Construction Folder "JFET Theremin"

Content:

1. Introduction

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Leon Theremin (aka Lev Termen) ca. 1927 with Theremin (Source: Wikipedia)

Alexandra Stepanoff plays a Theremin für NBC Radio in 1930 (Source: Wikipedia)

From Wikipedia:

See also: Leon Theremin

The theremin was the product of Soviet government-sponsored research into proximity sensors. The instrument was invented in October 1919 by the Russian physicist Lev Sergeyevich Termen, known in the West as Leon Theremin.[3][4] After a lengthy tour of Europe, during which time he demonstrated his invention to packed houses, Theremin moved to the United States, where he patented his invention in 1928.[5] Subsequently, Theremin granted commercial production rights to RCA.

Although the RCA Thereminvox (released immediately following the Stock Market Crash of 1929) was not a commercial success, it fascinated audiences in America and abroad. Clara Rockmore, a well-known thereminist, toured to wide acclaim, performing a classical repertoire in concert halls around the United States, often sharing the bill with Paul Robeson.

During the 1930s, Lucie Bigelow Rosen was also taken with the theremin and together with her husband Walter Bigelow Rosen provided both financial and artistic support to the development and popularisation of the instrument.[6][7]

In 1938, Theremin left the United States, though the circumstances related to his departure are in dispute. Many accounts claim he was taken from his New York City apartment by NKVD agents (preceding the KGB),[8] taken back to the Soviet Union and made to work in a *sharashka* laboratory prison camp at Magadan, Siberia. He reappeared 30 years later. In his 2000 biography of the inventor, *Theremin: Ether Music and Espionage*, Albert Glinsky suggested he had fled to escape crushing personal debts, and was then caught up in Stalin's political purges. In any case, Theremin did not return to the United States until 1991.[9]

The components of a modern Moog theremin, in kit form

After a flurry of interest in America following the end of the Second World War, the theremin soon fell into disuse with serious musicians, mainly because newer electronic instruments were introduced that were easier to play. However, a niche interest in the theremin persisted, mostly among electronics enthusiasts and kit-building hobbyists. One of these electronics enthusiasts, Robert Moog, began building theremins in the 1950s, while he was a high-school student. Moog subsequently published a number of articles about building theremins, and sold theremin kits that were intended to be assembled by the customer. Moog credited what he learned from the experience as leading directly to his groundbreaking synthesizer, the Moog. (Around 1955, a colleague of Moog's, electronic music pioneer Raymond Scott, purchased one of Moog's theremin subassemblies to incorporate into a new invention, the Clavivox, which was intended to be an easy-to-use keyboard theremin.) [10]

Since the release of the film *Theremin: An Electronic Odyssey* in 1993, the instrument has enjoyed a resurgence in interest and has become more widely used by contemporary musicians. Even though many theremin sounds can be approximated on many modern synthesizers, some musicians continue to appreciate the expressiveness, novelty, and uniqueness of using an actual theremin. The film itself has received positive reviews.[11]

Both theremin instruments and kits are available. The Open Theremin, an open hardware and open software project, was developed by Swiss microengineer Urz Gaudenz, using the original heterodyne oscillator

architecture for a good playing experience,[12] combined with Arduino. Using a few extra components, a MIDI interface can be added to the Open Theremin, enabling a player to use their Theremin to control different instrument sounds.[13]

Performance technique

Important in theremin articulation is the use of the volume control antenna. Unlike touched instruments, where simply halting play or damping a resonator in the traditional sense silences the instrument, the thereminist must "play the rests, as well as the notes", as Clara Rockmore observed.[18]

If the pitch hand is moved between notes, without first lowering the volume hand, the result is a "swooping" sound akin to a swanee whistle or a glissando played on the violin. Small flutters of the pitch hand can be used to produce a vibrato effect. To produce distinct notes requires a pecking action with the volume hand to mute the volume while the pitch hand moves between positions.

Thereminists such as Carolina Eyck use a fixed arm position per octave, and use fixed positions of the fingers to create the notes within the octave, allowing very fast transitions between adjacent notes.[19]

Although volume technique is less developed than pitch technique, some thereminists have worked to extend it, especially Pamelia Kurstin with her "walking bass" technique[20] and Rupert Chappelle.

The critic Harold C. Schonberg described the sound of the theremin as "[a] cello lost in a dense fog, crying because it does not know how to get home."[21]

Uses


RCA AR-1264 Theremin in Musical Instrument Museum, Phoenix, Arizona

Concert music

The first orchestral composition written for theremin was Andrei Pashchenko's *Symphonic Mystery*, which premiered in 1924.[22] However, most of the sheet music was lost after its second performance.[23]

Other concert composers who have written for theremin include Bohuslav Martinů,[24] Percy Grainger,[24] Christian Wolff,[24] Joseph Schillinger,[24] Moritz Eggert,[25] Iraida Yusupova,[25] Jorge Antunes,[24] Vladimir Komarov,[24] Anis Fuleihan,[26][27] and Fazıl Say.[28] Another large-scale theremin concerto is Kalevi Aho's Concerto for Theremin and Chamber Orchestra "Eight Seasons" (2011), written for Carolina Eyck.

Edgard Varèse completed the composition "Equatorial" for two theremin cellos and percussion in 1934. His work was a stated influence throughout the career of Frank Zappa,[29] who also composed for theremin.[30]

Maverick composer Percy Grainger chose to use ensembles of four or six theremins (in preference to a string quartet) for his two earliest experimental *Free Music* compositions (1935–1937) because of the instrument's complete 'gliding' freedom of pitch.[31][32]

Musician Jean-Michel Jarre used the instrument in his concerts Oxygen In Moscow and Space of Freedom[33] in Gdańsk, providing also a short history of Léon Theremin's life.

The five-piece Spaghetti Western Orchestra use a Theremin as a replacement for Edda Dell'Orso's vocals in their interpretation of Ennio Morricone's "Once Upon a Time in the West".[34]

Other notable contemporary Theremin players include Pamelia Kurstin,[35] Peter Theremin, Natasha Theremin, Katica Illényi.[36] and Lydia Kavina,[37] Dutch classical musician Thorwald Jørgensen has been described as "one of the most important exponents of classical music on the theremin".[38]

In 2019 a group of 289 theremin players (Matryomin ensemble) (including daughter, granddaughter and great-grandson Lev Theremin – Natasha Theremin, Masha Theremin and Peter Theremin) in Kobu, Japan, achieved a Guinness world record as the largest theremin ensemble. The name *Matryomin* is a portmanteau of the words *matryoshka* and *theremin*.[*citation needed*] The theremin concerto "Dancefloor With Pulsing" by the French composer Regis Campo was written for Carolina Eyck and premiered with the Brussels Philharmonic in 2018.[39]

Popular music

Theremins and theremin-like sounds started to be incorporated into popular music from the end of the 1940s (with a series of Samuel Hoffman/Harry Revel collaborations)[40] and has continued, with various degrees of popularity, to the present.

Lothar and the Hand People were the first rock band known to perform live with a theremin in November 1965. In fact, Lothar was the name they gave to their Moog theremin.[41]

The Beach Boys' 1966 single "Good Vibrations"—though it does not technically contain a theremin—is the most frequently cited example of the instrument in pop music. The song actually features a similar-sounding instrument invented by Paul Tanner called an Electro-Theremin.[42] Upon release, the single prompted an unexpected revival in theremins and increased the awareness of analog synthesizers.[43] In response to requests by the band, Moog Music began producing their own brand of ribbon-controlled instruments which would mimic the sound of a theremin.[44]

Frank Zappa also included the theremin on the albums *Freak Out!* (1966) and *We're Only in It for the Money* (1967).[45]

Jimmy Page of Led Zeppelin used a variation of the theremin (pitch antenna only) during performances of "Whole Lotta Love" and "No Quarter" throughout the performance history of Led Zeppelin, an extended multi-instrumental solo featuring theremin and bowed guitar in 1977, as well as the soundtrack for *Death Wish II*, released in 1982.[46]

Brian Jones of the Rolling Stones also used the instrument on the group's 1967 albums *Between the Buttons* and *Their Satanic Majesties Request*.[47]

Tesla guitarist Frank Hannon used a theremin in the band's song "Edison's Medicine" from the 1991 album *Psychotic Supper*.[48] Hannon is also seen using the instrument in the song's music video at the 2:40 mark.[49]

The Lothars are a Boston-area band formed in early 1997 whose CDs have featured as many as four theremins played at once – a first for pop music.[50][51]

Although credited with a "Thereman" [*sic*] on the track "Mysterons" from the album *Dummy*, Portishead actually used a monophonic synthesizer to achieve theremin-like effects, as confirmed by Adrian Utley, who is credited as playing the instrument;[52] on the songs "Half Day Closing", "Humming", "The Rip", and "Machine Gun" he has actually used a custom made theremin.[53]

Page McConnell, keyboardist of the American rock band Phish, plays the theremin on rare occasions. His last notable performance was on 6 August 2017, the final evening of the band's 13-night residency at Madison Square Garden.[54]

When Simon and Garfunkel performed their song "The Boxer" during a concert at Madison Square Garden in December, 2003, they utilized a theremin. The original recording of the song had featured a steel guitar and a piccolo trumpet in unison in the solo interlude, but for this performance, thereminist Rob Schwimmer played the solo.[55]

Film music

Russian composer Dmitri Shostakovich was one of the first to incorporate parts for the theremin in orchestral pieces, including a use in his score for the film *Odna* (Russian: Одна, 1931, Leonid Trauberg and Grigori Kozintsev). While the theremin was not widely used in classical music performances, the instrument found great success in many motion pictures, notably, *Spellbound*, *The Red House*, *The Lost Weekend* (all three of which were written by Miklós Rózsa, the composer who pioneered the use of the instrument in Hollywood scores), *The Spiral Staircase*, *Rocketship X-M*, *The Day the Earth Stood Still*, *The Thing from Another World*, *Castle In the Air*, and *The Ten Commandments*. The theremin is played and identified as such in the Jerry Lewis movie *The Delicate Delinquent*. The theremin is prominent in the score for the 1956 short film *A Short Vision*,[56] which was aired on *The Ed Sullivan Show* the same year that it was used by the Hungarian composer Mátyás Seiber. More recent appearances in film scores include *Monster House*, *Ed Wood*, *The Machinist*[57] and *The Electrical Life of Louis Wain*[58] (2021), (last three featuring Lydia Kavina), as well as *First Man* (2018).

