A field guide to

Salvaging Sound Devices

25 April 2025

Rosa Schuurmans

Thesis submitted to: the Department of [Experimental Publishing or Lens-Based Media], Piet Zwart Institute, Willem de Kooning Academy, in partial fulfilment of the requirements for the final examination for the degree of: Master of Arts in Fine Art & Design: [Experimental Publishing or Lens-Based Media].

Adviser: Marloes de Valk
Second Reader: Aymeric Mansoux
Word count: 7616 words

Introduction

"The real long-term future of computing consists of figuring out how to make the best possible use we can out of the literal millions of devices which already exist."

(Solderpunk, 2020, Cited in de Valk, 2022)

Beware! If you've picked up this publication expecting to learn how to make a flawless, DAW-less, in tune and always working polysynth, think again. However, if you, like me, are interested in making screamy, dreamy, sound devices using components you can find *in the wild*, you've come to the right place.

When I first read about salvage computing, I got very excited. Being part of the DIY Sound community, as a sound practitioner and hardware hacker, I've developed a growing discomfort with some aspects of the practice. Within the DIY Sound community, DIWO workshops are a common way of sharing knowledge (Richards, 2017), covering a wide range of topics, from the construction to bending and hacking and live coding. Over the past few years, I've hosted workshops around circuit bending[1] and LOFI sound devices in and around Rotterdam. These workshops are meant as an accessible way to get people tinkering with electronics, through something infinitely playful: making instruments[2].

[1] the practice around hacking discarded toys to find sonic potential through creating shorts, or sometimes literally bending the circuit.

[2] Making instruments is an engaging way to learn about and work with the flow of electricity.

In an ecosystem where a printer is only printing with a costly subscription [3], disruptive products become obsolete within a year[4], fixing your own flat tires is outsourced [5] and some smartphones literally have to be frozen to be able to replace the battery [6], it's clear we're no longer in charge of our own devices. Warranty-void stickers and lengthy terms and conditions scare us into compliance.

First time soldering workshops can be very empowering in taking back this autonomy by making (or breaking) a circuit together[7]. They are a shared attempt to uncover some of the black boxes in our own products (Hertz and Parikka, 2012). However, the toys and materials used in the workshops are single-use [8] and, with ease, thrown out afterward. The carelessness notion creeps in that waste has no value, and is easily replaceable, and broke my heart a bit, one workshop at a time.

This is where the field guide comes into play: Can we shift the practice of playful tinkering to acknowledge, rather than ignore, the waste streams they are part of? Limiting ourselves to only use salvaged components and discovering; is it possible to live off (create with) electronic components salvaged in the wild? And what would such a practice entail?

Because salvage is not just about reusing materials; but about confronting the systems that create the waste in the first place. Not only the obsolete media but also the by-product of the entire production lifecycle of an electronic product; From the mining of minerals that make up the hardware to the inevitable disposal site (Gabrys, 2012). Since the rate at which waste is collected and recycled isn't growing at the same pace as our collective buying and production, the landfills will continue to grow. Parikka even goes as far to say as that recycling is ultimately "waste-trade", where our abandoned devices are shipped across the ocean (Parikka, 2012).

[3] HP's "all-inclusive" printers can only be used with an active subscription (Hachman, 2024).

[4] Humane Inc. Ai Pin closed their servers within one year after releasing their *A.I. Pin*. Now, you can only ask this piece of hardware how many batteries it has left (Chokkattu, 2025).

[5] Swapfiets promote their bike subscriptions as "We give you a bike that you never have to repair".

[6] The Nothing Phone scored a 1/10 in iFixit's repairability score (Havard, 2017).

[7] Especially during a workshop in collaboration with the kunsthal, where it was the first time making a circuit for many attendees. It was great to see how people without much electronics experience figured out circuit making and playing, together.

[8] and often require much preparation in terms of collecting, transporting, repairing, testing, and cleaning.

Beyond the kit

The preference for buying new is noticeable in the DIY synth community as well. When publishing a project, it's common to share a pre-filled webshop cart along with the schematics or even sell it as a pre-compiled kit[9]. To me, this goes against the ethos of DIY that resonates with me the most: making do with what you have, with a focus on doing, and not the outcome (Hertz, 2023). Instead, a whole market is created for Lego-like kits. These kits gloss over the challenges and difficulties of creating sound devices, preventing the development of much-needed problem-solving skills, and not actually discovering anything new (Brown, Ferguson and Bennett, 2019).

[9]

fig 1. Kit from Bastl Instruments

Instead, what you will learn to build using this guide is a starting point. Small electronic circuits that produce sound on their own, but can also be duplicated, manipulated, and modulated [10], while diving into the questions around the practice of salvaging. The guide is tested, tinkered, and tweaked during (un)repair cafe evenings at the Klankschool[11]. In these hangouts we modify, hack and repair devices together.

[10] *I am by no means an expert in electronics. This guide represents my personal understanding of electronics, which, in no doubt, contains incorrect assumptions or oversimplifications.*

[11] Klankschool is a loose-knit group of sonic practitioners based in Rotterdam who share a common interest in performances, sound art, improvisation and noise. Everyone involved is a teacher, student, musician, janitor and more. Check the calendar for the next event!

The guide is split up into the different stages of salvaging:

1. Gathering hardware
We trace where to find discarded electronics and how industry practices shape what ends up in the trash.

2. Dismantling devices
Opening up devices to uncover design strategies that prevent access

3. Components to salvage
Identifying and extracting useful components—motors, sensors, chips, while diving deeper in their material.

4. Recipes for making
Methods for building sound devices.

5. Taking inventory
Time to clean the workbench and reflect

Happy scavenging!

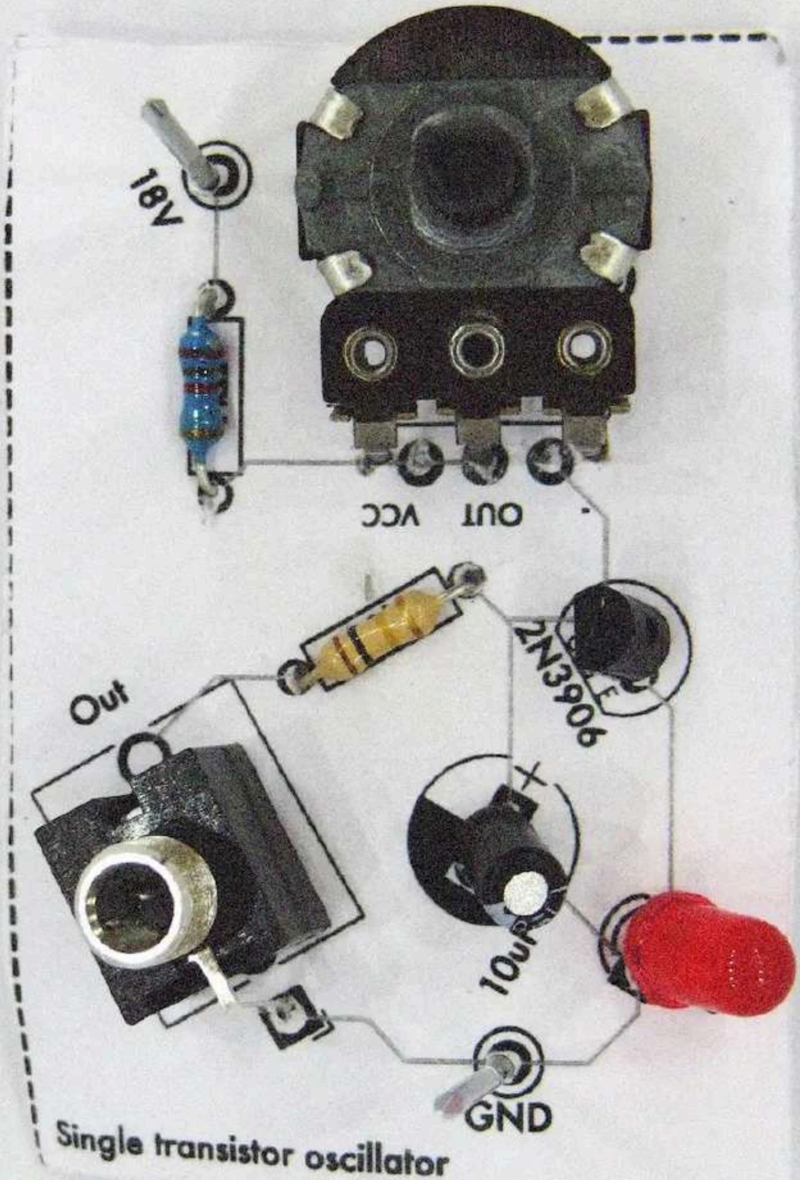


fig 2. A sound device

Chapter

Gathering hardware

Gathering hardware

When salvaging for parts, we are looking for abandoned hardware. Hardware that is still fine on the inside but no longer considered as functional by its previous owners[12]. These devices can be a literal goldmine of working parts that could be repurposed, as they probably still function, it's the stylistic obsolescence that is the problem.

