1 and Ui2 and thus the microphone voltage is:

Ui=Ui1-Ui2

The positive pin voltages are called Ua1 and Ua2 and:

Ua1=Ui1

Ua2=Ui2

The output voltages are called Uo1 and Uo2 and the output voltage of the pre amplifier which will enter the amplifier thereafter is:

Uo=Uo1-Uo2

No current shall fly from the source (microphone) because of the huge input impedances of the operational amplifiers which is almost isolation from the point of view of the source (microphone) when there are negative feedbacks at each of the operational amplifiers.

Since Uo1 has been accepted to be higher than Uo2, a current I shall fly from Uo1 through R2, R13, R4, will meet Uo2 and go to the negative rail of the operational amplifier OA2. No current shall fly to the imaginary ground. Such is not physically connected. Just assumed to be in order to conduct the potential analysis in accordance with the laws of Kirchhoff and Ohm. This current I shall make voltage drops across each and every resistor the current passes through as per the Ohm’s law.

The Kirchhoff’s law says the sum of the voltage drops across the resistors the current passes through must be equal to the voltage across the two points between which the resistors are:

Uo1-Uo2=IR2+IR13+IR4=I(R2+R13+R4)

But

Uo=Uo1-Uo2

Therefore:

Uo=I(R2+R13+R4)

Also:

Ua=Ua1-Ua2=IR13 (this is the voltage between the negative pins of the operational amplifiers OA1 and OA2 which is the same as the voltage across R13 because the two points of R13 are connected to the two negative pins.)

But we have said:

Ua1=Ui1

Ua2=Ui2

And

Ui=Ui1-Ui2

Therefore:

Ua=Ui

But we have said:

Uo=IR2+IR13+IR4

And

Ua=IR13

Therefore:

Uo=IR2+Ua+IR4

But

Ua=Ui

Therefore:

Uo=IR2+Ui+IR4

This is the first relationship between input and output voltage. This is what we have been looking for. Once we have the whole, we will get the gain. There is current I in this relationship. We want to have only input voltage, output voltage and resistors (constants) in order to calculate the gain.

Thankfully, we have said:

Uo=I(R2+R13+R4)

Therefore:

I=Uo/(R2+R13+R4)

Now we have the current expressed as a function of the voltage. Before, we had the relation amongst input voltage Ui, output voltage Uo and current I. When we substitute the current we will get a relation between the input and the output voltages:

Uo=IR2+Ui+IR4

Therefore:

Uo=Ui+I(R2+R4)

Substitute the current and:

Uo=Ui+(R2+R4)Uo/(R2+R13+R4)

And this is the Input Output relation. In order to calculate the gain we need to work out the equation a bit in order to get it in shape: Output equals gain \* Input or Uo=GUi. To do so, we need to have a multiplier in front of one of the voltages:

Uo-(R2+R4)Uo/(R2+R13+R4)=Ui

Uo(1-(R2+R4)/(R2+R13+R4))=Ui

Uo((R2+R13+R4-R2-R4)/(R2+R13+R4))=Ui

Uo(R13/(R2+R13+R4))=Ui

Uo=Ui(R2+R13+R4)/R13

Uo=Ui(1+(R2+R4)/R13)

Therefore the gain is:

G=1+(R2+R4)/R13

In case R2=R4= ½ R13, G=2.

In case R2=R4=R13, G3.

In case R2=R4=0, G=1. Physical check: We have two operational amplifiers with outputs connected to their positive pins. Buffers. Voltage of the output repeats the voltage of the input! True. The whole schematic is a buffer.

In case R13 is infinity (not equipped), G=1. Physical check. True. The output voltage goes from the outputs to the negative inputs and does not get divided. The availability of the resistor does not make a difference. The input impedance of the unfeedbacked operational amplifier is huge. No current flies. Even in case there was some current, the current wouldn’t get divided between the resistor and the huge input impedance. (The division will be negligible.)

In practice, the operational amplifier needs some negligible currents in order to operate hence no input must be blocked by huge resistances. Anyways, huge resistance in the feedback is not good because the noise picked up by the huge resistance goes straight into the feedback path and screws up the whole stabilisation of the circuitry. Rule of thumb is 1MΩ which will provide enough current for most of the operational amplifiers and not so much noise. Best don’t go over this value, although there is such a possibility with most of the operational amplifiers.

In this case, the source (microphone) would provide the current needed for the positive pin to work. This is why in other schematics positively connected operational amplifier must not be used without a caution where the current comes from and how much. Negatively connected amplifier may be preferable because the feedback brings current for the negative pin to work and ground provides to the positive. Yes, but then the negative resistor in parallel to the feedback resistor become the input resistance and the input impedance will not be so high. But the working current will be provided by the feedback. The input resistance will be for discharge of the microphone but not for throwing current out of the resistance.