A theremin was not used for the soundtrack of *Forbidden Planet*, for which Bebe and Louis Barron built disposable oscillator circuits and a ring modulator to create the electronic tonalities used in the film.[59][60]

Los Angeles-based thereminist Charles Richard Lester is featured on the soundtrack of *Monster House*[61] and has performed the US premiere of Gavriil Popov's 1932 score for *Komsomol – Patron of Electrification* with the Los Angeles Philharmonic and Esa-Pekka Salonen in 2007.[62]

In Lenny Abrahamson's 2014 film, *Frank*, Clara, the character played by Maggie Gyllenhaal, plays the theremin in a band named Soronprfbs.[63]

Theatre and performing arts

Charlie Rosen, orchestrator of the Broadway musical *Be More Chill*, credits the show as being the first on Broadway to have a theremin in its band.[64]

Television

- In May 2007, the White Castle American hamburger restaurant chain introduced a television advertisement[65] centered around a live theremin performance by musician Jon Bernhardt of the band *The Lothars.* It is the only known example of a theremin performance being the focus of an advertisement.[66]

- Celia Sheen plays the theremin in the *Midsomer Murders* series.[67]
- In October 2008, comedian, musician, and theremin enthusiast Bill Bailey played a theremin during his performance of Bill Bailey's Remarkable Guide to the Orchestra at the Royal Albert Hall, which has subsequently been televised. He had previously also written an article,[68] presented a radio show[69] and incorporated the theremin in some of his televised comedy tours.
- Charlie Draper plays the theremin in the soundtrack (written by Natalie Holt) for TV series *Loki* on Disney+.[70][71]

Video games

- A theremin tune serves as the theme for the Edison family in the NES port of *Maniac Mansion*[72]
- Lydia Kavina's solo theremin is featured on the soundtrack for the 2006 MMORPG computer game *Soul of the Ultimate Nation*, composed by Howard Shore.[73]

The First Theremin Concert for Extraterrestrials

Further information: Teen Age Message


Theremin performer Anton Kershenko and his young pupil at Eupatoria Deep Space Communication Center

The First Theremin Concert for Extraterrestrials was the world's first musical METI broadcast dispatched from the Evpatoria deep-space communications complex in Crimea,[74] and was sent seven years before NASA's Across the Universe message. Seven different melodies were transmitted from audio-cassette recordings of the theremin being played by Lydia Kavina, Yana Aksenova, and Anton Kerchenko, all from the Moscow Theremin Center. These seven melodies were:

1. "Egress alone I to the Ride" by E. Shashina
2. The finale of the *9th Symphony* by Beethoven
3. *The Four Seasons: Spring*, "Allegro" by Vivaldi
4. "The Swan" by Saint-Saens
5. "Vocalise" by Rachmaninoff
6. "Summertime" by Gershwin
7. Russian folk song "Kalinka-Malinka"

They were played in succession six times over the span of three days from August–September 2001 during the transmission of Teen Age Message, an interstellar radio message.[74]

Similar instruments

- The Ondes Martenot, 1928, also uses the principle of heterodyning oscillators, but has a keyboard as well as a slide controller and is touched while playing.[75]
- The Electronde, invented in 1929 by Martin Taubman, has an antenna for pitch control, a handheld switch for articulation and a foot pedal for volume control.[76]
- The Syntheremin is an extension of the theremin.

- The Croix Sonore (Sonorous Cross), is based on the theremin. It was developed by Russian composer Nicolas Obouchov in France, after he saw Lev Theremin demonstrate the theremin in 1924.
- The terpsitone, also invented by Theremin, consisted of a platform fitted with space-controlling antennas, through and around which a dancer would control the musical performance. By most accounts, the instrument was nearly impossible to control. Of the three instruments built, only the last one, made in 1978 for Lydia Kavina, survives today.
- The Z.Vex Effects Fuzz Probe, Wah Probe and Tremolo Probe, using a theremin to control said effects. The Fuzz Probe can be used as a theremin, as it can through feedback oscillation create tones of any pitch.
- The MC-505 by Roland by being able to use the integrated D-Beam-sensor like a Theremin.
- The Audiocubes by Percussa are light emitting smart blocks that have four sensors on each side (optical theremin). The sensors measure the distance to your hands to control an effect or sound.[77]
- A three radio theremin (Super Theremin, スーパーテレミン) invented by Tomoya Yamamoto (山本智矢), composed of three independent radio sets. Radio set #1 is to listen and to record the signal at around 1600 kHz. Radio set #2 is tuned at 1145 kHz so that its local oscillator of around 1600 kHz is to be received by radio set #1. Radio set #3 is also tuned at 1145 kHz so that its local oscillator may produce the beat with radio set #2. Operator's hand movement around bar antenna of radio set #3 may affect the local oscillator to produce tonal change.[78][*non-primary source needed*]
- The Matryomin by Masami Takeuchi, is a single-antenna Theremin-type device mounted inside a matryoshka doll.[79]
- The *Chimaera* is a digital offspring of theremin and touchless ribbon controller and based on distance sensing of permanent magnets. An array of linear Hall-effect sensors, each acting as an individual theremin in a changing magnetic field, responds to multiple moving neodymium magnets worn on fingers and forms a continuous interaction space in two dimensions.[80]

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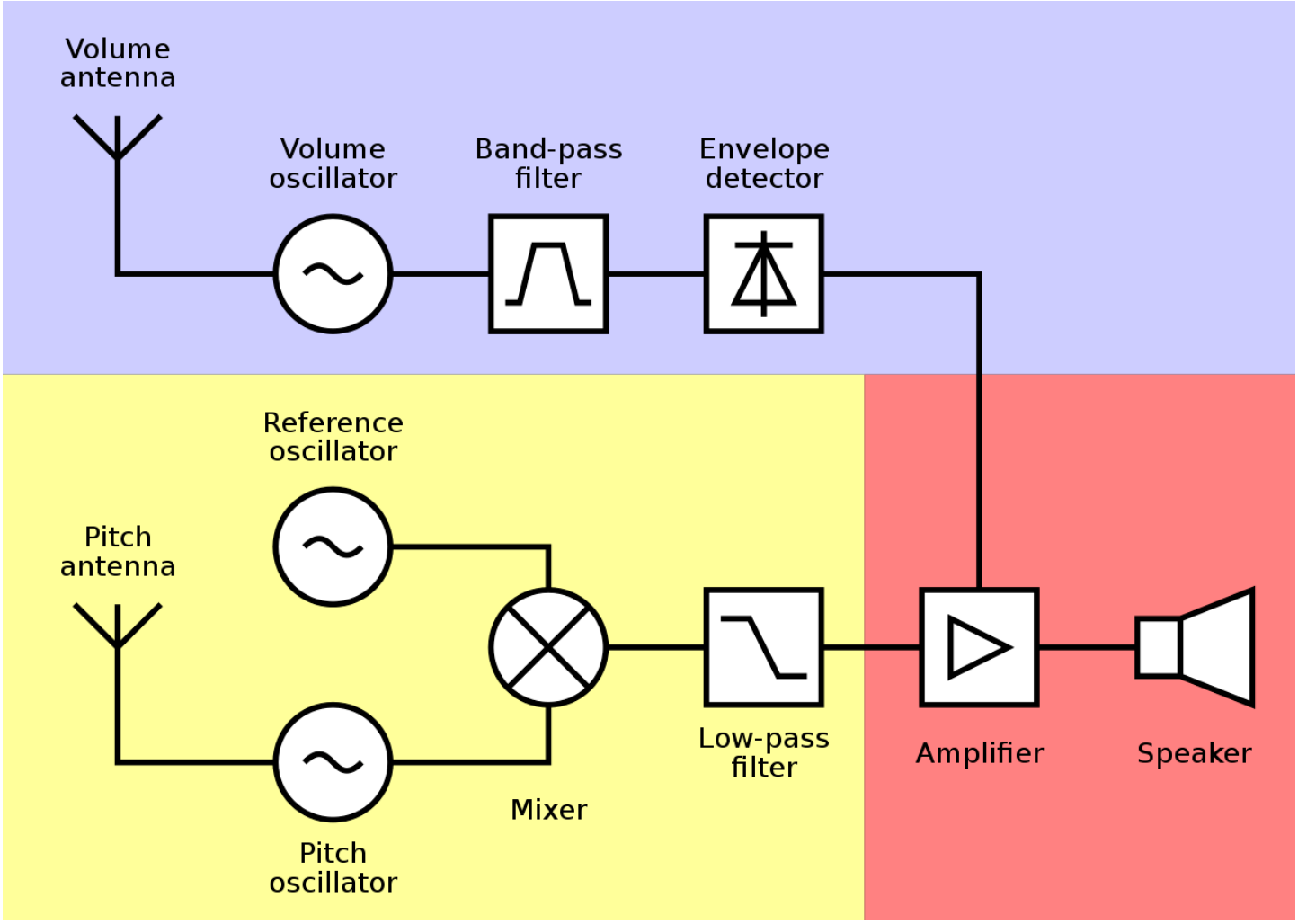
2. Operating principle, circuit diagram and circuit description



Block diagram of a theremin. Volume control in blue, pitch control in yellow and audio output in red.

The theremin is distinguished among musical instruments in that it is played without physical contact. The thereminist stands in front of the instrument and moves their hands in the proximity of two metal antennas.

While commonly called antennas, they are not used as **radio antennae** for receiving or broadcasting radio waves, but rather act as plates of **capacitors**. The distance from one antenna determines frequency (pitch), and the distance from the other controls amplitude (volume). Higher notes are played by moving the hand closer to the pitch antenna. Louder notes are played by moving the hand away from the volume antenna.

Most frequently, the right hand controls the pitch and the left controls the volume, although some performers reverse this arrangement. Some low-cost theremins use a conventional, knob operated volume control and have only the pitch antenna.

The theremin uses the heterodyne principle to generate an audio signal. The instrument's pitch circuitry includes two radio frequency oscillators set below 500 kHz to minimize radio interference. One oscillator operates at a fixed frequency. The frequency of the other oscillator is almost identical, and is controlled by the performer's distance from the pitch control antenna.

The performer's hand has significant body capacitance, and thus can be treated as the grounded plate of a variable capacitor in an L-C (inductance-capacitance) circuit, which is part of the oscillator and determines its

frequency. In the simplest designs, the antenna is directly coupled to the tuned circuit of the oscillator and the 'pitch field', that is the change of note with distance, is highly nonlinear, as the capacitance change with distance is far greater near the antenna. In such systems, when the antenna is removed, the oscillator moves up in frequency.

To partly linearise the pitch field, the antenna may be wired in series with an inductor to form a series tuned circuit, resonating with the parallel combination of the antenna's intrinsic capacitance and the capacitance of the player's hand in proximity to the antenna. This series tuned circuit is then connected in parallel with the parallel tuned circuit of the variable pitch oscillator. With the antenna circuit disconnected, the oscillator is tuned to a frequency slightly higher than the stand alone resonant frequency of the antenna circuit. At that frequency, the antenna and its linearisation coil present an inductive impedance; and when connected, behaves as an inductor in parallel with the oscillator. Thus, connecting the antenna and linearising coil raises the oscillation frequency. Close to the resonant frequency of the antenna circuit, the effective inductance is small, and the effect on the oscillator is greatest; farther from it, the effective inductance is larger, and fractional change on the oscillator is reduced.

When the hand is distant from the antenna, the resonant frequency of the antenna series circuit is at its highest; i.e., it is closest to the free running frequency of the oscillator, and small changes in antenna capacitance have greatest effect. Under this condition, the effective inductance in the tank circuit is at its minimum and the oscillation frequency is at its maximum. The steepening rate of change of shunt impedance with hand position compensates for the reduced influence of the hand being further away. With careful tuning, a near linear region of pitch field can be created over the central 2 or 3 octaves of operation. Using optimized pitch field linearisation, circuits can be made where a change in capacitance between the performer and the instrument in the order of 0.01 picofarads produces a full octave of frequency shift.[14]

The mixer produces the audio-range difference between the frequencies of the two oscillators at each moment, which is the tone that is then wave shaped and amplified and sent to a loudspeaker.