Remy & Huang argue that the core goals of ICT are simply researching new technologies and selling more products (Remy and Huang, 2015). To achieve the latter, manufacturers have embraced structured obsolescence: the idea that a product has a limited lifespan and ought to be consumed and upgraded within a few years (Sterne, 2007). This strategy is embedded in the manufacturing, marketing and even the naming of products [13]. It's been embedded in consumer culture since the late 19th century, originally invented as a solution for overproduction (Hertz and Parikka, 2012). As a result, many devices have since been upgraded, replaced, devalued, and thrown out, before ever reaching their full potential (Parks, 2007). It is exactly these machines we are looking for. So, where to find them?

I've identified 3 strategies for gathering electronic hardware.

1. Institutional discards
Offices, schools, museums, or other companies often replace their hardware every 5 years, whether it's broken or not, due to tax regulations[14]. If electronics aren't central to their operations, their leftovers often gather dust. Keep your ears open, utilize your network, these forgotten machines could be your best source.

[12] The spectrum of "still fine" and "no longer deemed as functional" is very wide; printers with discontinued cartridges, Blu-ray players, an iPhone 8 with a bad battery, or Spotify's "Car Thing."

[13] Samsung Galaxy S8, iPhone 12s, Dyson V12 Absolute. The naming itself implies there's a next version, making yours outdated by default.

[14] Business assets such as laptops and computers are given a depreciation rate of 20%, implying a standard lifespan of 5 years for tax purposes.

2. Browsing the streets

I feel like good waste "comes to you". Keep your eyes open, look around. Actively going on waste walks has not paid off [15]. Their chances depend heavily on local waste policies [16] and activities[17].

3. Donations from friends & family

As you enthusiastically keep your friends & family in the loop about your salvaging endeavors, you'll notice the phenomenon of donations. Since a sizeable portion of our replaced computing devices still reside in our storage units, waiting to be of any value, most would be happy to find such a good destination as you (Gabrys, 2011).

Infiltrating the waste stream

My attempts to create a consistent waste-income through more official routes have not been successful. These established waste streams, where trash is being collected, organized, and processed in multiple facilities, are difficult to trace. Rotterdam collects e-waste via official centers and drop-off bins, usually placed inside supermarkets. The emphasis is on bringing waste in. What happens after is vague and leans heavily on a promise of a circular economy[18].

Consumer devices can be returned to the manufacturer through recycling programs. Here too, it's unclear what exactly happens with the returned devices, and the program is always part of a customer journey [19]. This relieves the consumer of the disposal responsibility but keeps the cycle of buying new unaltered.

[15] Artist Unbinair, who works with reverse-engineering e-waste, points out that in the early 2000s, going on e-waste walks was more beneficial. and squatter communities actively repaired and reused these discarded devices. Now that e-waste is channeled into designated recycling centers, the waste stream has become more concealed, obstructing repair-based reuse (Fennis, 2022).

[16] The municipality waste guide website & app of Rotterdam is not functioning and has not been updated since 2022.

[17] In Rotterdam, there are various WhatsApp & Facebook groups exchanging geo locations for great trash.

[18] A model where everything is recycled, nothing is wasted, and new raw materials are never needed. A seductive but mostly mythical narrative, that keeps consumers consuming.

[19] For instance, Samsungs recycle program starts with "Step 1. Buy your new device with trade-in discount on samsung.com".

Trying to engage with these streams differently, by salvaging, not just discarding, is nearly impossible. Access is tightly controlled. Waste is only moved when it can be translated into monetary value, and even then, only in bulk. Taking from recycling centers is prohibited; solo salvaging has no place in this transaction[20].

Pick your battles

When inspecting a device for salvage possibilities, I try to imagine what the inside of the device looks like. What kind of components might I find? Are there any motors or moving parts? What kind of material is the device made of? What time period does it come from? Which companies manufactured the device and its parts? Is there an audio signal on the inside? Do I see any use for it now?

If I don't expect much, I'll leave it for the next person to salvage.

[20] My attempts to establish a relationship with the thrift shop failed. Out of pity I was allowed to snoop in their garbage bin (which was locked away and filled with goodies). Their waste was already part of a monetized system, and my presence didn't fit.

Chapter

Dismantling

Dismantling

Once you've found a piece of hardware, it's time to start dismantling the device. Let's set up a workspace where you can easily move your device around and keep track of small parts. To take the device apart, we will need some tools. Which specifically differ a bit per device, but this is what I have in my own toolkit:

To open devices

- A set of screwdrivers with various bits and sizes [21]
- Plastic spudger or pick — *Used to pry open seams without damaging the casing*
- Saw or utility knife - *cut through plastic cases or stubborn sections*
- Flat pliers - *for heavy duty pulling*
- Drill - *to drill through stuck and damaged screws*
- Tweezers

[21] Apple designed their own *pentalobe* screws for their products. When first released in 2009, no hardware store sold these bits, locking you out of your device.

For salvaging & making

- Multimeter — *Tests components for continuity, resistance, or voltage*
- Soldering iron & solder
- Desoldering pump
- Solder wick
- Flux
- Alligator clips - *quickly make connections without soldering*
- Thin copper wire [22]
- Battery powered speakers for listening + audio cable
- 9V batteries

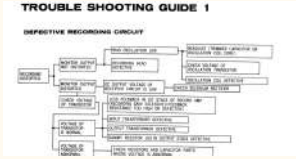
[22] These save you from stripping wires repeatedly. I found mine cheaply in the model-making store.

fig 3. Create a toolkit that works for you!

Opening up

It's not always clear where to start. Grabbing a heavy duty tool immediately could result in permanent damage. It is better to start more carefully. In some cases, product manufacturers provide service manuals[23]. But in most cases, we're left to figure it out ourselves. Fortunately, online communities like IFixIt create their own teardown guides, that can sometimes give us a head start.

[23] These manuals contain valuable information that can help you to understand the device and to take it apart.



Let's take a look at the device. Can you spot any screws? They might be hidden behind warranty stickers[24] or tucked away in obscure corners. I find it helpful to follow the seams of the casing. Especially with plastic enclosures, it's not just screws—look for small tabs or glue holding things together.

[24] Warranty stickers seem intimidating but are not legally binding, as warranties are dictated by consumer laws (Aragon, 2023).

fig 4. Following the seams of the device

If you manage to create a small slit gap in a seam, insert a thin plastic pic and carefully push it along the seam. There might be small tabs holding the casing together. If the manufacturer really didn't want you to get in there, they've glued it all up, and it is impossible to get in the device without causing permanent damage[25].

[25] A hot air gun could help to dissolve the glue, or you could cut out the plastic using a knife or drill.

Disassembly is really about patience and finding those small gaps in the enclosures, pulling and pushing until you've dismantled the entire device. Did you manage? Amazing! You're now staring at the messy, material reality of your device[26].

Uncovering black boxes

Through design choices like hiding screws, heat stakes[27], strong adhesive, and using various screw sizes, it becomes clear: the manufacturer really does not want you in there. These are black boxes by design, destined to become obsolete, as replacement parts are not available, and critical components are not interchangeable. The only option is to buy an entirely new product again.

The act of black boxing are an attempt to keep us unconsciously incompetent, and increases the distance between the consumer and the materiality of the device. The modern laptop is silent, not giving any indication of whatever is happening on the inside, or its material origins. It is only when something breaks, that their materiality becomes a reality again (Hertz and Parikka, 2012) (Emerson, 2021).

It is by opening the devices, however, that we can rediscover materiality. Then it becomes clear that what may appear so robust, seamless, and futuristic on the outside is fragile, breakable and almost futile on the inside. With the Multimeter we can track the traces from the speaker to the microchip to the microphone. Or is there something else in between?

[26] The inside can tell you more about the time the device was made in. For instance, I mostly find aluminum and iron type materials on the inside of older machines.

[27] Plastic pins that are melted to hold parts in place.

Discoveries at the (un)repair cafe

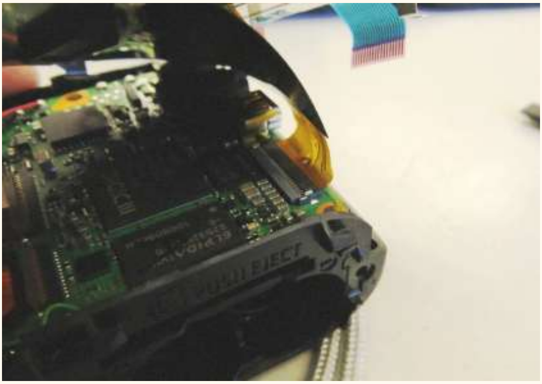


fig 5. The PCB has used ribbon wires to make an angled connection. This makes disconnecting, and later putting it back, a difficult task

fig 6. This speaker had no visible screws on the outside. 4 screws where found removing glued on protective caps

