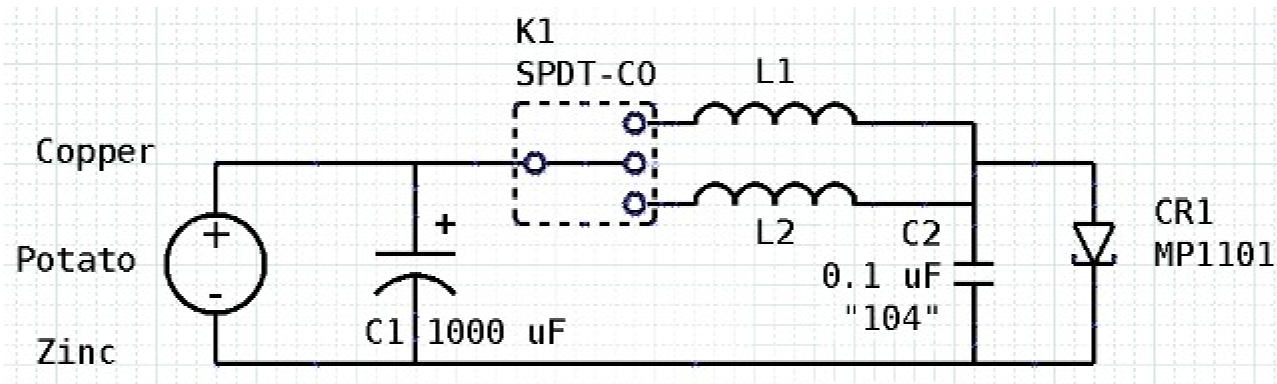
Reverse Engineering Willis Linsay's Stepper

Steven Baxter and Terry Pratchett have provided a science-fiction gem with "The Long Earth". Unfortunately, the Stepper assembly diagram by Richard Shailer has numerous errors and omissions, making replication a frustrating experience. Likewise, an uncredited stepper photo found on "www.io9.com" has errors and irrelevancies.

As you will recall, Step Day was in 2015. For the impatient among you who wish to try stepping out earlier (Sooners), enjoy the schematics and explanations below.

Schematic



Notes (from left to right)

Potato = Russet Red recommended with active eyes.

> We are simply using the phosporic acid in the potato as the electrolyte of a battery. Any potato will work, as will any citrus fruit or tangy root. I recommend the Russet as a future food stock. Carve out the eyes and plant in an elevated, well drained sunny location for a future harvest. That said, oranges work. Grapefruit work. Lemons work. Granny Smith apples work. Your choice.

Copper

> I am using 14 gauge copper wire taken from scrap Romex. True copper pennies, prior to 1982, work very well.

Zinc

> I am using strips of zinc cut from a roofing product called "Moss Boss". A roll of this material costs about $30.00, and will be enough for hundreds of Steppers. Share this with your friends.

Alternatively, get a modern penny, and some 400 grit sandpaper. Tape the sandpaper on a flat working surface, grit side up. Put on a glove, to save the skin on finger in case of a slip, then using your forefinger, orbit the penny on the sandpaper using a figure eight motion until the copper is off, and only zinc remains. Flip the coin, and repeat. Finally, sand the outer edge, so that all copper is gone. You will have a thin, fairly flimsy slice of zinc, but this will work well.

Do *not* use galvanized steel, such as roofing flash. During the step, the iron is left behind, leaving a powder or fragile film that falls apart the first motion you make.

C1 = 1000uF electrolytic capacitor, surface mount. Mouser # 661-EMV-6R3ADA102MJA $0.28

I recommend the 6.3 V capacitor by United Chemicon part number # 6R3ADA102MJA0G, but any low ESR electrolytic should work here. The motivation for the surface mount parts is to avoid the solder plated iron leads commonly found on through hole parts. If you must use through hole parts, at least magnet test the component before use. Its a real drag to step out, and then find a bunch of unconnected parts in your kit.

Notice the polarity markings on the capacitor. The minus sign needs to connect to the zinc strip to prevent premature capacitor failure.