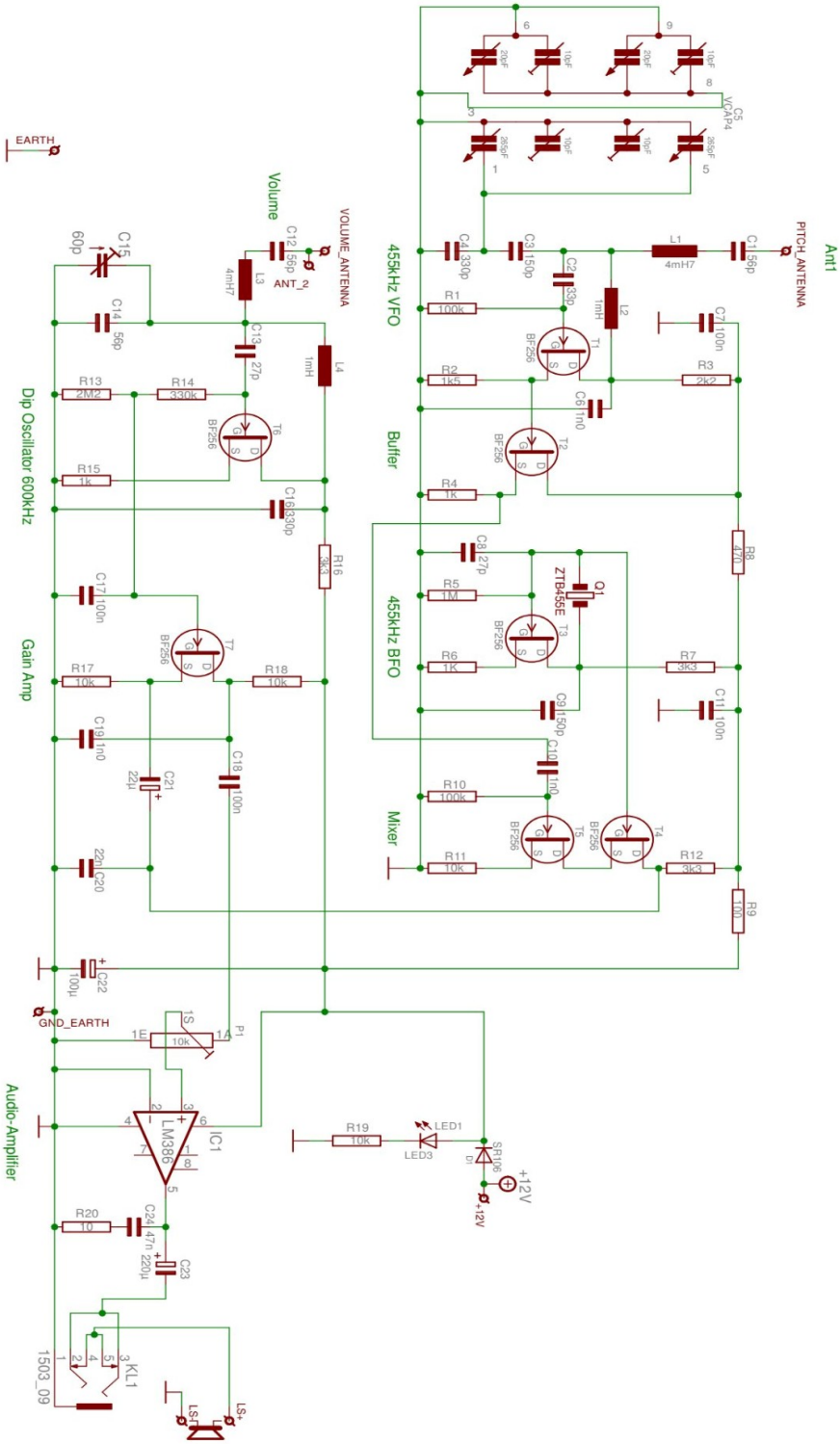
To control volume, the performer's other hand acts as the grounded plate of another variable capacitor. As in the tone circuit, the distance between the performer's hand and the volume control antenna determines the capacitance and hence natural resonant frequency of an LC circuit inductively coupled to another fixed LC oscillator circuit operating at a slightly higher resonant frequency. When a hand approaches the antenna, the natural frequency of that circuit is lowered by the extra capacitance, which detunes the oscillator and lowers its resonant plate current.

In the earliest theremins, the radio frequency plate current of the oscillator is picked up by another winding and used to power the filament of another diode-connected triode, which thus acts as a variable conductance element changing the output amplitude.[15] The harmonic timbre of the output, not being a pure tone, was an important feature of the theremin.[16] Theremin's original design included audio frequency series/parallel LC formant filters as well as a

3-winding variable-saturation transformer to control or induce harmonics in the audio output.[5]

Modern circuit designs often simplify this circuit and avoid the complexity of two heterodyne oscillators by having a single pitch oscillator, akin to the original theremin's volume circuit. This approach is usually less stable and cannot generate the low frequencies that a heterodyne oscillator can. Better designs (e.g., Moog, Theremax) may use two pairs of heterodyne oscillators, for both pitch and volume.[17]

Circuit diagram



3. Parts List

Number	Numbering	Type	Value	Mark	Specifications
1x	R20	Resistor	10 Ohms	Brown-Black-Black	Carbon; +/- 5%
1x	R9	Resistor	100 Ohms	Brown-Black-Brown	Carbon; +/- 5%
1x	R8	Resistor	470 Ohms	Yellow-Violett-Brown	Carbon; +/- 5%
3x	R4, R6, R15	Resistor	1.0 kOhms	Brown-Black-Red	Carbon; +/- 5%
1x	R2	Resistor	1.5 kOhmss	Brown-Green-Red	Carbon; +/- 5%
1x	R3	Resistor	2.2 kOhms	Red-Red-Red	Carbon; +/- 5%
3x	R7, R12 ,R16	Resistor	3.3 kOhms	Orange-Orange-Red	Carbon; +/- 5%
4x	R11, R17, R18, R19	Resistor	10 kOhms	Brown-Black-Orange	Carbon; +/- 5%
2x	R1, R10	Resistor	100 kOhms	Brown-Black-Yellow	Carbon; +/- 5%
1x	R14	Resistor	330 kOhms	Orange-Orange-Yellow	Carbon; +/- 5%
1x	R5	Resistor	1 Mohm	Brown-Black-Green	Carbon; +/- 5%
1x	R13	Resistor	2.2 Mohm	Red-Red-Green	Carbon; +/- 5%
2x	C8, C13	Capacitor	27 pF	**27** (or 27p)	Ceramic
1x	C2	Capacitor	33 pF	**33** (or 33p)	Ceramic
3x	C1, C12, C14	Capacitor	56 pF	**56** (or 56p)	Ceramic
2x	C3, C9	Capacitor	150 pF	**151** (or 150p)	Ceramic
2x	C4, C16	Capacitor	330 pF	**331** (or 330p)	Ceramic
3x	C6, C10, C19	Capacitor	1.0 nF	**102** (or 1n0)	Ceramic
1x	C20	Capacitor	22 nF	**223** (or 22n)	Ceramic
1x	C24	Capacitor	47 nF	**473** (or 47n)	Ceramic
4x	C7, C11, C17, C18	Capacitor	100 nF	**104** (or 100n)	Ceramic
1x	C5 (+Achse)	Variable Capacitor	250 pF		2x125 p
1x	C15	Capacitance Trimmer	20…80 pF	-	
1x	C21	Electrolytic cap.	22 µF		25...50V
1x	C22	Electrolytic cap.	100 µF		25...50V
1x	C23	Electrolytic cap.	220 µF		25...50V
2x	L2, L4	Inductor	1.0 mH	Brown-Black-Red	
2x	L1, L3	Inductor	4.7 mH	Yellow-Violett-Red	
7x	T1, T2, T3, T4, T5, T6, T7	Transistor	BF256B	BF256B	N-Channel JFET
1x	D1	Diode	SR106		60V/1A
1x	LED	LED	Blau	3mm, transparent	round
1x	Q1	Ceramic-Resonator	455 kHz		
1x	IC1	Audio-Amplifier	LM386		
1x	P1	Potentiometer	10 kOhm	logarithmic or linear	6mm shaft
2x	Knob		6 mm		for 6mm shaft
1x	Ant1	Telescopic rod	ca. 70 cm		
1x	Ant2	Copper tubing		4 mm x 0.5mm	½ Meter
3x	Bu1, Bu2, Bu3	Banana jacks		2x black; 1x yellow or green	
1x	St1	Banana plugs	yellow/grn.		
1x	Battery holder	8xAA (Mignon)			
1x	Toggle switch	SPDT	1P1T		For 6mm hole
1x	Twin strand	2x0,5mm^2		red+black	0,3m
1x	Earth-cable 2m	with „Schuko“-plug			
1x	Loudspeaker	LS1	ca. 57 mm	0.5W / 32 Ohms	
1x	3,5mm audio-jack	Bu4	3,5 mm		With switch contact
1x	PCB	FR4, douple-sided	160x50 mm		

4. Construction, testing and operation

4.1. Required tools

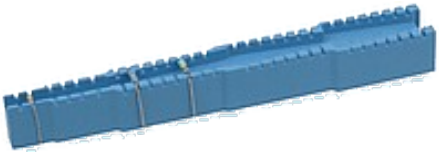
see also: http://www.ak-modul-bus.de/stat/laborzubehoer.html

- Electronics soldering iron
- Electronics solder (0,5mm oder 0,7mm recmendd.)
- Electronics side-cutter (flush-cutter)
- Wire stripper
- Screwdrivers slotted/Phillips
- Flat nose pliers
- Glues for speaker (and acrylic)

4.2. Helpful tools and aids

see also: http://www.ak-modul-bus.de/stat/laborzubehoer.html

- Bending gauge for resistors and inductors



- Component tester (for identifying parts)

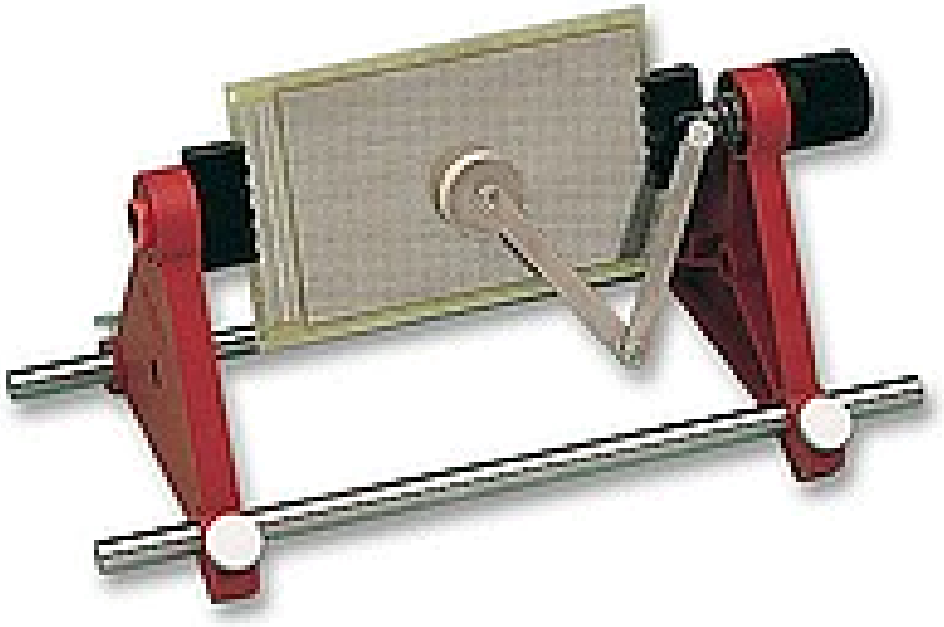
- Silicone solder mat

- Solder wick and flux

- "Spiral Spring" for volume antenna made of copper tubing

- Self-retaining cross tweezers for holding and placing components

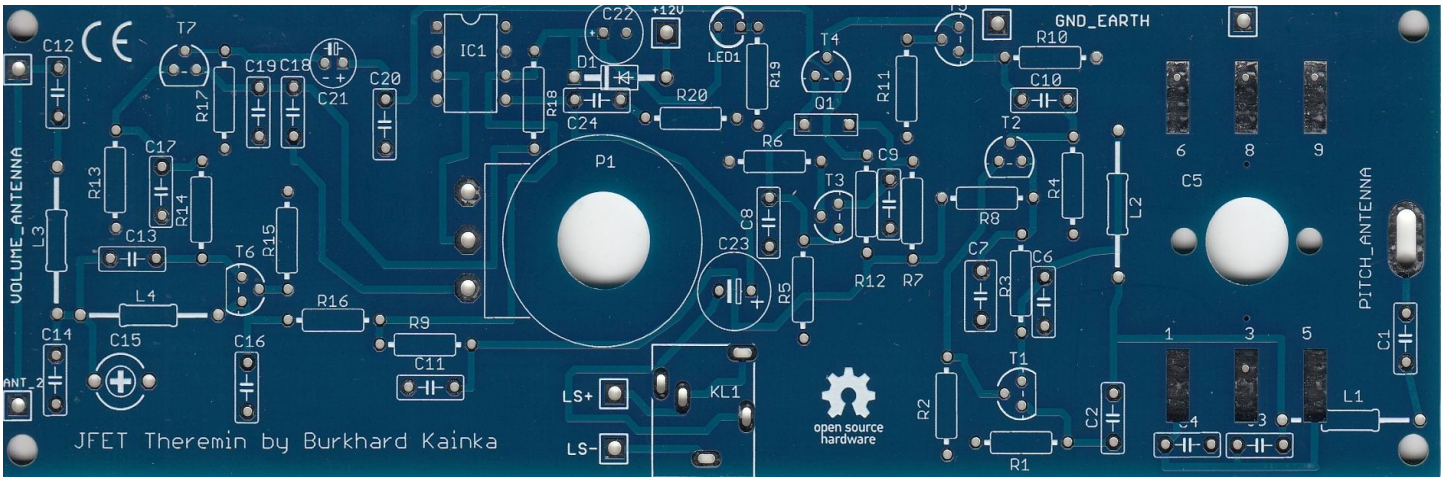
- PCB holder for placing, fixing and soldering components