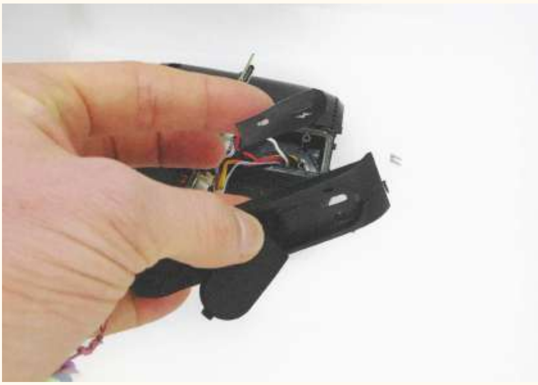


fig 7. The last screw was even better hidden. It was found behind a sticker labeling the two input ports of the device

fig 8. Manufacturer deliberately obscured the label of this chip

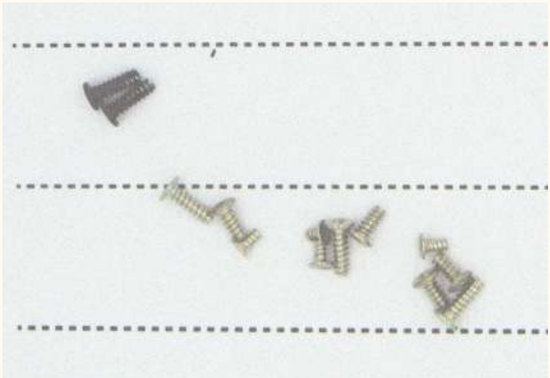


fig 9. The camera contained a variety of screw sizes

Chapter

Components

Components

Once you've broken your device down into its individual puzzle pieces, we can zoom in on them more closely. Is there anything that immediately sparks your interest? Did you already uncover unexpected materials? Chances are you uncovered one or more Printed Circuit Boards (PCBs), and—very generally speaking—some kind of input and output components, all connected by several types of wire[28]. For example, inside a digital picture frame I found a power input, a battery, a screen, speakers, a two-sided PCB, and an antenna.

[28] Great for reuse as well!

PCBs are populated with either "through hole" (THT) or "surface mount" (SMD) components. SMD components are very small and soldered directly onto the board's surface. Their size makes labels hard to read, and they're designed for automated assembly, making them impractical for salvage[29]. That's why I rarely salvage from computer-type devices. These usually contain nothing but SMD components and lack interesting interactions or mechanical parts.

[29] The biggest issue is the size of the legs, which are impossible to solder without making your own PCB's. I've made prototypes with cutting the entire PCB, using conductive ink, copper tape and charcoal pens. None of the strategies worked well

Desoldering

Desoldering components is generally more difficult than soldering and requires patience and practice. Ironically, desoldering guns are much more expensive than soldering irons, so here's how I do it, without one.

In a well-ventilated[30] room, heat up the blob of solder that connects the component to the PCB using a soldering iron. After a couple of seconds, you'll notice the solder becomes liquid[31].

Then, using tweezers or a plier, I carefully pull the leg out from the backside of the board, and then do the same for the other legs. This process can take somewhere between 10 seconds and 10 minutes and can be both frustrating and meditative.

Common components

In the next few pages, I'll briefly address some of the more common components. If you want to know more about what each component specifically does, I recommend Getting started in electronics (Mims, 1983).

Many components, like transistors and chips, have datasheets available online. You can usually find them by entering the part number, often printed directly on the component[32], into a search engine. While datasheets can be overwhelming and full of technical jargon, they typically show a pinout, explaining what each leg does, and a description of the component's behavior.

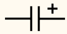
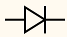
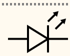
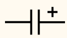
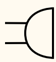
In the next chapter, we'll get into making with the salvaged components. The recipes need some specific components, which are highlighted below. It's always wise to have some extra! Components might break, speaking from experience, having to stop because you've run out of working components, is very discouraging.

[30] whilst modern devices cannot contain lead anymore, older solder will. Do not lick the PCB, clean your hands after and open a window.

[31] How fast this happens depends on the temperature of the soldering iron and the melting point of the solder that is on the board. If it won't melt, adding a bit of your own solder helps.

[32] Since the manufacturer didn't think you ever needed to know which oddly specific chip you're looking at, they sometimes deliberately scratched it off.

Overview of common components

Name	Category	Description	Found in	Symbol
555 Timer	Chip	A small chip that generates pulses	Timers, LED dimmers	
● **Capacitor**	Capacitor	Store a voltage	Everywhere!	
● **Coil**	Passive	These funky components can create sounds on their own	Transformers, relays, wireless charging	
Crystal Oscillator	Passive	Generates a frequency that is often used as a clock	Devices that have processors	
Diode	Passive	Forces current to flow in one direction	Everywhere!	
Displays	Output	Display information	Monitors, calculators, embedded systems	
● **LED**	Output	Emit a small light	Everywhere!	
Logic chips	Chip	Create logic and switches	Computers, microcontrollers, control circuits	
MOSFET	Chip	Not sure yet	Power supplies, motor control	
● **Magnet**	Misc	Electromagnetic applications, motors	Speakers, hard drives	
Microcontroller	Chip	Programmable chip, for example the ATmega328	Embedded systems, Arduino, automation	
Microphone	Input	Record sound	Phones, vapes	
● **Motor**	Output	Spins when a power is applied	Printers, blenders, vacuums	
NPN Transistor	Transistor	Amplification/switching	Everywhere!	

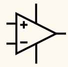
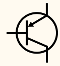
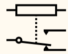
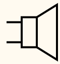
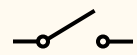
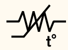
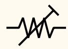
Name	Category	Description	Found in	Symbol
Op-Amp	Chip	Amplifying signals	Audio circuits, sensors, control systems	
PNP Transistor	Transistor	Amplification/switching	Everywhere!	
Piezo disc	Ouput/Input	Records or creates vibrations	Buzzers, sensors	
Potentiometer	Resistor	Limiting voltage through a knob	Volume knobs, light dimmers	
Relay	Switch	Switches power	Household appliances	
Resistor	Resistor	Limiting voltage	Everywhere!	
Speaker	Ouput	Outputs sound	Toys, (portable) radios	
Switches & buttons	Input	Interact with the device	Light switches, keyboards	
Thermistor	Resistor	Limiting voltage dependent on temperature	Not sure yet	
Trimpots	Resistor	Limit voltage through a small knob adjustable with a screwdriver	Audio circuits, calibration devices	
Voltage regulators	Chip	Not sure yet	Power supplies, embedded systems	

fig 10. These resistors were salvaged from a Reel to Reel recorder

Resistors

Also known as knob, pot, potentiometer, variable resistor, dial

You'll find resistors in nearly every electronic device and schematic. It's useful to keep a wide range of values around, from 1Ω(ohm) up to 10 million Ω. Their colored bands indicate their value[33]. In my experience, their values on schematics are usually an indicator, and you can divert slightly without too much impact on your project.

Variable resistors—like photoresistors and potentiometers—are especially worth salvaging, along with their knobs[34]. They can make your circuit interactive, by replacing fixed resistors with variable ones. This is also a common circuit bending technique, as with older toys the pitch of a sample is often regulated by a *pitch transistor*, replacing this with a variable one allow you to control the playback speed into drone like sonic realms[35].

[33] Each color represents a number or a multiplier. A table of this can be found online.

[34] I've found a lot of old gas stoves left out for trash collection. They often have nice knobs, that can be pulled off without need for tools.

[35] With more modern toys, this is no longer the case, lowering the number of mods you can do on a toy.

Types of resistors

Component	Description
Carbon or metal film resistor	Comes in different values, marked with color bands
Photoresistor	Changes resistance based on ambient light levels
Potentiometer	A knob-controlled resistor
Stereo potentiometer	Controls two channels at once, often used for stereo audio
Slide potentiometer	A slider-controlled resistor
Trim pot	A small, precise variable resistor you adjust with a screwdriver, used for circuit calibration
Thermistor	Changes resistance based on temperature