This capacitor is the primary energy store for the step event. The current capacity of the battery is miniscule, around 10 to 100 uA, and is inadequate to run the tunnel diode oscillator. The battery however, can charge the 1000 uF capacitor in about 10 seconds or so. The current from the capacitor is much higher than the battery steady state current, and can easily drive the oscillator for the 25 msec jump window. By depleting the capacitor during each jump, and having a long recharge time, we guarantee "one-shot" behavior, where each switch activation results in only one step.

Caution: Substitution of a much larger capacitor, or use of higher current battery, will result in stuttering. Don't Tim Allen this device, unless you like being lost.

K1 - Rocker Switch : Electroswitch RK8001 or C&K 7105J1CQE2

This is usually the most expensive part of this kit at about $8.00 and change. It also needs a little attention before stepping. Magnet test your switch before use. The RK8001 usually uses a beryllium copper return spring, but for some production runs have had a steel spring. The 7105, in addition to the ferrous return spring, may have ferrous stamped metal hardware as well. IF your switch passes the magnet test, your clear to go. Otherwise, tape a four inch strip of 1/2 black electrical tape over the rocker, keeping the rocker centered. This tape will be the return spring, after stepping, and will reduce the likelihood of unwanted stepping due to a floppy switch. Both of these switches use non-ferrous contacts, so we are good there.

Of the three pins sticking out of the switch, the middle pin is the common, usually labelled C. This center pin connects to the positive terminal of C1 and the battery. The other two leads go to

L1 and L2 respectively. The consequence of confusing pins 1 and 3 on the switch will be disagreement between you and your buddies on East and West. Before doing group jumps, you should probably test and synchronize your nomenclature. (If you leave some excess wire as a service loop attached to the switch, you can simply rotate the rocker switch in the case by 180 degrees to change the East - West selection.)

L1 = 7 turns close wound 14 gauge copper on 3/4 inch PVC pipe.

The 14g wire solid wire is sold by the foot in most hardware stores in the electrical department (Lowes and Home Depot stock this). If you have some Romex laying around, the ground wire from Romex is perfect. Do *not* remove ground wires from circuit breaker boxes or transformers.

Close wound means that the turns are initially side by side as close as possible on the form. Later, we will remove the form, and fine-tune the circuit by spreading the coils.

L2 = 5 turns close wound 14 gauge copper on 1 inch PVC pipe.

C2 = 0.1 uF SMT MLCC capacitor. $0.06

I am using a Vishay # VJ1206V104ZXJPBC 16V capacitor in a 1206 SMT package. The 1206 package is large enough to solder by hand. I am using a little bit of Vera-Board to hold the capacitor and wires. Use a Dremel tool or a knife to remove the trace that runs under the chip to prevent accident bridging during soldering. I usually buy 25 or 50 of these at a time. Just as with the "Moss Boss" zinc, share these with your friends.

C2, along with the active inductor, either L1 or L2, and the stray capacitance caused by the water in your body, sets the resonant frequency of the tunnel diode oscillator. C2 can vary by as much as 20%, and we will be able to compensate by adjusting the pitch of the coils.

CR1 - Tunnel diode.

Tunnels diodes, also called Esaki diodes, are not exactly a stocked item at the local store anymore. The part called out in the drawing is available at aerospace prices from M-Power Microwave, in San Jose, CA. A much more fun approach, however, is to make your own tunnel diodes using Nyle Steiner's (aka K7NS) process with zinc and aluminum. (Reference: http://www.sparkbangbuzz.com/els/ntype-nr-el.htm)

I start by cutting a 2" by 1" strip of aluminum from an empty soda can. I rinse the strip, and then solder a 24 gauge red solid wire to the left top corner of the strip. (The red wire indicates that this will be our positive terminal). The solder technique requires that your melt/drip a blob of solder on the corner of the aluminum, then using the 24 gauge wire, scratch the aluminum surface through the molten blob, then let the blob freeze with the wire in place. Aluminum will oxidize almost immediately in air. We need to get the metal contact with the solder made by scraping the oxide off under solder, isolated from air. If your solder does not adhere, practice again a few times until you have it figured out.