- Ceramic screwdriver or insulated screwdriver to adjust the capacitance trimmer

4.3. Construction

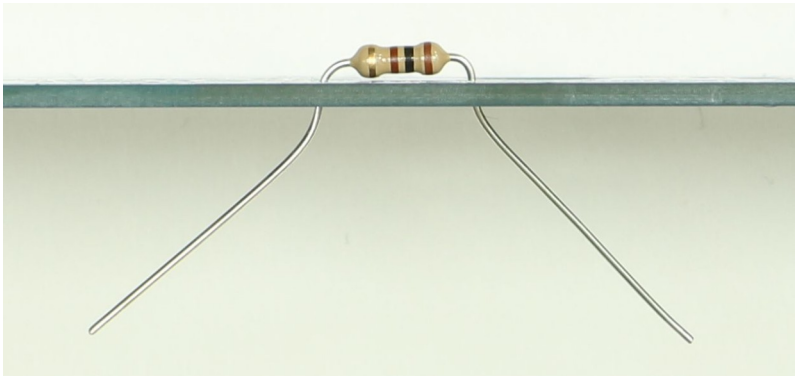
First identify all components in the list and check for completeness. We will solder the parts in groups with the same overall height.

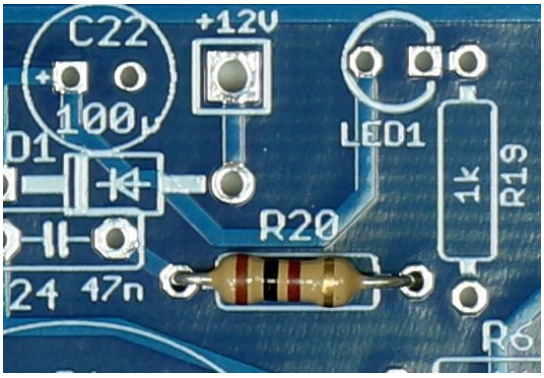


We start by soldering in the resistors.
It makes sense to bend the resistors to a wire spacing of 10mm (0,4“) before soldering using a bending gauge, a piece of 10mm wide squared timber or similar.

Then you put the resistor through the holes and bend the two wire ends apart a little on the back so that the resistor doesn't fall out or protrude from the board when you turn the board over. The resistors should lay flat on the board.

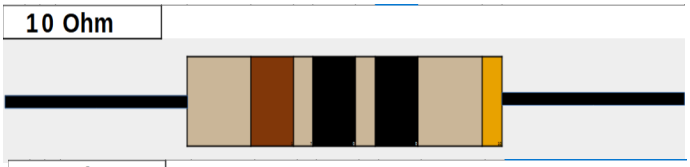
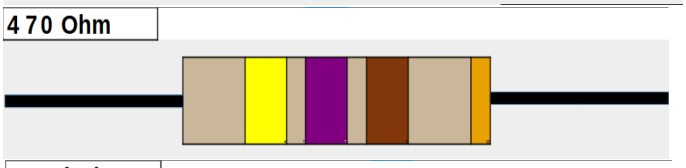
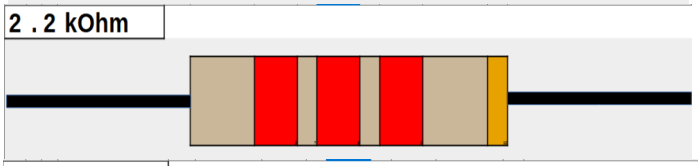
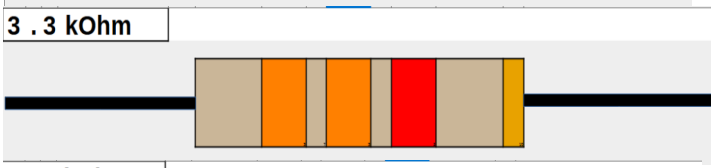
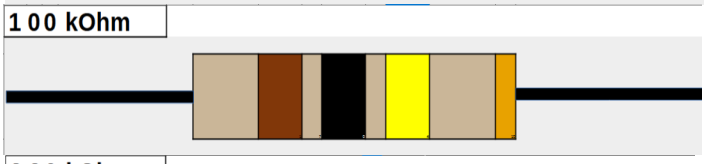
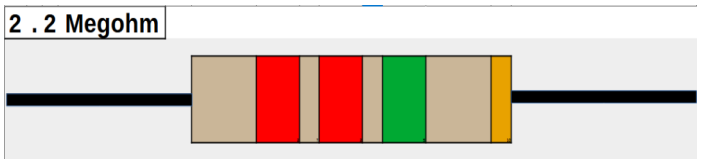
After soldering, cut off the protruding legs with side cutters.





4.3.1. Resistors

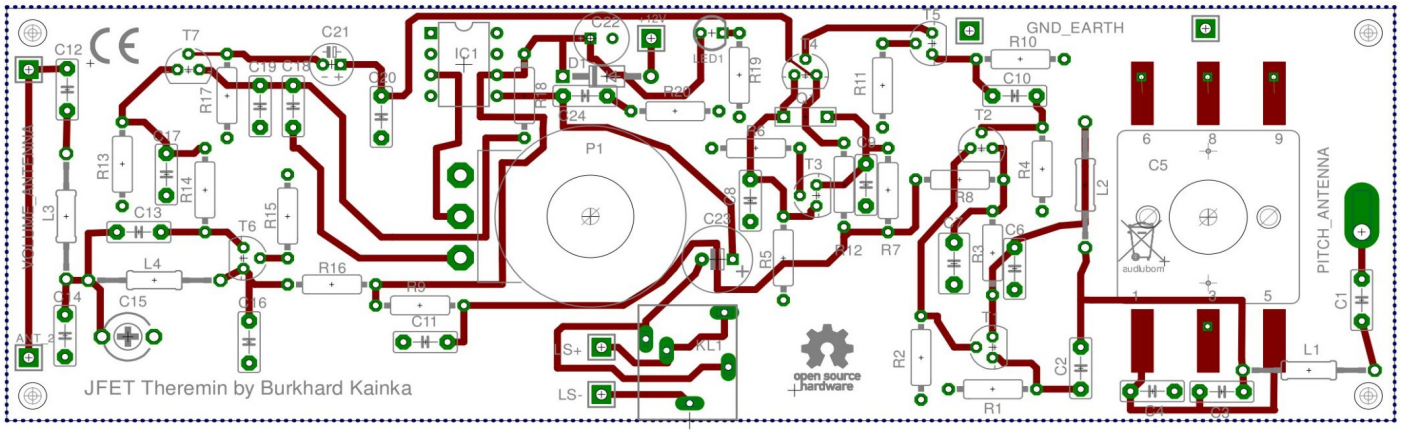
ATTENTION: There are 4 inductors, which also have colored rings and look like resistors at first glance. But they are much thicker than the resistors.

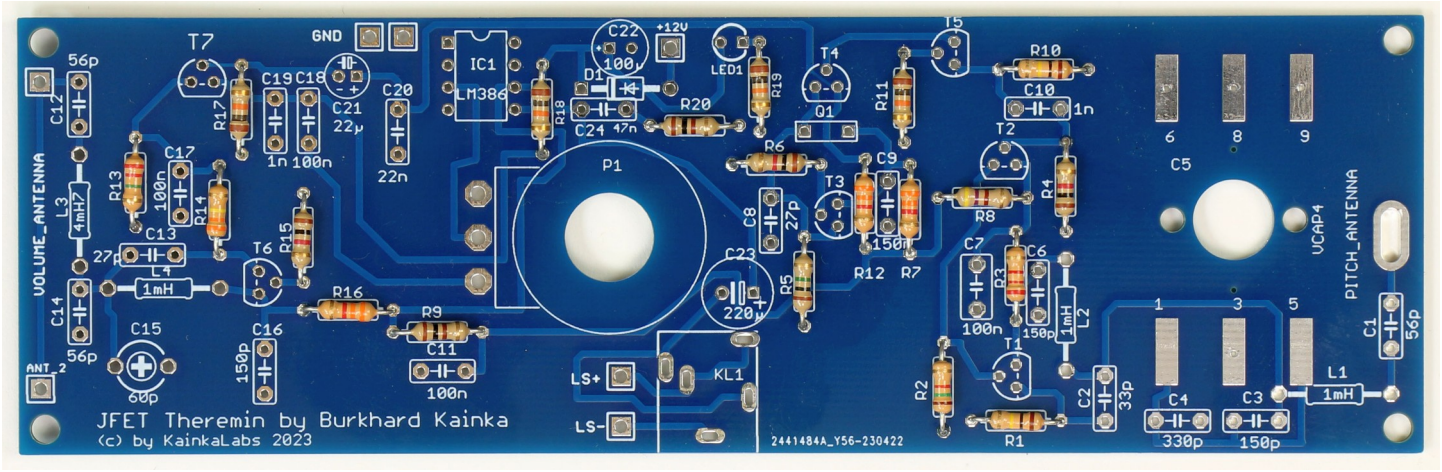
Numbering	Value	Coloring	
R20	10 Ohms	Brown-Black-Black	
R9	100 Ohms	Brown-Black-Brown	
R8	470 Ohms	Yellow-Violett-Brown	
R4, R6, R15	1.0 kOhms	Brown-Black-Red	
R2	1.5 kOhms	Brown-Green-Red	
R3	2.2 kOhms	Red-Red-Red	
R7, R12 ,R16	3.3 kOhms	Orange-Orange-Red	
R11, R17, R18, R19	10 kOhms	Brown-Black-Orange	
R1, R10	100 kOhms	Brown-Black-Yellow	
R14	330 kOhms	Orange-Orange-Yellow	
R5	1 MegOhms	Brown-Black-Green	
R13	2.2 MegOhms	Red-Red-Green	

It is best to first indentify the resistors and sort them in ascending value according to the table on the previous page.
Sometimes it is difficult to identify individual colors of the rings (red looks like brown etc.). But then the correct value results from the exclusion principle.

It is best to solder in each resistor individually and cut off the excess wire ends directly.