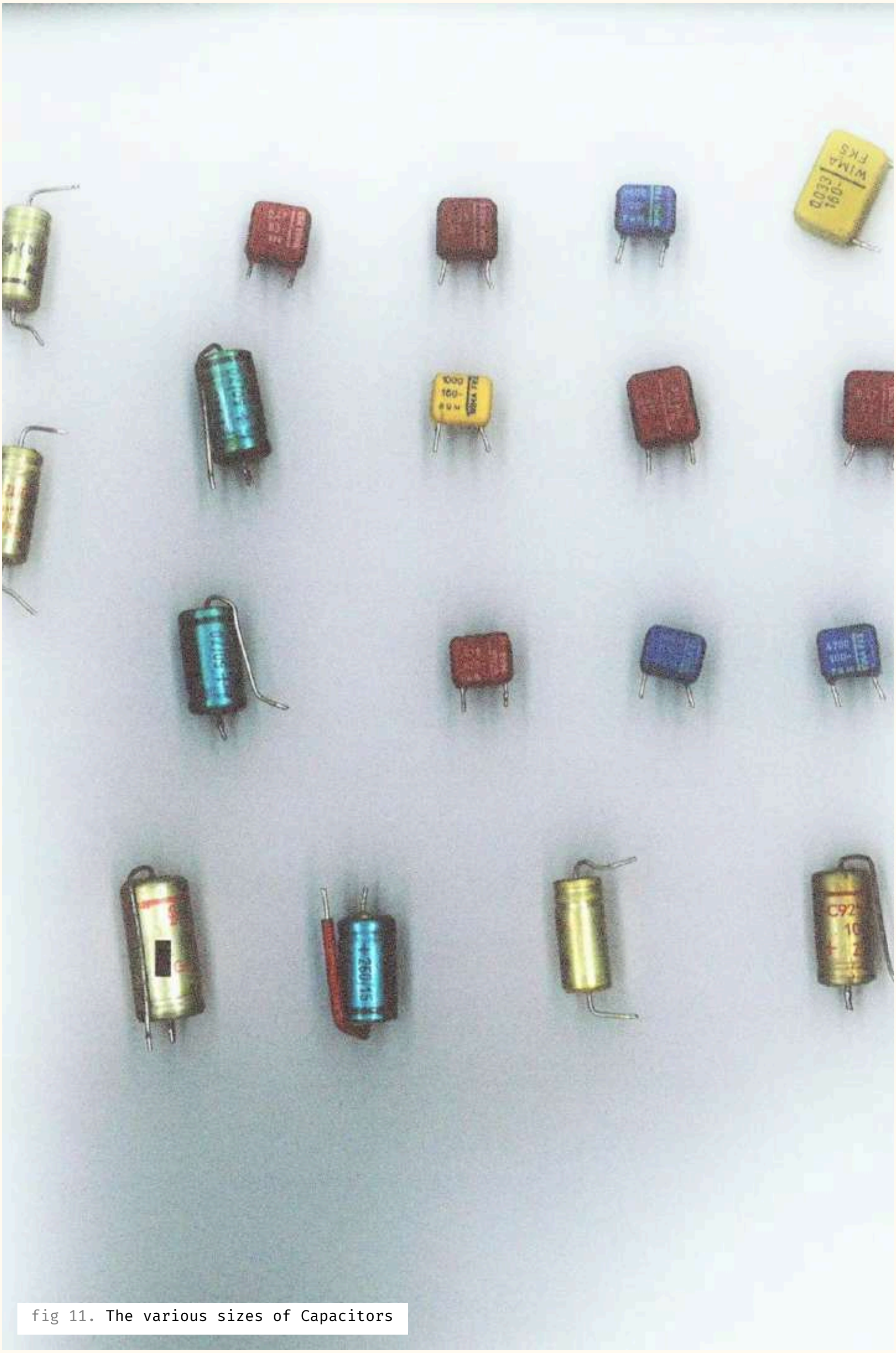


fig 11. The various sizes of Capacitors

Capacitors

Also known as cap, condenser

Capacitors come in all sizes. I've seen ones as big as a coffee cup, and SMD types so small they're barely visible. Like resistors, these passive components appear in nearly all circuits and store limited amounts of electricity. This is measured in farads (F).

Capacitor Type	Typical Value Range	Polarized
Ceramic	1 pF – 100 nF	No
Electrolytic (Aluminum)	0.1 µF – 10,000 µF	Yes
Film	1 nF – 10 µF	No

Salvaging capacitors safely

Capacitors store electricity even after power is cut. Touching a charged one can shock you. Larger types, like those in camera flashes or TVs, can store a dangerous amount. Always discharge big capacitors before storing. I do this by shorting the legs with a screwdriver. This may cause a small spark, as you've just created a short circuit.

Testing capacitors

Electrolytic capacitors don't age well. Left unused, they have a lifespan of 2 to 3 years (Jang *et al.*, 2017). After that, they can leak, spreading a yellow gooey material over the PCB, causing other connections to malfunction [36].

[36] Surprisingly, most of the capacitors that I've tested (that didn't visually leak) passed the test and were still usable, even the electrolytic ones.

You can verify the capacitor's capacitance with a multimeter. In continuity mode, which beeps if there's a connection, touch both legs of the discharged capacitor with the probes. If you hear no sound, or a continuous volume/pitch: the capacitor is dead. Otherwise, it's fine.

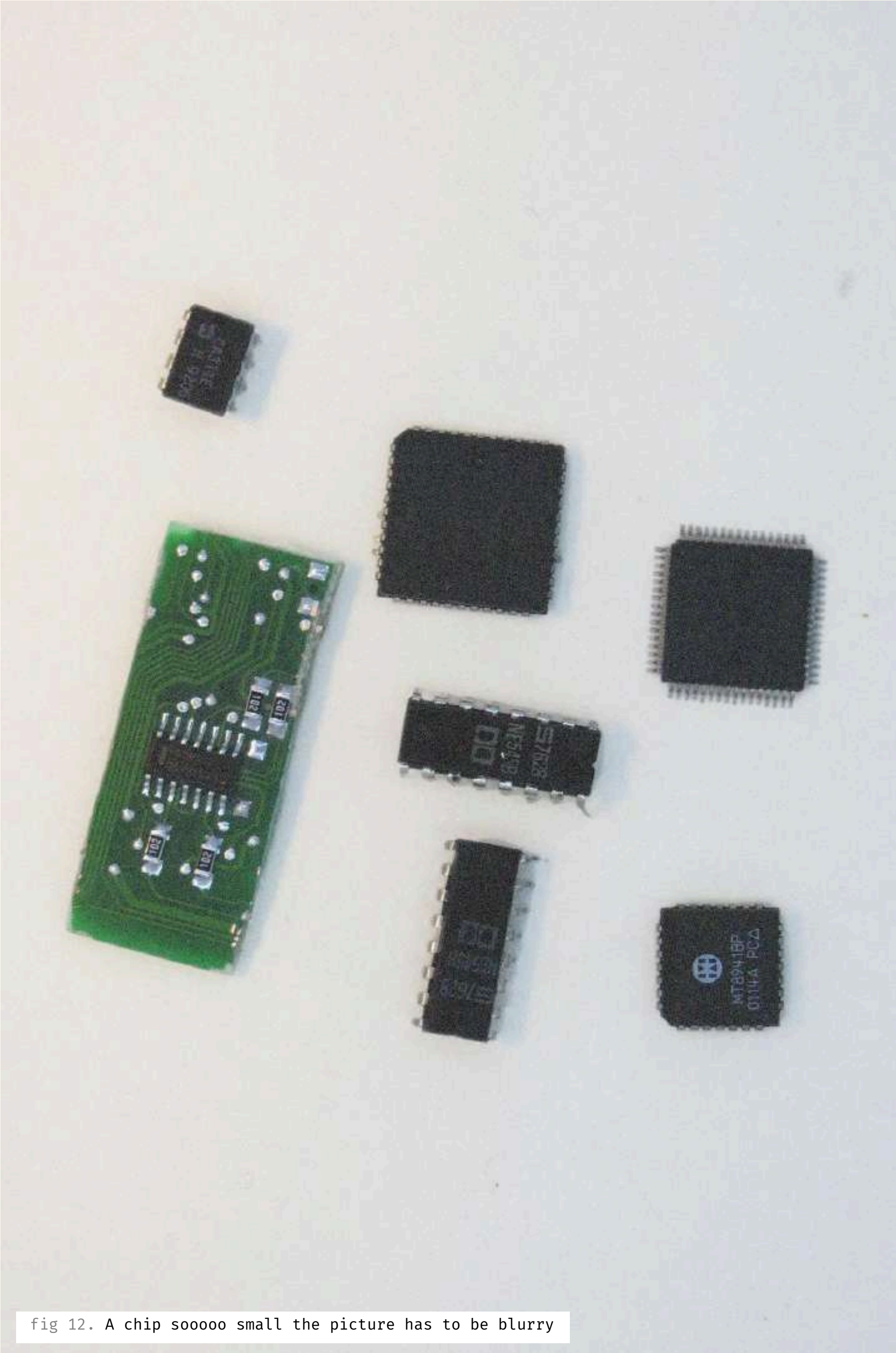


fig 12. A chip sooooo small the picture has to be blurry

Chips

Also known as IC, Intergrated Circuit

Chips, or integrated circuits, are tiny black boxes packed with microscopic components. You'll find them on nearly every modern circuit board. Some handle small, specific tasks, like controlling LEDs, while others run full operating systems.

Don't let the size fool you! The creation of a chip, from toxic chemicals to the black container, involves around 300 steps, during which 99% of material byproduct is discarded, creating hazardous waste sites (Gabrys, 2011). So, if there is one part worth salvaging, it's this one.

Unfortunately, as modular as they might seem, reusing chips is not plug 'n play. While some are common and well-documented[37], most are obscured and specific. For instance, reusing the network chip found in a USB phone can lead to a rabbit hole of reverse engineering. And then you find another phone that has a slightly different chip, and the process starts all over again.