This is illustrated below:

Microphone

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In case of a positively connected operational amplifier, the necessary current for work of the amplifier is provided by the source (the microphone) and gets returned to the source (the microphone) through the rest of the circuitry. This current CANNOT be compensated for. Will result in signal loss. Hopefully this current is not so high. Operational amplifiers with input built by JFET (Junction Field Effect) transistors have extremely low input currents. Even a microphone is supposed to be able to deliver these.

The resistor, however, does not lead to signal loss, contrary to what I may have said. The microphone generates a current or a voltage (irrelevant) which, in case of current, will circle through the resistor and, in case of perfect amplifier, has nowhere else to go. The voltage has nowhere to go to and cannot be divided. The current may be divided between the low resistor and the huge input resistance of the operational amplifier which means the current will not be divide too.

There is only one problem with the resistor: in case of CURRENT (not voltage, contrary to what I may have said) and a low resistor, the voltage across the resistor will be incredibly tiny. A huge gain may be necessary to amplify. Worse, the noise across the resistor may be stronger than the signal. In this case, the resistor can be taken over and the microphone (in case of perfect amplifier) would work alike with an open circuit: the input impedance of the operational amplifier is huge and is alike isolation (air). So the microphone will provide the highest signal possible. Theoretically, the signal will be infinitely high because the microphone generates current which has nowhere to go and builds up an infinitely high voltage: Ohms law: current through infinitely high resistance equals infinitely high voltage. In practice, the microphone current will go through microphones internal resistance which is in parallel to the microphone. Perfect microphone would have this internal resistance infinitely high. Real ones have lower internal resistance. And this is why a resistor across the microphone will not result in signal loss when the microphone is perfect but with real microphones, this resistor is in parallel to the internal resistor, hence the signal loss.

What I would like to figure out is what happens when I try to force the microphone to operate current inside the microphone (through the internal resistance). I am sure I would get a huge signal BUT I am sure I would get a huge noise too.

The rule of noise is: noise levels are huge across large resistance and tiny across tiny resistances. When the cable is taken into consideration (although shielded) one may as well find to have built an antenna instead.

Microphone

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A GOOD IDEA WOULD BE TO TRY TO DO THE CIRCUIT WITH INVERTING AMPLIFIERS THIS IS WITH THE NEGATIVELY CONNECTED OPERATIONAL AMPLIFIERS.

Most of the necessary current which must enter the inputs is supplied by the output of the operational amplifier through the feedback resistor.

As a gross generalisation: when possible, always use the inverting amplifier schematics. For microphone pre amplifier where there is a discharge resistor across the capacitor anyways, use the inverting amplifiers schematics and calculate R1||R2 to be equal to whatever the discharge resistor is desired to be.

Pseudo filtering considerations:

Microphone

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OA1

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Rm

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R2

C2

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OA2

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+

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R13

-

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R4

C4

In case of a noise problem, a resistor Rm can be put across the microphone. Thus, current will cycle there and not go to the rest of the circuit. This may reduce the sensitivity of the microphone, i. e. result in lower voltage of the microphone. A filter capacitor can be put across the microphone too but the unknown parameters of the microphone will result in impossibility to know the value of the capacitor to adjust the cut off frequency to 25KHz.

C2 and C4 are filtering capacitors which partly “shunt” R2 and R4 at frequencies higher than the cut off frequency which is to be 25KHz in this case. However, this cannot fully filter the frequencies higher than 25KHz because the gain of the whole circuit gives value of 2 when R4 and R2 are shunted. In case we substitute 0’s for R2 and R4 in the formula of the gain, the formula gives a value of 2. Physically, when R2 and R4 are shunted (replaced with a short connection) we achieve two separate buffers similar to the Instrumentation Amplifier with Buffers and the gain is 1.

The easiest inverting amplifier schematic would be:

C2

R2

R1

Microphone

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OA1

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However, there will be a common point between output and the microphone but there isn’t any common point between the power supply and the microphone which:

* + 1. Cannot reference the input voltage to the working voltage range of the operational amplifier (the power supply)
    2. The current cannot be returned

Thus this schematic would not work without any of our “ground” circuits: either the one with the operational amplifier or the one with the Zener.

+

-

5 to 30V

+

-

1kΩ

1kΩ

+

10µF

1µF

330nF

+

-

10K

120K

39K

10K

0 to 100K

100Ω

10µF

56pF