On the 2 pictures below you can clearly see where the resistors are soldered in.
<u>ATTENTION</u>: R20 is soldered in with the wrong value <u>100 ohms</u> (brown-black-brown) on all pictures.
However, <u>10 ohms</u> (brown-black-black) are correct, as specified in the component list.

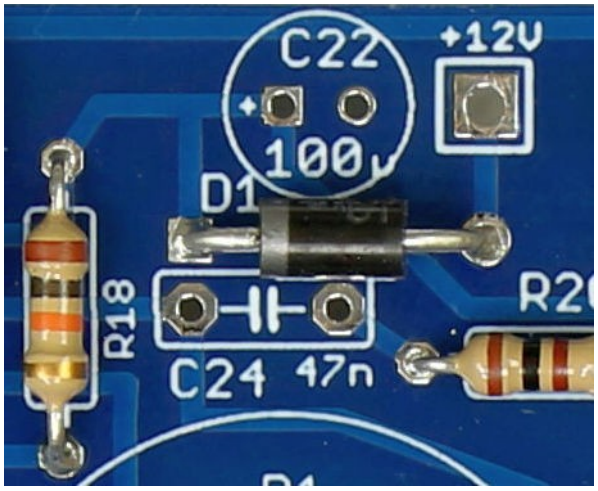




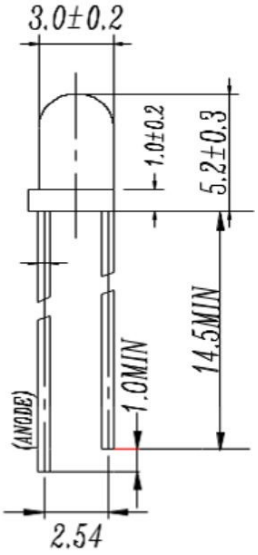
4.3.2. Diode D1 (SR106)

D1 SR106

The diode must be soldered in such a way that the silver line on the diode is positioned over the white line on the diode drawing on the circuit board.

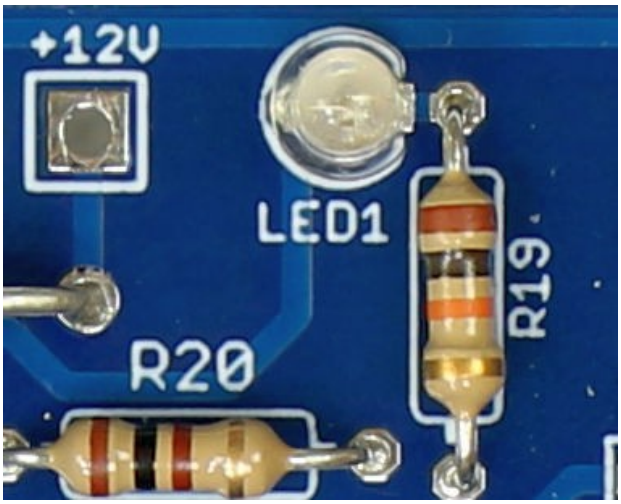


4.3.3. LED

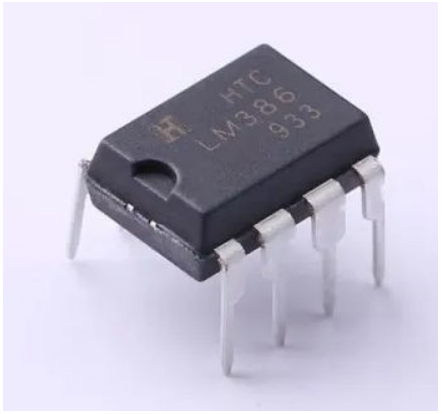


LED	blue	3mm round

The body of the LED is flattened on one side at the bottom.
This is also the side with the shorter leg.
This leg must also be soldered to the flat side of the LED drawing on the board.



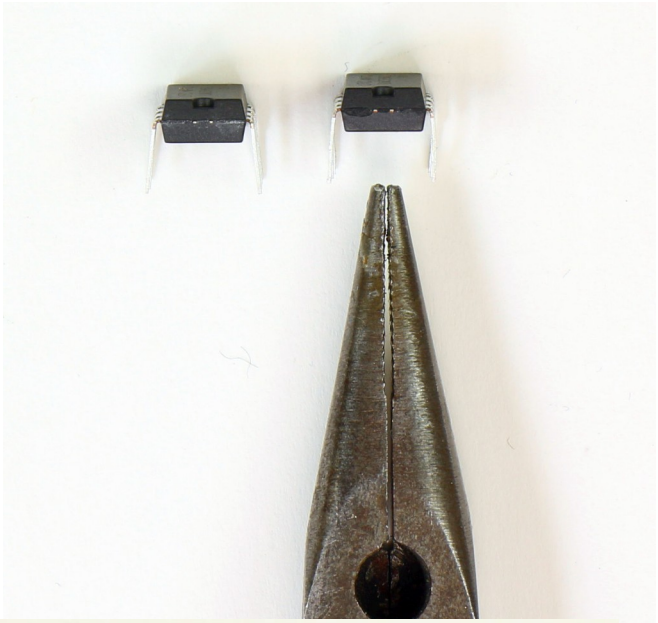
4.3.4. IC1 (LM386)

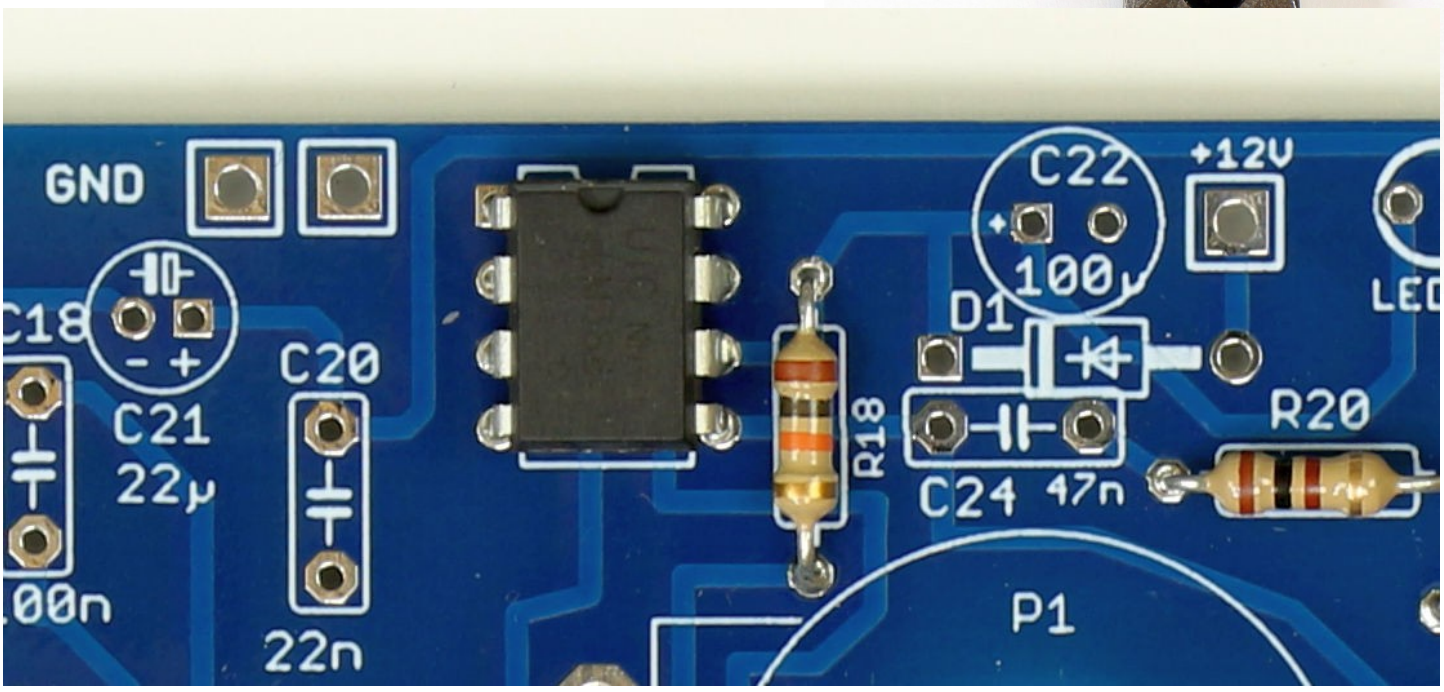


IC1 LM386 DIP8

Using flat-nosed pliers, bend the 2 rows of the IC's "legs" inwards so that they are perpendicular to the case.
Then the IC fits exactly into the rows of holes on the circuit board.
You can also adjust the legs by applying a little pressure when inserting them.

When inserting, make sure that the oval recess on the front side of the IC matches the recess on the schematic drawing of the IC on the circuit board.