[37] In the last 6 months of searching, I've found only a couple of op-amps, one trigger inverter (that I blew by placing it upside-down), and no 555 timers…

Common chips to look out for

Component	Description
555 Timer	*This chip can generate audible pulses. This can be used as a sound source on its own, or to trigger other circuits, or control motors*
Op-Amps (e.g., TL072, TL074, LM358)	*Op-amps are used to amplify signals, and therefore used in loads of sound-related applications.*
CD40106	*A Schmitt trigger inverter can generate audible frequencies that can be tuned. They are often the core of oscillator schematics.*
CD4017	*A Decade counter is often used for linear step sequencers.*
Microcontrollers	*If you're lucky, you can use the microcontroller to write your own program.*

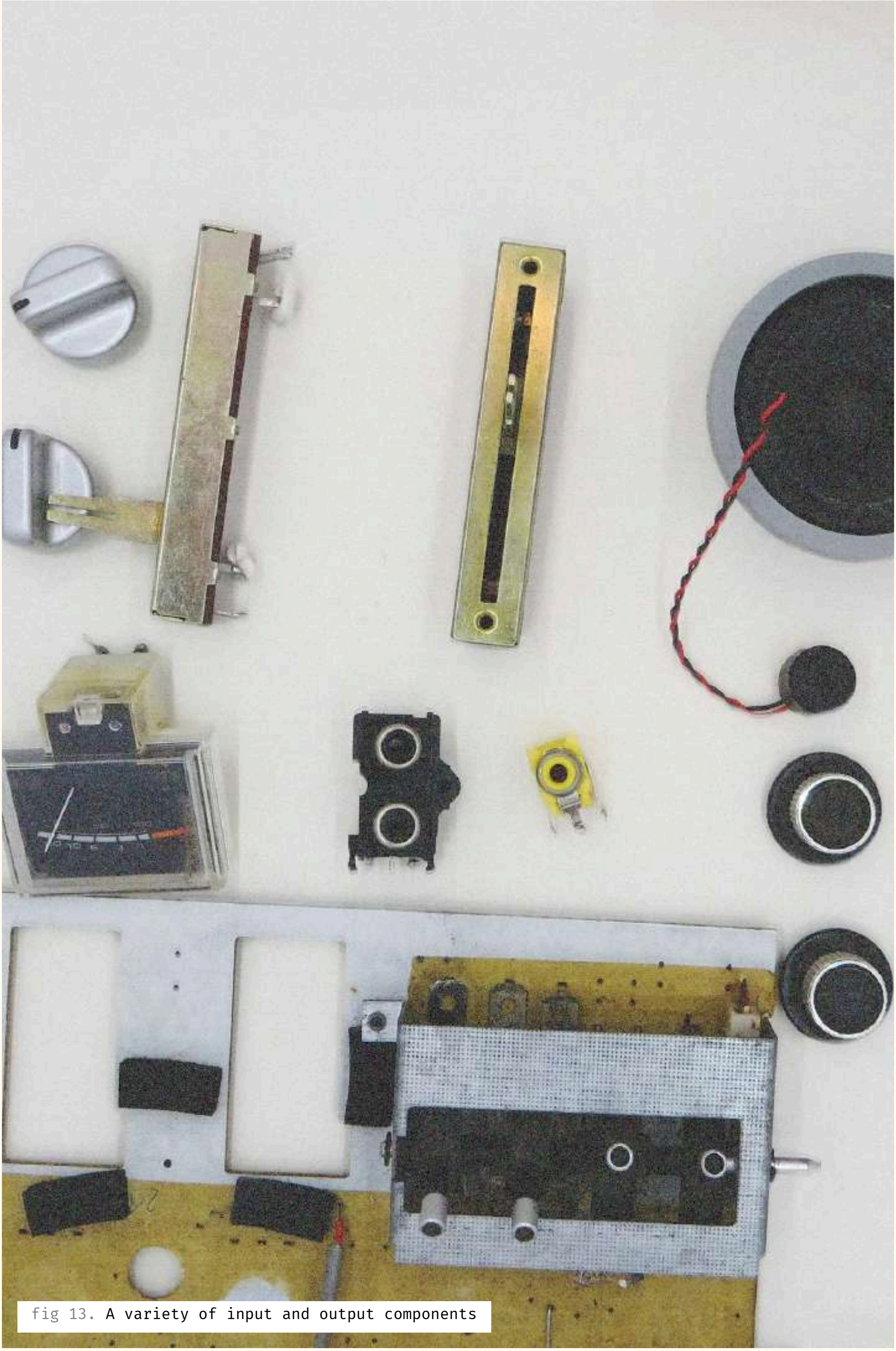


fig 13. A variety of input and output components

Inputs & outputs

Inputs and outputs are often the most visible parts of an electronic device—and among the most accessible to salvage. They are the parts that are most often visible on the outside and thus carry the cultural context of the device. But this visibility is a double-edged sword: it risks turning salvaging and recycling into solely aesthetic choices.

Recycling facilities, manufactures and product design universities often tend to focus on recycling, when talking about reducing e-waste. But among the levels of circularity reduce, reuse, repair, recycle, refuse, recycling is the least effective. More than half of material is lost when going through the recycling process and often involves shipping waste to countries with cheaper labor costs and fewer environmental regulations, resulting in toxic conditions for both workers and the environment (iFixit, no date) (Gabrys, 2011) (Roura *et al.*, 2021). Shredding a device doesn't just lose raw material; it erases the labor, energy, and environmental costs embedded in its original creation. And then a new device replaces it.

Instead of focusing on the visual esthetic that is visible on the outside of the original device, I think it's more interesting to focus on what made the object the object. According to Richards, this objecthood is the central theme of DIY/repurposing. Through hacking and bending we can amplify certain properties of the object (Richards, 2017). Turning a printer into a live coded instrument for instance, amplifying the scratches a piece of stuck paper can make.

fig 14. PCB with labeled parts

fig 15. Thicker and handdrawn traces

fig 16. Smaller components are difficult to desolder

fig 17. The blob cannot be removed

PCB (Printed Circuit Board)

Also known as Protoboard, breadboard, circuit

Printed Circuit Boards, or PCBs, are the panels on which the electronic circuit is placed. Older boards often reveal hand-drawn traces, which are much more fluid in design. With computerized PCB design, those lines straightened out. Most PCBs are made from FR4 (glass fiber and epoxy)[38].

The copper tracks on a PCB are usually covered with a green protective layer, known as solder mask. Sand this off to expose the copper underneath, ready to solder onto again.

Most boards are labeled. They can include a date, information about connections, component numbering[39], and sometimes even their values [40].

Not all PCBs follow the industrial template. Artists and other tinkerers have come up with alternatives: the paper circuits of Ciat-Lonbarde, or Dirty Electronics' boards made from wood and nails. These kinds of formats offer a more punk-diy way of publishing projects, where the format is not set in stone. Paper can be cut, nails can be moved, inviting a maker to explore the circuit more than just soldering a pre-compiled kit (Blasser, 2015) (Richards, 2013).

Protective

Did you spot "the Blob" on one of your PCB's? The blob (fig 17) is meant to protect certain bare parts of a PCB, but is also known as a type of reverse engineering protection. Another method of protection is applying a transparent layer across the entire board, preventing you from poking around with a multimeter.

[38] Fiberglass is very strong, but can be sawn through. When cutting, make sure you wear the right protection, microfibers can end up anywhere.

[39] The schematic contains references to the component number, helping with debugging.

[40] Some devices take this idea further. The Korg Monotron includes extra patch points directly on the board for DIY mods and expansions.