Once you have your aluminum strip with wire attached, bend the strip into the shape of a sidewise letter U, and hot-melt glue him onto a 2" x 1" scrap of stiff plastic. (I am using an old cassette tape cover for my base.) Being more specific, draw a capital U on the plastic, align the aluminum strip long length along the U, have the wire sticking in the air, and then glue that strip down.

Now, we do a similar process of a attaching a black solid 24 gauge wire to the zinc terminal.
I make a U-ish, teardrop shape, where I touch the two long ends of the strip together, and have a natural oval/teardrop in the middle. I don't want sharp creases, but a nice rounded surface. I orient this with the flat downwards. I have the rounded zinc touch the rounded aluminum at right angles, resulting in a single, spring loaded, point of contact.

If you are using a sanded penny, you will want to use a pair of pliers, and gently bend the disk along a diameter to get a slightly round curve (maybe 2 mm across the face of the coin.) Let this curved surface gently push against the aluminum surface at a single point.

The goal is to make a tunnel diode, where the thin layers of aluminum oxide and zinc oxide are the insulating barrier that the electrons must tunnel through.

If you have a curve tracer, or a scope, you should verify the negative incremental resistance valley in the positive voltage range from 0.2 to about 0.7 volts. (Increasing current results in decreased voltage across the diode.)

If your diode passes that test, pat yourself on the back, and then pot the diode and assembly using hot-melt glue. After cooling, verify proper operation once again, and then finish stepper assembly.

When installing the diode, the red wire corresponds to the top of the diode, connecting to the inductors, while the black lead connects to the zinc strip.

The Box

Not shown on the schematic, but important none the less, is the box. I am using a plastic pencil box aimed at the elementary school students, available at the local grocery store for $3.00 and change. The switch is mounted on the top cover, the potato and electronics fit nice inside, and I can easily open the case to fuss with the coils as necessary.

Tuning

Once you have your box assembled, you will be impatient and want to test it immediately. I can tell you from experience, *IT'S NOT GOING TO WORK*. Here is the idea. You are a large bag of mostly water, to quote Star Trek, and water is 80 times more conductive for electric and dielectric fields than vacuum. Your body capacitance is participating in the tuned circuit. (Turns out we need this anyway, for pilot field localization.) How much you weigh, and where you hold the box affects the synchronizer frequency.

You may have heard that each person needs to finish their own box, and tune it themselves. This is a nice fiction to reduce customer support calls. If you and your buddy are about the same weight and water content, you can swap boxes. You will likely need to hold the other box a little further out, or a little closer in, but you will be able sync and step.

So here is the process. Start early in the day. Choose a direction, say East, and stick with that until successful. Make sure you know which coil will be active when you toggle the switch. (When the switch is up, the lower contact is connected to common.) Stretch the coils slightly, and try it. Repeat this process until success, or until the coil is about 40% longer than initial size. If your coil is 40% stretched, you missed, and need to compress, and try again.

For the mechanically inclined, a stretching mechanism using 6-32 nylon allthread and nylon nuts is not hard to improvise. Quarter turn stretching steps seem to work well. Brass allthread and nuts is not recommended, as it lowers the Q and the inductance too much.

After you have East working, repeat the process with West. If you succeed with East, but don't succeed with West, you have a long walk home in front of you. (You did tell your experienced friends where you were, and where you were going, right?)

So, How Does It Work?

Per Hugh Everett, universes are spawning like mad for each and every possible transaction. Adjacent universes have a wavefunction that is almost perfectly the same, differing in only one transaction, and being anti-symmetric, experience a tremendous exchange force, requiring an energy of two universal masses to transfer from one frame to the next immediate frame. Consequently, this just does not occur. The phase space encompassing all universes I'll call the over-verse, for want of a better name.