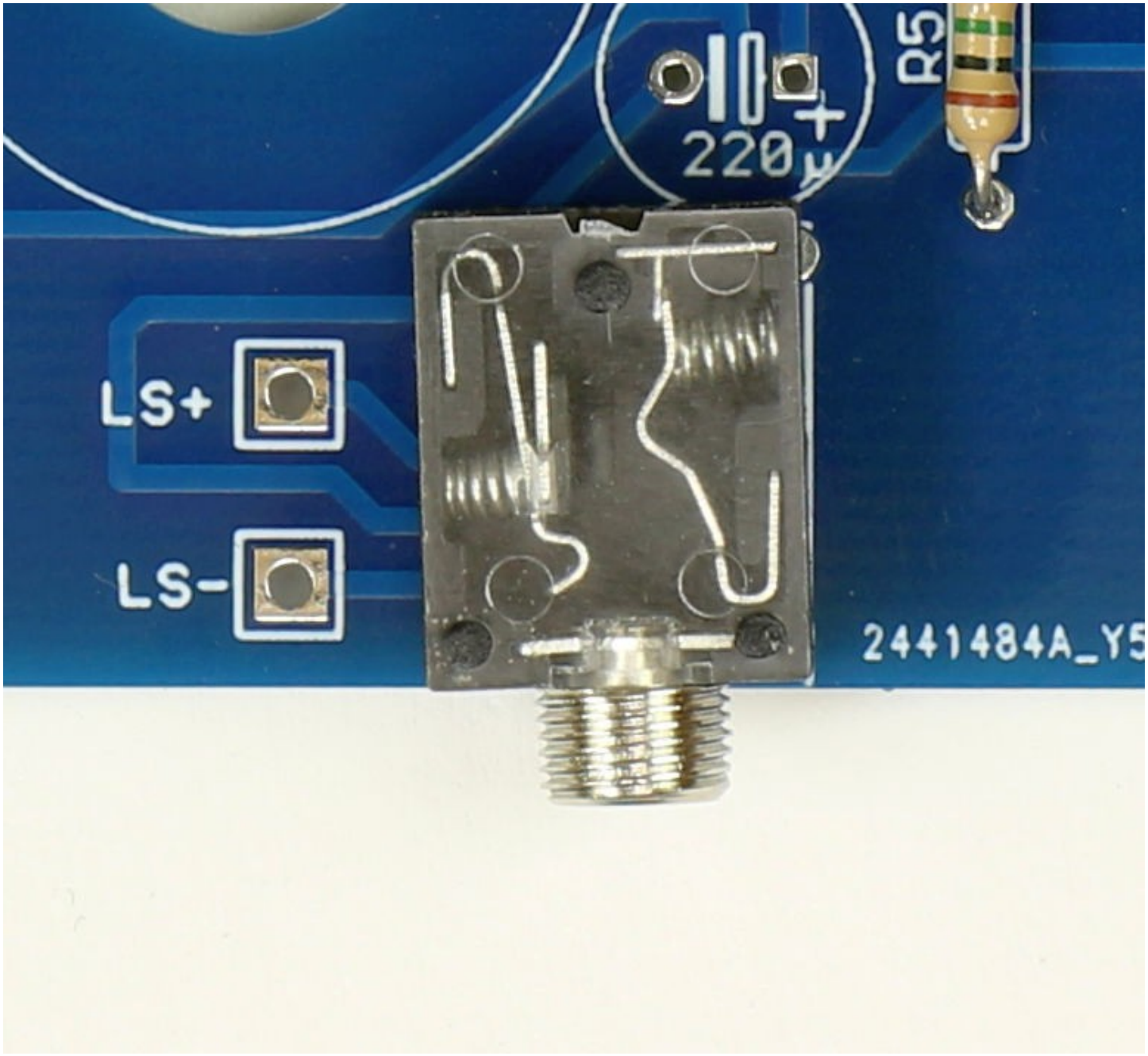




4.3.5. Audio jack (BU4)

Bu4	Audio jack	Stereo, with switch-contact

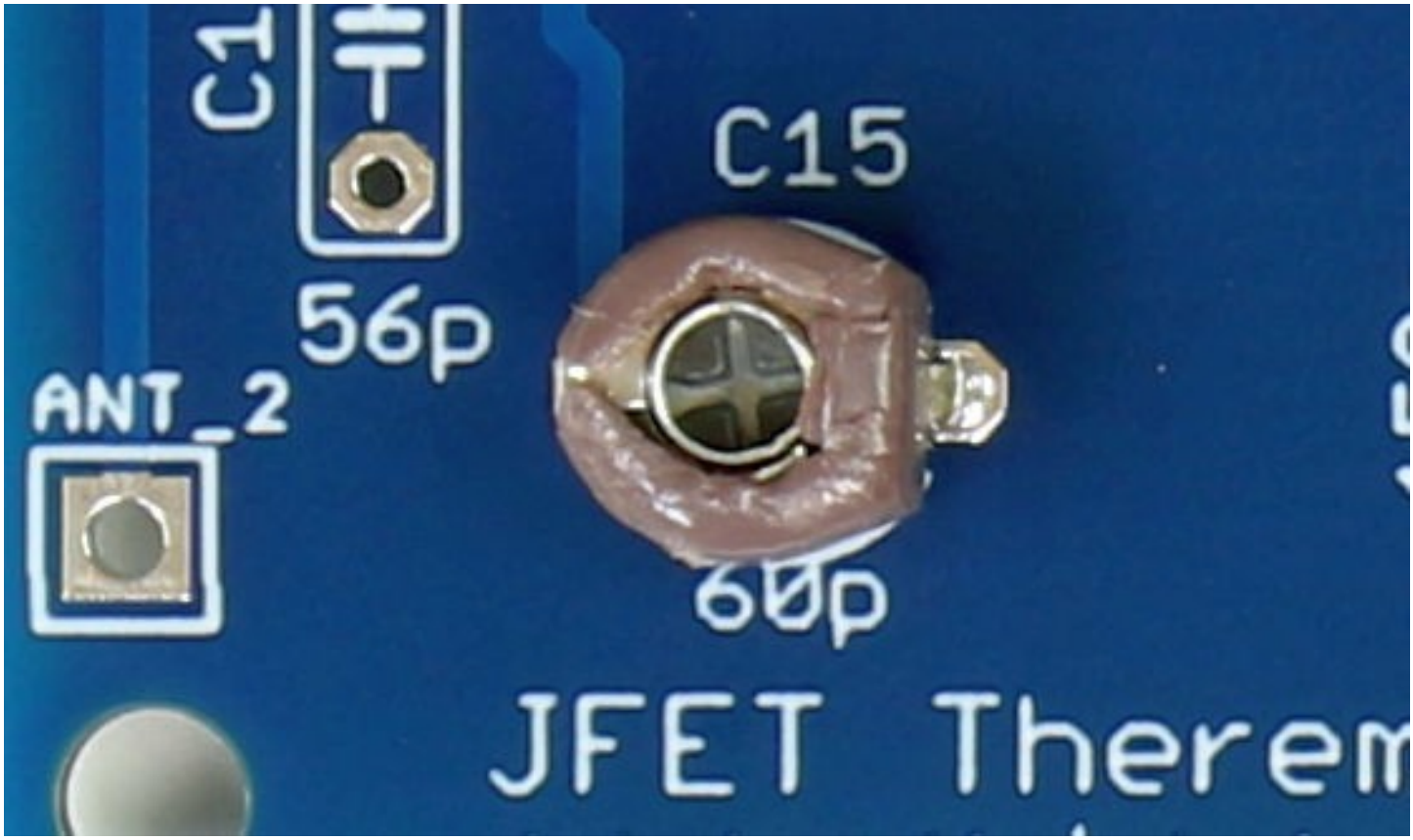
The legs on the underside must not be kinked sideways.
Before soldering, check that all legs are in the holes.



4.3.6. Capacitance trimmer (C15)

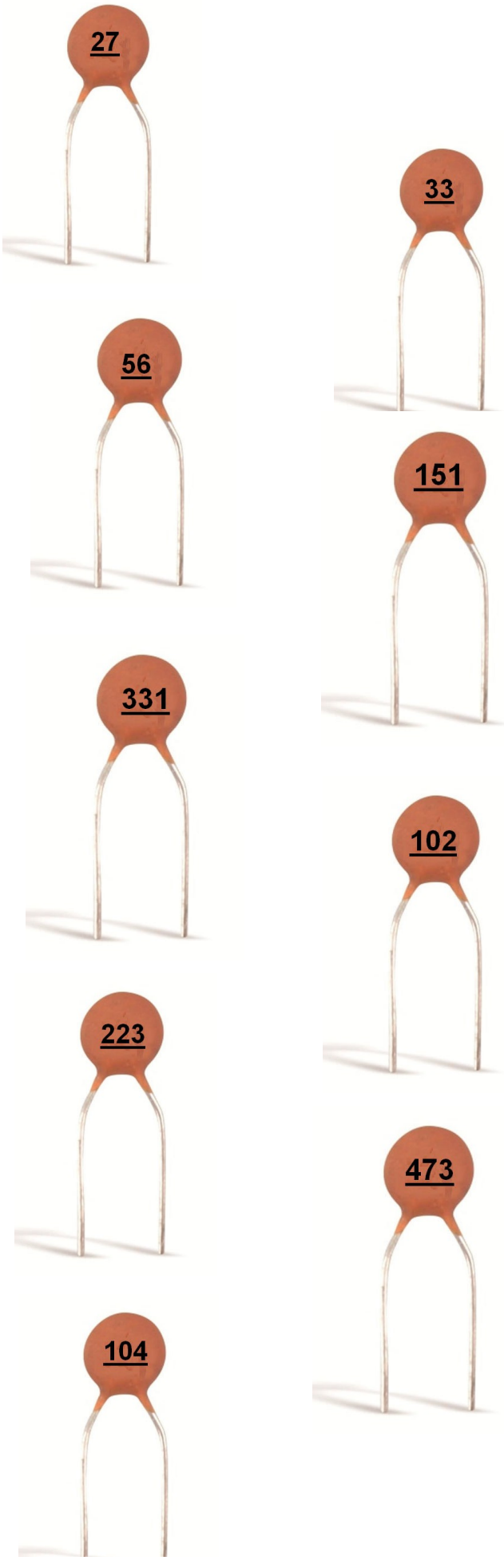
C15	Capacitance trimmer	15-60 pF

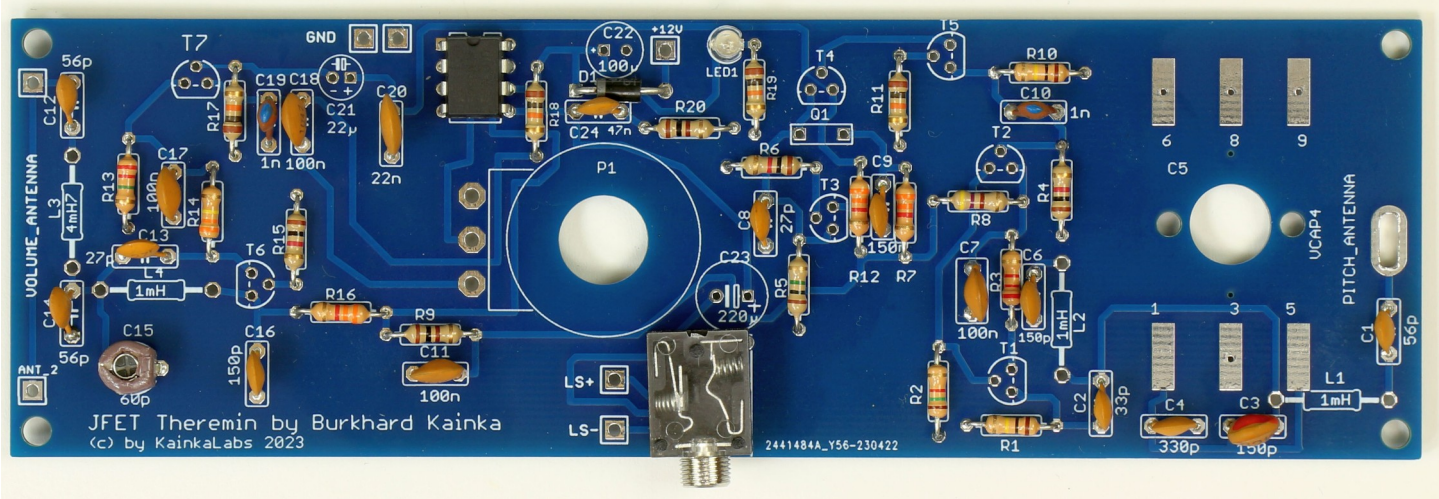
The design may differ from the illustration.
Soldering should be done quickly here so that the plastic does not melt.



4.3.7. Capacitors

Numbering	Value	Lettering
C8, C13	27 pF	**27** (or 27p)
C2	33 pF	**33** (or 33p)
C1, C12, (**C14 → don't solder at first!**)	56 pF	**56** (or 56p)
C3, C9	150 pF	**151** (or 150p)
C4, C16	330 pF	**331** (or 330p)
C6, C10, C19	1.0 nF	**102** (or 1n0)
C20	22 nF	**223** (or 22n)
C24	47 nF	**473** (or 47n)
C7, C11, C17, C18	100 nF	**104** (or 100n)

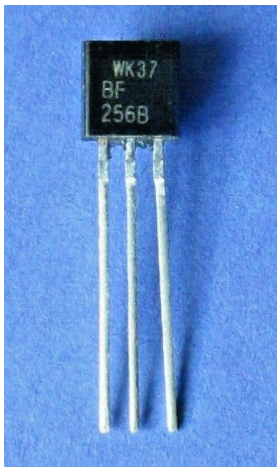


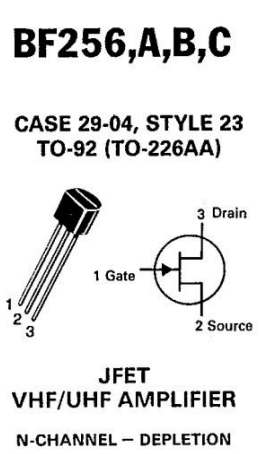


This is what it should look like after soldering in all the capacitors.