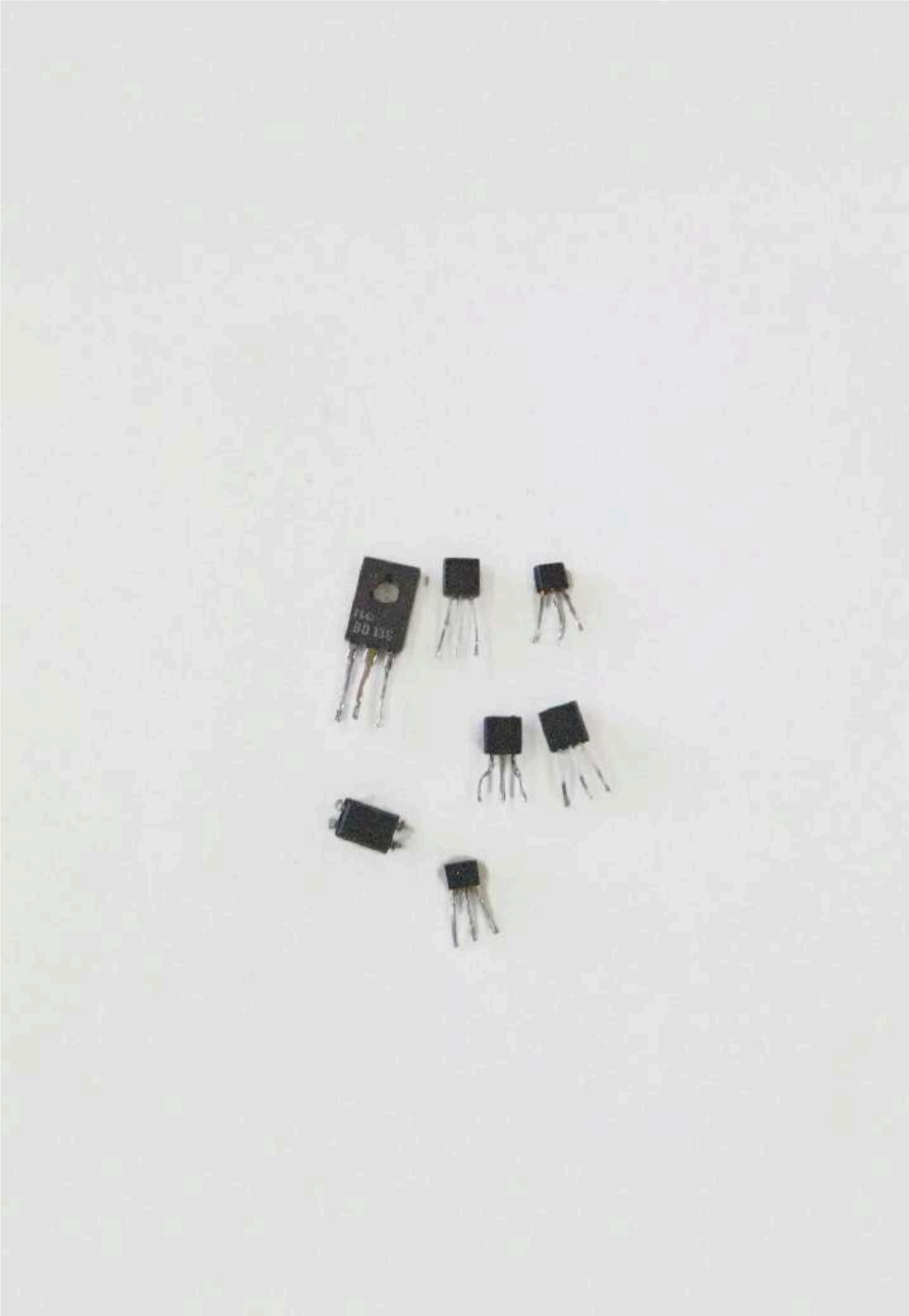


fig 18. ‘note to self, not sure all of these are transistors’

Transistors

Also known as switch, BJT

A transistor is a tiny switch that controls a large current with a smaller one. Depending on its type, applying a small voltage to one leg causes another to "open" or "close." This way, transistors can amplify signals or switch things on and off. You'll find them near power supplies, audio paths, and logic circuits. They are sometimes glued to a heatsink to shed excess heat. They're sensitive to ambient temperature, which makes them interactive in sound devices [41].

The transistor is often seen as a turning point in computing history. It replaced big and expensive vacuum tubes, paving the way for portable radios, cheap toys, and eventually silicon chips. Theories like Moore's law[42] create an expectation of constant upgrading, where your computer will be obsolete in two years' time, and the illusion of infinite growth.

This miniaturization of components did not result in more efficient technology use. On the contrary, Jevons' Paradox shows that increased efficiency in the production process would lead to even more resource consumption (Remy and Huang, 2015) (Gabrys, 2011) (Parks, 2007).

[41] In sound circuits, touching a transistor heats it up, which can alter the sound.

[42] Moore's Law is the prediction that the number of transistors in an IC doubles every year. This plays into the idea that you must upgrade your hardware every two years or you'll be behind and creates the illusion that innovation and development is endless.

Chapter

Recipes for reuse

Recipes for reuse

Hopefully, you've salvaged a variety of components by now, and we can start building sound with them. In this chapter you'll find a bunch of recipes; the starting points for sound devices. These modular recipes can be used standalone or connected together into a bigger system. This modularity makes problem-solving slightly easier[43], and you can pick and choose your modules based on your salvaged inventory.

Every recipe contains a paper circuit[44] to print. These circuits are the blueprint of your device, between a schematic and an industrial PCB. The biggest advantage of using paper, apart from being able to solder the connections of your components right on top of the circuit, is that it is flexible. You can take notes, draw lines, and adjust the schematic as you go.

Assembling the circuit

1. Cut out the circuit and fold it in half, creating a two-sided print [45].
3. Gather the components listed in the "Bill of Materials" (BOM).
4. Populate the first components by pinning the legs through the paper in their designated areas. Keep an eye on the orientation[46]. Start small (resistors) then move to larger parts.
6. Create the connections according to the circuit by soldering the legs together using (copper) wire.
7. Repeat until all components are in place!
8. Test & triple-check all connections [47].

[43] Still a headache! But now you only have to triple check a handful of components, instead of 120.

[44] A method introduced by synthesizer builder Ciat Lonbarde, who used paper circuits to distribute his circuits and ideas for free (Blasser, 2015).

[45] printing on thicker paper is advised

[46] Some capacitors, LED's and other components all have a specific polarity/orientation.

[47] With salvaged components you'll have a limited supply. Test to prevent component loss.

There is no need to understand every single component on each recipe [48] but try to follow the connections on the circuit. Which road is the audio signal taking? This will help you a lot with troubleshooting.

!Safety notes!

- **Audio can be surprisingly loud**. Use small speakers (never headphones! [49]) you wouldn't miss if they break and keep your hand on the volume dial when plugging in your sound device for the first time.
- **Use batteries**. Plugging into a wall (120V) can be incredibly dangerous. Always unplug the power from the circuit when making changes, to prevent shorts.
- **Watch that smell**. "Magic smoke" has a certain smell. Unplug immediately when something smells/smokes!
- **Two know more than one**. If you're not sure, invite a friend and I'm sure you'll figure it out together.

Finding recipes

The DIY synth community is not shy in sharing their schematics. There are fantastic resources online, such as the Experimentalists Anonymous DIY Archives the wiki, Music from Outer Space and Handmade Electronic Music (Collins, 2009). However, finding resources using salvaged components can be tricky, as our requirements are a bit different. Most schematics either contain 20+ components or require (specific) chips, which have proven to be difficult to find. This limitation has been interesting, as it forces me to experiment with smaller schematics. Turning the oscillators into self-modulating instruments, by attaching them together using alligator clips, actually helped me to learn more about electronics & sound than any pre-made kit could ever do.

[48] Rule #17 from Handmade Electronic Music states, "If it sounds good and doesn't smoke, don't worry if you don't understand it." (Collins, 2009).

[49] Your hearing is precious, and accidentally blasting an overpowered sinewave Through your ears can cause permanent damage.

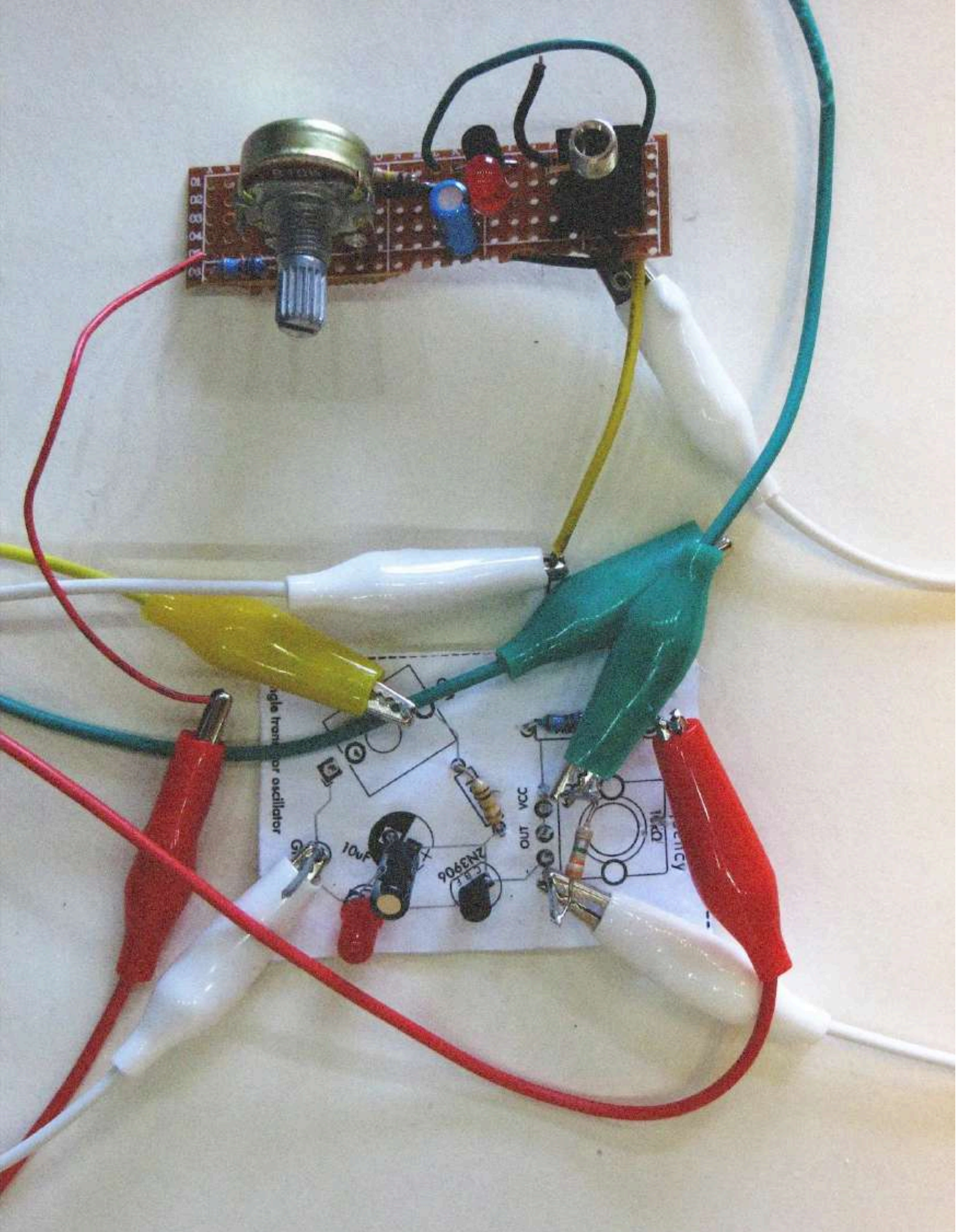


fig 19. Combine multiple recipes to create a self-modulating glitch device!