The over-verse topology is close to that of a 4D Clifford torus. As these universes spew, in the in and out directions for example, their trajectories loop 360 degrees around the over-verse, and are found adjacent to our here and now, but with a 180 degree phase shift. Now the exchange force, which was a maximum for our closest neighbors, has declined to practically zero (pseudo-bosonic behavior). As there is no energy barrier to speak of between these universes, there is no conservation of energy penalty for travel, as these really are but two aspects of the same equipotential universe.

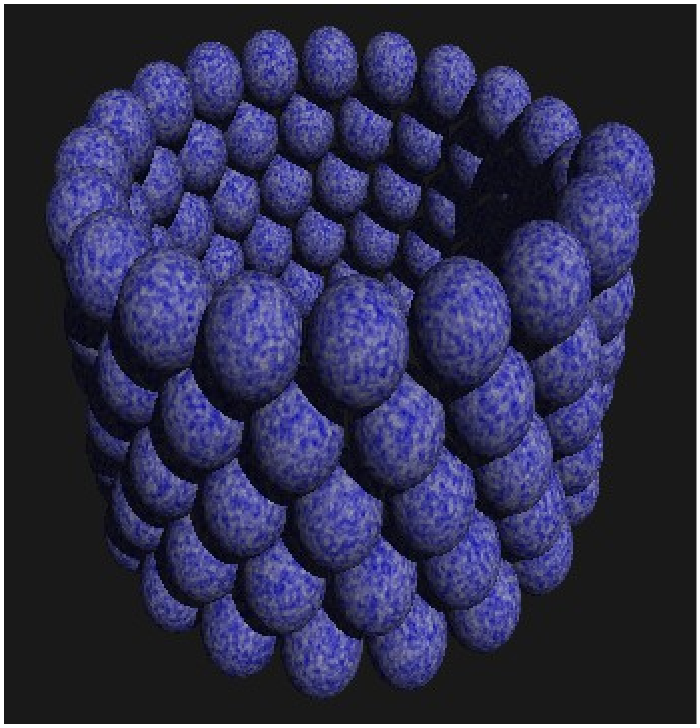


Illustration of adjacent universes east-west, and soft-spot connections north-west and south-east. Real time universes are spewing in/out radially, and not shown in this illustration.

In reality the barrier energy is not exactly zero, but rather micro-joules. Further, the universes don't perfectly align, but there is a small slip, a regular little bump, bump, bump occurring as we align, then misalign, and re-align again. This keeps the images discoherent, so we see our reality, but not theirs. So, here what happens when you throw the switch. The 1000uF capacitor dumps into a tuned circuit comprised of the L, C2 and you. If the frequency of resonance matches the slip rate between our universes, you get an evanescent wave tunneling from us to them. Under these conditions, the tunneling electrons in the tunnel diode act like a spark in a room full of gas and oxygen, with bulk tunnelling occuring in the domain of the evanescent wave. As high frequency currents flow on the surface of conductors, this includes all of you, as well as your internal organs. The evanescent wave has an extinction length of a cm or so, and consequently you also get to keep your clothes, most of your shoes, and a bit of dirt or concrete you might have been standing on.

Why are East and West different? East is on the inside radius of the Clifford torus, where the strands are more closely packed compared to West, which is in the outside radius of the 4D torus, with greater spacing and lower frequency.

Why doesn't iron transfer? Iron *does* transfer, as long as it is in a non-magnetic compound or above the Curie temperate. The ferromagnetic (and antiferromagnetic) materials have a strong enough local exchange force to interfere with the equipotential transfer. The exchange field responsible for making the magnetic field splits the local transfer energy levels for their location. The iron tries to go both ahead and behind our target, and consequently, on the average is left behind.

Since the lowest energy match is slipping continuous, do we ever revisit the same West 1? You can never step in the same stream twice, right? Technically, we never re-enter the same level, but as the transactional differences are effectively zero across those universes, we practically will never see the difference until billions of years of slip occur. (Pretty wild, right?)

Hope y'all enjoy!

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Datum