4.3.8. Transistors

T1-T7 BF256B TO92

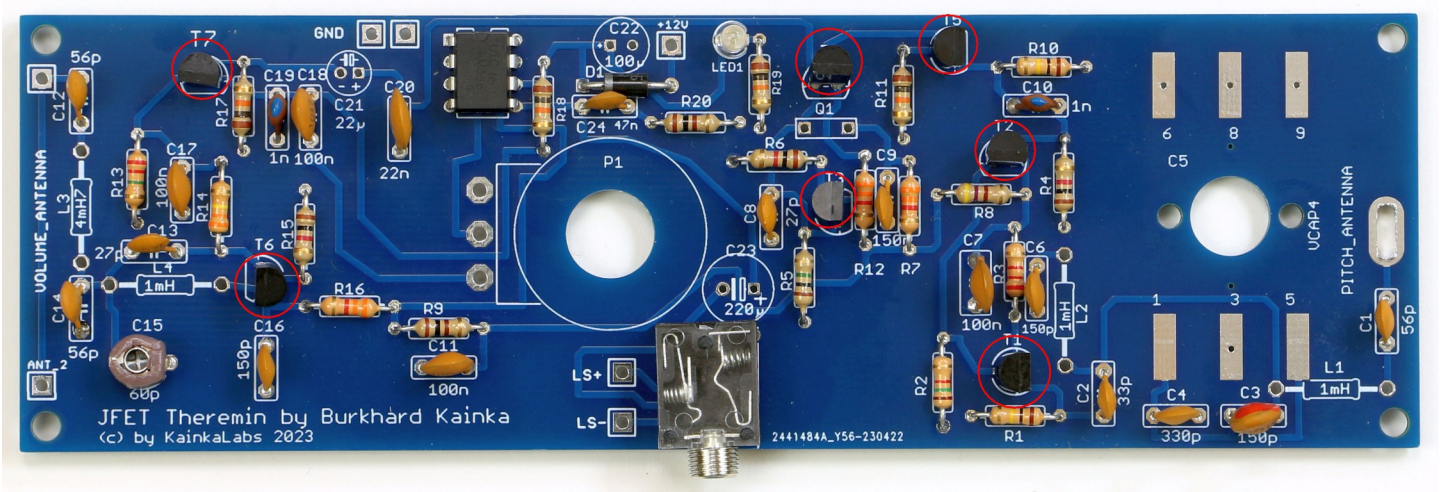




The crescent side of the transistor must match the crescent side of the transistor drawing on the circuit board.

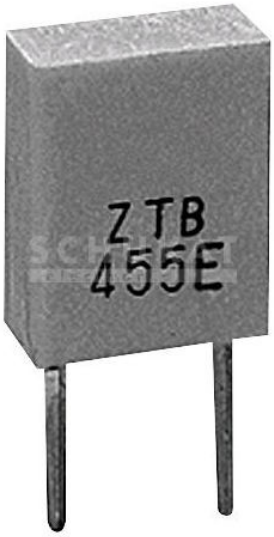
You have to bend the legs next to each other a bit when inserting them so that they fit into the triangular hole-patterns on the circuit board.

In the picture below, the positions of the 7 transistors are circled in red.

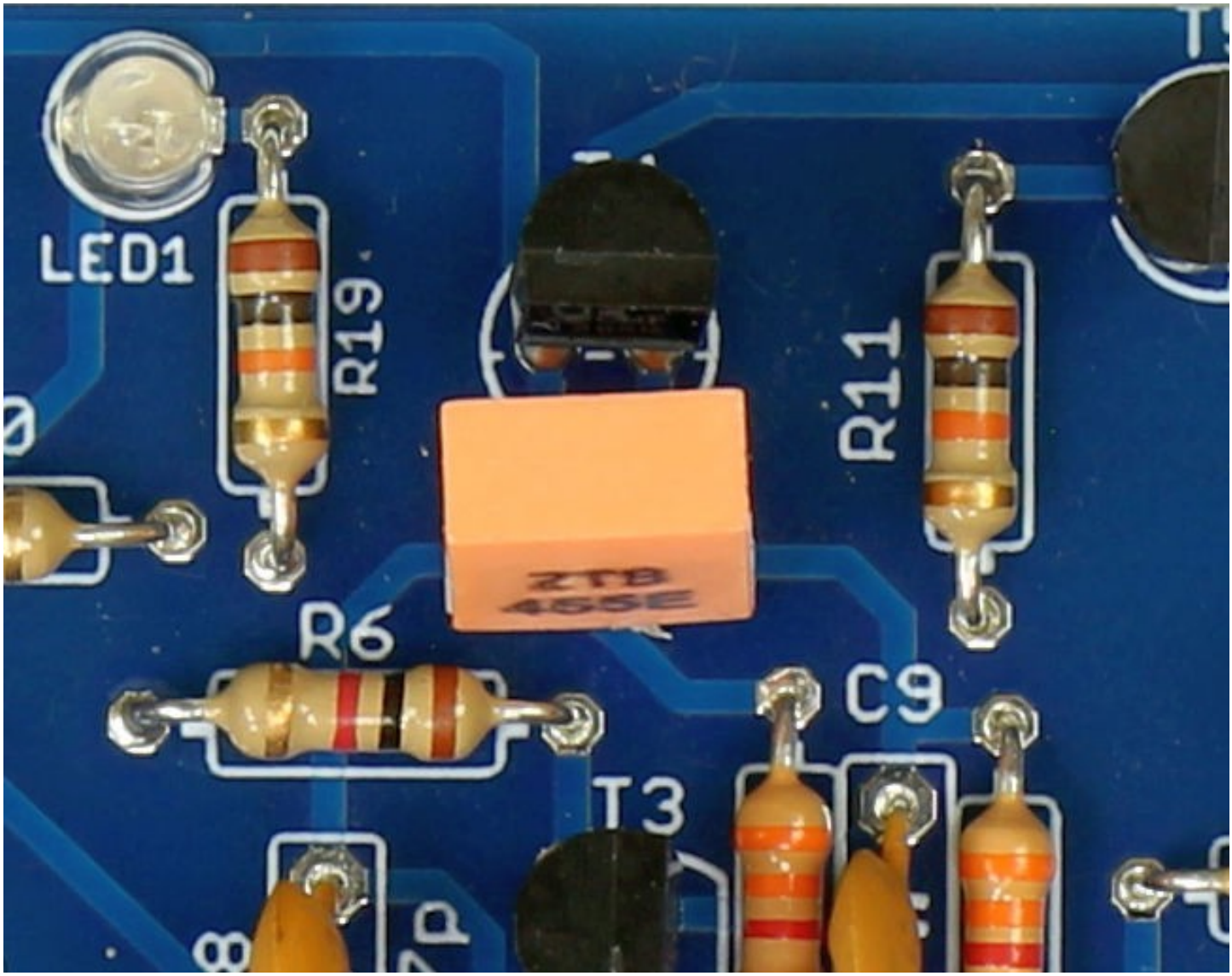


4.3.9. Ceramic-Resonator (Q1)

Q1	455 kHz or 470 kHz	ZTB 455E

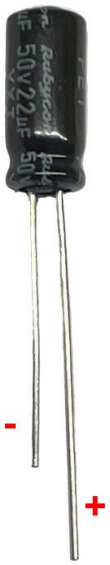


The ceramic resonator usually has the frequency in the imprint.



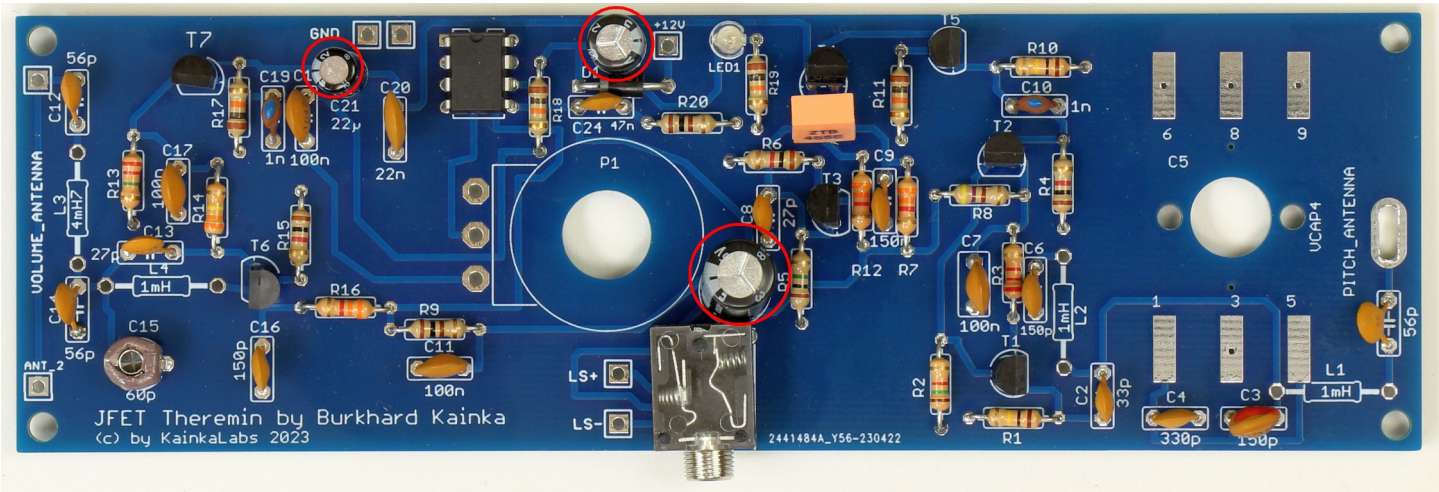
4.3.10. Electrolytic Capcitor

Numbering	Value
C21	22 µF
C22	100 µF
C23	220 µF



With electrolytic capacitors, the negative pole is marked by the shorter leg and usually by an imprint.

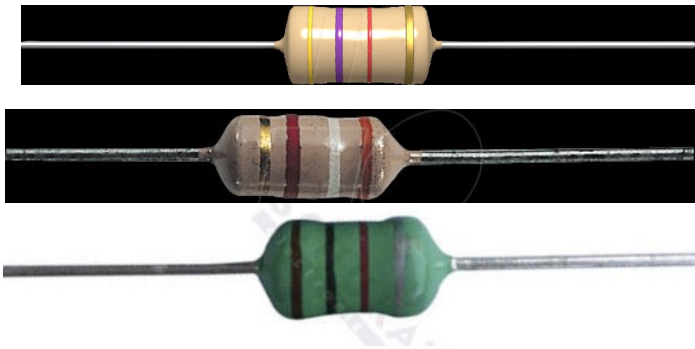
Electrolytic capacitors must be soldered correctly with the plus and minus poles according to the drawings on the circuit board.



4.3.11. Inductors

Numbering	Value	Coloring	
L1, L3	4.7 mH	Yellow-Violett-Red	
L2	1.0 mH	Brown-Black-Red **(kleine Version)**	
L4	1,0 mH	Brown-Black-Red **(grosse Version)**	

The inductors can have a different appearance depending on availability) .
Some possible types are shown on the right.
They can be identified either by the color code or (for the "spool" types) by an imprint.



The legs must then be bent individually so that they fit into the corresponding holes.