Power Supply

Create a power supply for your future circuits

This circuit provides -9V[50], 0V/Ground and +9V outputs, by combining two 9V batteries. If your project requires it, you can use any kind of battery instead of the 9V one, as long as they're two of the same [51].

You could skip the capacitors and resistors and just connect the batteries together. However, they help filter electrical spikes, making the output smoother [52].

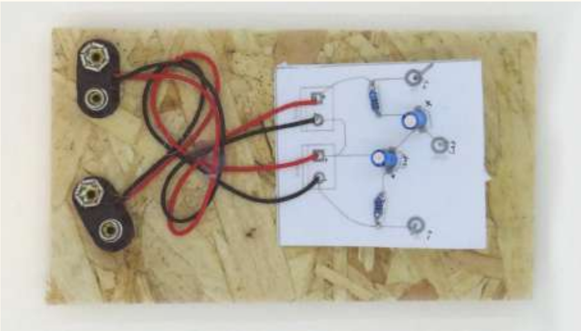


fig 21. Since this power supply will be used a lot, I made it a bit more permanent by glueing it to a piece of wood.

[50] Some chips, mostly op-amps, require a negative voltage, which does not come out of a battery by default.

[51] You can also get 18V: treat the -9V pin as 0V, making the 9V pin 18V

[52]

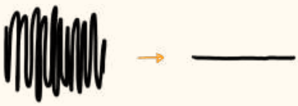


fig 20. The capacitor can filter electrical spikes for a more smooth voltage input

Testing

Before plugging in the batteries, check your connections[53]. When the batteries are plugged in, your pins should read -9V and +9V[54].

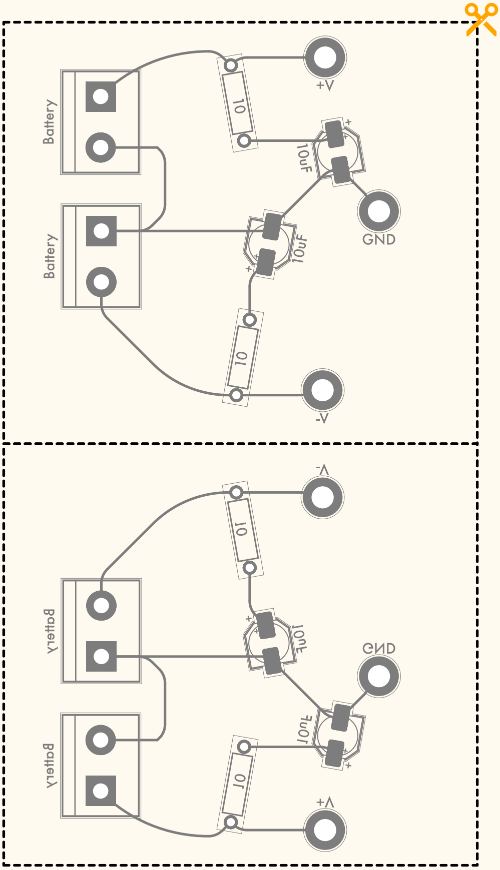
Upgrade

An upgrade that could be useful is adding a power switch and/or LED to show if the power supply is active.

[53] You can test this using the *continuity* mode on your multi meter, which beeps if electricity can pass through.

[54] Test this by using the volt meter on the multimeter. One probe touches your ground pin, the other the pin you'd like to test.

Paper circuit: Power Supply



BOM

- 2 10uF Capacitor
- 2 10Ω Resistor
- 2x 9V battery clips
- 3 conductive nails for the +V, -V & GND pins

Your notes

....

Single Transistor Oscillator

This unreliable schematic creates a tone!

▶ play sample (web only)

This *super simple oscillator circuit*[55] makes use of something called a "reverse avalance breakdown effect" in transistors. As I understand it, the capacitor and transistor of this circuit constantly trigger each other, creating a on-off-on-off-on-off situation, which in the audible realm sounds like a saw wave. Not all transistors can do it, so it's a bit of a trial and error process [56].

[55] I am very fed up with the amount of times someone has said something would be easy. It is not.

[56] This is why Reddit has advised against building this oscillator. But this is the only sound generating schematic that has worked so far and doesn't use chips.

Powering

Select the amount of voltage you need based on the transistor[57] you have. Mine needed 18V, so using alligator clips, I've connected our previously built power supply.

[57] Find a datasheet online to discover your transistors' voltage limits before plugging in the circuit

Testing & Troubleshooting

After double-checking all your connections, hook the audio out to an amplified speaker. No sound? Try:

- Check your connections and orientation of the capacitor.
- Play around with the potentiometer[58].
- using a multimeter, follow the entire audio trace from the transistor up until your audio cable.
- Try a different transistor

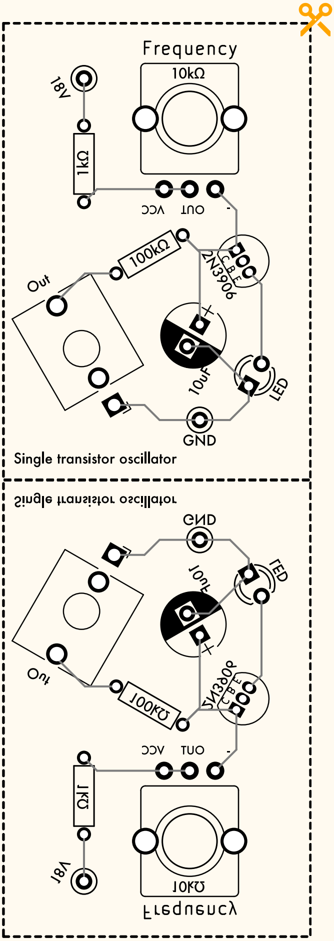
[58] mine only makes a sound for a small portion of the potentiometers range.

When there is noise

If you, like me, have struggled a lot to get any sound whatsoever, I can hopefully tell you that **this is where things will get fun(ky)**. Getting a single sound out of anything is such a eureka moment [59]. Because from here, you'll be able to play around with the circuit and use our own imagination. For instance, using a different sized resistor to change the pitch. Or, using a Light Dependant Resistor to control the pitch based on the sound. Or adding a on/off button. Or, building your own keyboard using multiple resistors...

[59] Making and playing this circuit helped me a lot with understanding how electricity flows and how you can manipulate the flow.

Paper circuit: Single Transistor Oscillator



BOM

- 1 2N3906 Transistor *alternative: 2N4401, SS9014, 2N4124, 2N3904, BD137, BD139, BC337, SS9018*
- 1 10uF Capacitor
- 1 1K Resistor
- 1 100K Resistor
- 1 10K Variable Resistor
- 1 LED
- 1 Audio jack
- 18V Power Supply

Build notes

- “Use alligator clips to connect your 18V and GND to your power supply"
- Cut the middle leg of the transistor for this to work

Your notes

....

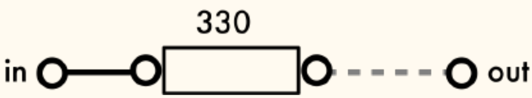
PCB Keyboard

A keyboard to play your oscillator

▶ play sample (web only)

This recipe uses the Single Transistor Oscillator created in a previous recipe. The keyboard will replace the resistor of the oscillator that is in charge of the pitch. That pitch resistor will now exist on the keyboard.

From a PCB that you have salvaged, remove *all* of the components and, with a piece of sandpaper, scratch off the green mask of the PCB, making the copper visible. Now, the traces of the PCB can be reused as wires. We will place multiple resistors on the PCB, to create the following circuit:

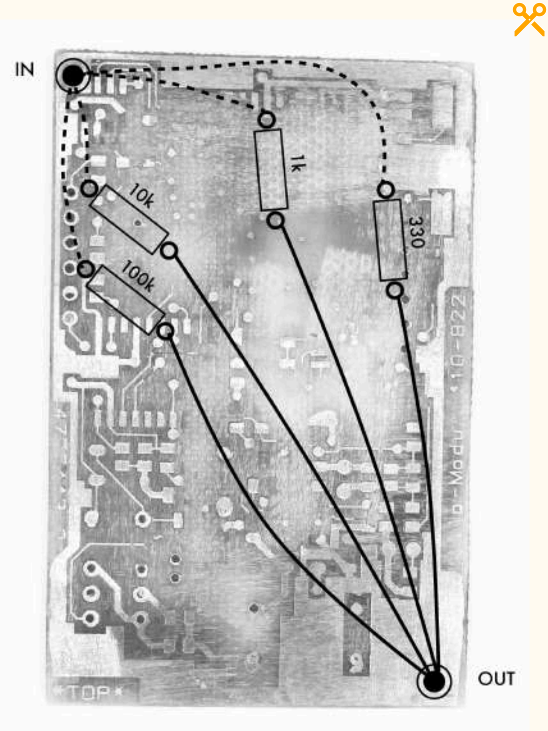


`fig 22. Since this power supply will be used a lot, I made it a bit more permanent by glueing it to a piece of wood.`

Find or make a couple of tracks or traces that are not connected to each other (using the multimeter). These will act as your wires! To one trace, solder the audio in from the oscillator. Find a trace nearby, close enough that if you can touch the two traces with your thumb and solder a resistor on that trace. The other end of the resistor should go back to your oscillator.

Now, when you touch both traces with your finger, a bridge is created, closing the circuit, and causing the audio signal to go through your resistor back into the original circuit. If you do this multiple times with various resistor values, you've created a playable keyboard!

Paper circuit: PCB Keyboard



BOM

- A completely clean PCB
- Multiple resistors between 1K and 100K

Your notes

....

Taking inventory

After all the dismantling, salvaging, desoldering, and re-making, it's time to take inventory. For me, this is the moment to sit in the middle of a workshop, surrounded by the carcasses of printers, cassette recorders, and radios, and deal with the remainders. Can we shift the practice of playful tinkering to also account for the waste streams it engages with?

In the DIY synth community, tinkering often happens collaboratively, through workshops where participants solder prefabricated kits, as an accessible entry point into electronics. When I started the field guide, I imagined creating a similar format, but using only salvaged components. Logistically, that turned out to be much harder than expected:

Waste streams are difficult to tap into
The circular economy, often marketed as a fix for the mountains of e-waste, is structured to keep the consumer lifecycle of buying intact. There is no method in place for taking waste, meaning we must revert to using what comes on our path or is donated. Which is a lot, but not consistent.

Salvaging the right components
Most synths built in workshops rely on chips like the 555 timers and op-amps. These chips simplify builds, lower the total amount of components needed, increasing the chances of a participant completing the circuit. In the past few months, I haven't salvaged a single 555 timer, and only a handful of op-amps. That is not nearly enough to provide a group of participants with components.

But maybe these limitations can also be an opportunity. If we let go of the expectation that everyone would walk out with a polished synthesizer, similar to those that can be bought in shops, new possibilities open up. The constraints of using e-waste as material can help us to think differently—to engage with different contexts or reimagine how existing technologies might be repurposed. Instead of following a set in stone schematic, the recipes are a starting point, which everyone can execute differently.

Fennis urges us to rethink waste, not just as a pile of discarded phones, but as the material it was before, including the toxic, environmentally catastrophic legacy. Through reverse engineering and hacking, they explore the material and learn what the technologies can do other than what it was designed for(Fennis, 2022). In other words, by dismantling a wired electronic razor, that was deemed obsolete and replaced for a battery powered razor, we can remove the abstraction layer and see that it is actually a blade, a power supply, and a motor, which in turn can become an instrument. In this way, we can see the end-of-life of a device, where the consumer is done consuming, as a moment of celebration, and give it an afterlife (Mansoux *et al.*, 2023)!

It is this kind of tinkering that I think will make us more resilient against the ongoing attempts by major companies and manufacturers to keep us locked out of our devices (Lu and Lopes, 2024). For me, that means not just rethinking waste but also questioning the workshop format itself—and whether I want to keep using the format with it. And the truth is, I don't think so. I see much more to explore in collaborative spaces such as the (un)repair cafe. This means, this is not the end of the field guide! It's the beginning. There are many more alligator clips to connect.

References

Brown, A., Ferguson, J. and Bennett, A. (2019) 'Cooperative Experimentalism: Sharing to enhance electronic media', in. *Proceedings of the International Symposium on Electronic Art (ISEA2019)*, pp. 480–483. Available at: http://hdl.handle.net/10072/409917.

Chokkattu, J. (2025) *What to Do With Your Defunct Humane Ai Pin*. Wired. Available at: https://www.wired.com/story/what-to-do-with-your-humane-ai-pin/ (Accessed: 13 March 2025).

de Valk, M. (2024) 'Salvaged computing', *Damaged Earth Catalog*. Available at: https://damaged.bleu255.com/Salvage_Computing.

Gabrys, J. (2012) 'Salvage', in *Depletion design: A glossary of network ecologies*. Amsterdam: Institute of Network Cultures (Theory on demand, 8). Available at: https://issuu.com/instituteofnetworkcultures/docs/tod_8_depletion_design.

Hachman, M. (2024) *The nightmare is real: HP makes printing a monthly subscription*. PCWorld. Available at: https://www.pcworld.com/article/2251993/the-nightmare-is-real-hp-makes-printing-a-subscription.html (Accessed: 14 April 2025).

Havard, S. (2017) *Essential Phone Teardown*. iFixit. Available at: https://www.ifixit.com/Teardown/Essential+Phone+Teardown/96764 (Accessed: 14 April 2025).

Hertz, G. (2023) *Art + DIY electronics*. Cambridge, Massachusetts: The MIT Press.

Hertz, G. and Parikka, J. (2012) 'Zombie media: Circuit bending media archaeology into an art method', *Leonardo*, 45(5), pp. 424–430. Available at: https://doi.org/10.1162/LEON_a_00438.

Parikka, J. (2012) 'Dust Matter', in Institute of Network Cultures, *Depletion design: A glossary of network ecologies*. Amsterdam: Institute of Network Cultures (Theory on demand, 8), pp. 53–57.

Richards, J. (2017) 'DIY and Maker Communities in Electronic Music', in J. d'Escrivan and N. Collins (eds) *The Cambridge Companion to Electronic Music*. 2nd edn. Cambridge: Cambridge University Press (Cambridge Companions to Music), pp. 238–257. Available at: https://doi.org/10.1017/9781316459874.015.

Fennis, M. (2022) 'Ontology Of Electronic Waste'. Available at: https://vigia.tech/1159-2/.

Gabrys, J. (2011) *Digital Rubbish: A Natural History of Electronics*. University of Michigan Press. Available at: https://doi.org/10.2307/j.ctv65swcp.

Parks, L. (2007) 'Falling Apart: Electronics Salvaging and the Global Media Economy', in Acland, C. R., *Residual Media*. Minneapolis: University of Minnesota Press, pp. 32–47.

Remy, C. and Huang, E.M. (2015) 'Limits and sustainable interaction design: Obsolescence in a future of collapse and resource scarcity'. Available at: https://doi.org/10.5167/UZH-110997.

Sterne, J. (2007) 'Out With the Trash: On the Future of New Technologies', in C. Acland (ed.) *Residual Media*. Minneapolis: University of Minnesota Press, pp. 16–31. Available at: https://sterneworks.org/OutwiththeTrash.pdf.

Aragon, N. (2023) *Warranty Void Stickers: Are they legal outside the US?* iFixit. Available at: https://www.ifixit.com/News/74736/warranty-void-stickers-are-illegal-in-the-us-what-about-elsewhere (Accessed: 20 April 2025).

Emerson, L. (2021) *Six (Difficult and Inconvenient) Values to Reclaim the Future with Old Media* . Available at: https://loriemerson.net/2021/11/21/six-difficult-and-inconvenient-values-to-reclaim-the-future-with-old-media%ef%bf%bc/ (Accessed: 5 January 2025).

Mims, F.M. (1983) *Getting started in electronics*. 4th edn. Niles, Ill: Master Publishing.

Jang, E. *et al.* (2017) 'Unplanned Obsolescence: Hardware and Software After Collapse', in *Proceedings of the 2017 Workshop on Computing Within Limits. LIMITS '17: Workshop on Computing Within Limits*, Santa Barbara California USA: ACM, pp. 93–101. Available at: https://doi.org/10.1145/3080556.3080566.

iFixit (no date) *Recycling is Destruction*. Available at: https://www.ifixit.com/Right-to-Repair/Recycling (Accessed: 22 April 2025).

Roura, M. *et al.* (2021) 'Circular digital devices: Lessons about the social and planetary boundaries', in *Computing within Limits. Seventh Workshop on Computing within Limits 2021*, LIMITS. Available at: https://doi.org/10.21428/bf6fb269.3881c46e.

Blasser, P. (2015) *Stores at the Mall*. Wesleyan University. Available at: https://doi.org/10.14418/wes01.2.84.

Richards, J. (2013) 'Beyond DIY in Electronic Music', *Organised Sound*, 18(3), pp. 274–281. Available at: https://doi.org/10.1017/S1355771813000241.

Collins, N. (2009) *Handmade electronic music: The art of hardware hacking*. Second edition. New York: Routledge.

Lu, J. and Lopes, P. (2024) 'Unmaking Electronic Waste', *ACM Transactions on Computer-Human Interaction*, 31(6), pp. 1–30. Available at: https://doi.org/10.1145/3674505.

Mansoux, A. *et al.* (2023) 'Permacomputing Aesthetics: Potential and Limits of Constraints in Computational Art, Design and Culture', in *Ninth Computing within Limits 2023. Ninth Computing within Limits 2023*, Virtual: LIMITS. Available at: https://doi.org/10.21428/bf6fb269.6690fc2e.