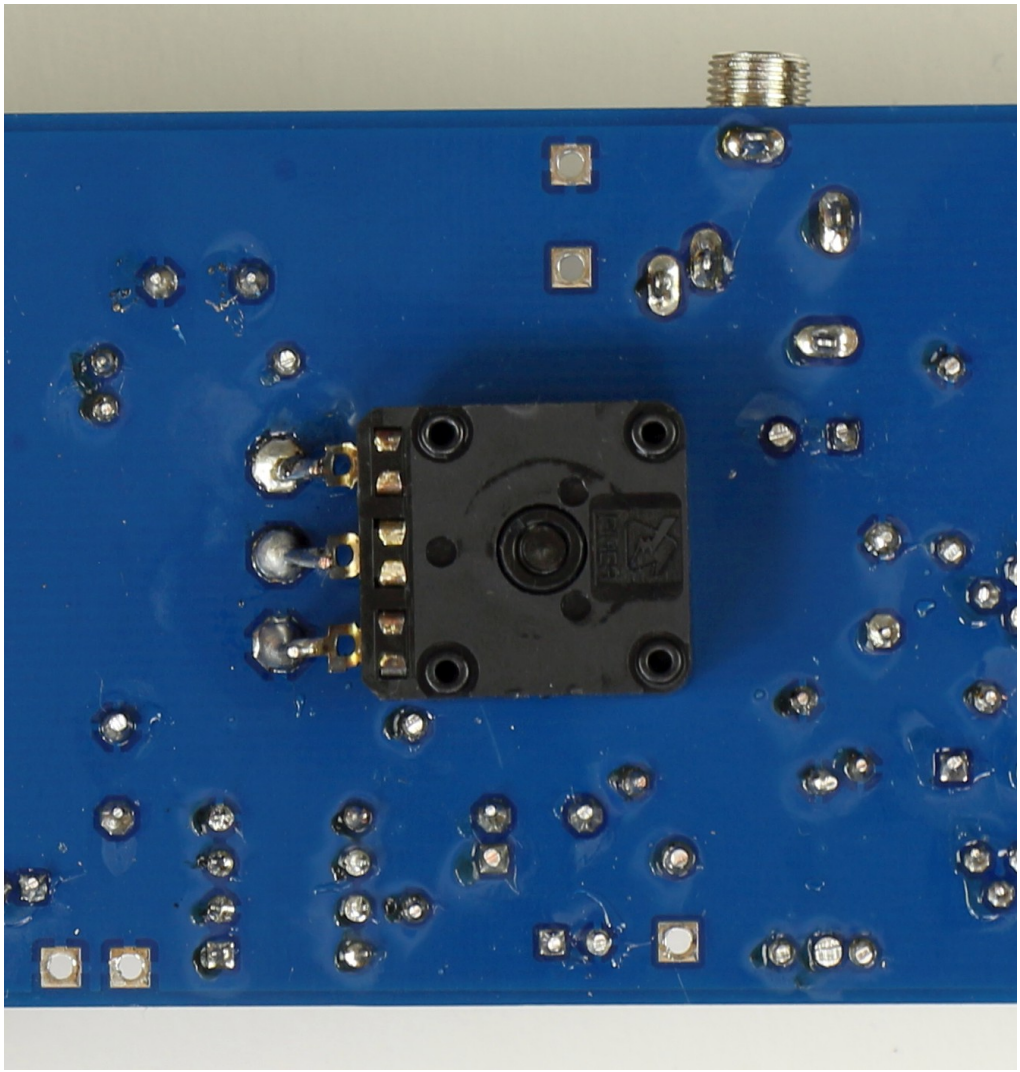
<u>ATTENTION:</u> L2 and L4 have the same value and color code (1.0 mH) and the same color code (Baun-Black-Red), but differ in size.
<u>L2 is slightly smaller and L4 slightly larger.</u>
If you swap the two types, the theremin may not work!

.4.3.12. Volume Potentiometer (P1)

P1 10 kΩ linear or log.

Different types of potentiometer can be used.
With the potentiometer, the connecting pins must be bent by 90° before soldering so that they come to rest on the soldering holes.
If necessary, the leads must be "extended" with short pieces of wire up to the soldering holes.

Before soldering, screw the enclosed nut with washer to the top of the circuit board so that the shaft is exactly at right angles to the circuit board.
Do not "overtighten" the plastic thread otherwise it could tear out.

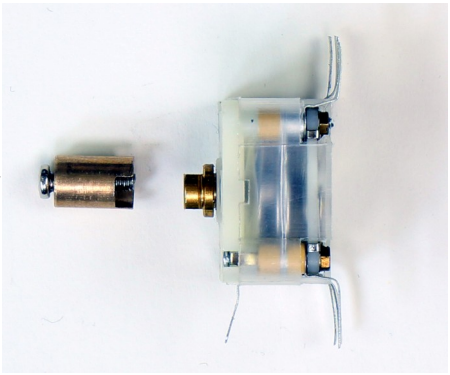


4.3.13. Preparing and soldering the variable capacitor

C5 2x125 pF

The variable capacitor must first be connected to the small extension shaft before soldering. This is first attached, which is sometimes only possible with a little force. You may have to bend or file the shaft a bit. Then insert the screw from above and gently screw it into the thread by hand.

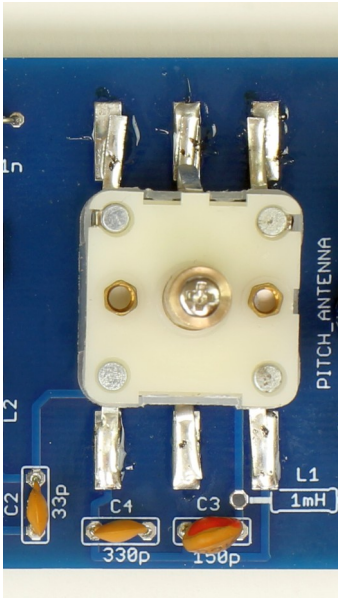
ATTENTION:
When tightening, the shaft-extension must be held firmly with flat-nosed pliers, otherwise the stop inside the rotary capacitor may break. So hold the shaft-extension when tightening and not the body of the variable capacitor! See figure below.



When tightening, the shaft-extension automatically pulls itself towards the rotary capacitor.

Next, the lugs need to be bent as shown in the picture on the right.

ATTENTION: The lugs may have to be shortened a little with side cutters before soldering, so that they do not protrude beyond the solder pads.



ATTENTION: There are 4 lugs on one side and only 3 on the other.
The side with the 3 lugs goes onto the board on the side where C3, C4 etc. are.
The side with the 4 lugs goes onto the relatively unpopulated side on the board where no other components are around.

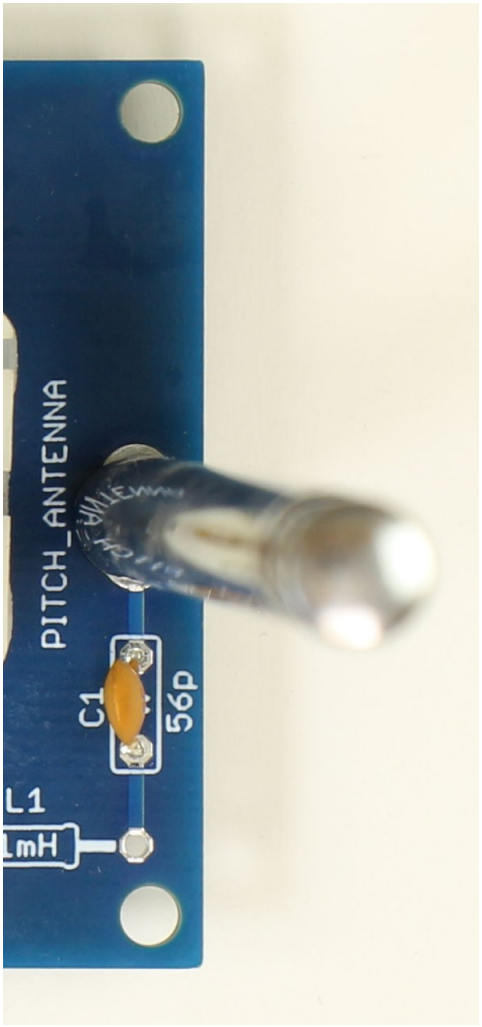
ATTENTION: The variable capacitor must remain flat when soldering so that the shaft and later the knob sit straight and fit through the acrylic housing.

ATTENTION: Always take a break when soldering the lugs so that the plastic housing of the variable capacitor can cool down in between and the inner workings do not melt together.

4.3.14. Solder in the telescopic rod antenna

The round connection lug at the lower end fits into the long hole on the right edge of the board (“pitch antenna”) with a little “wiggling”.

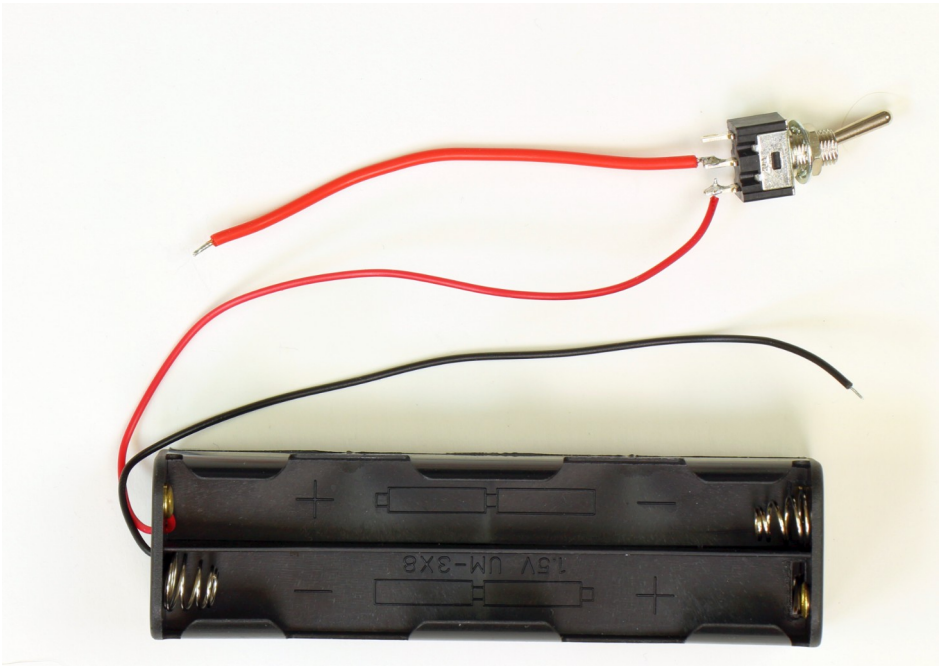
Before soldering, check the antenna from all sides for a right-angled fit, otherwise it will not fit through the opening in the acrylic housing.
Solder from below with plenty of solder and allow time to cool.



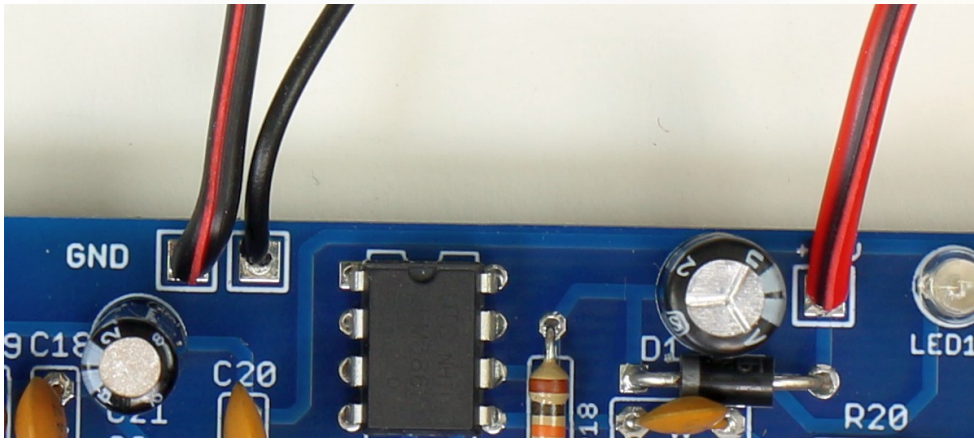
4.3.15. Battery holder and power switch

ATTENTION: All cables are (contrary to the pictures in the instructions here) soldered to the board from below!
As a result, the cables do not get in the way on the top and the housing installation is easier.

Solder a short length (approx. 10 cm) of red wire to the middle lug of the power switch.
Then solder the red ("+") wire from the battery holder to one of the outer lugs on the power switch as shown below.



Then solder this piece from below to the "**+12V**" connection on the circuit board.



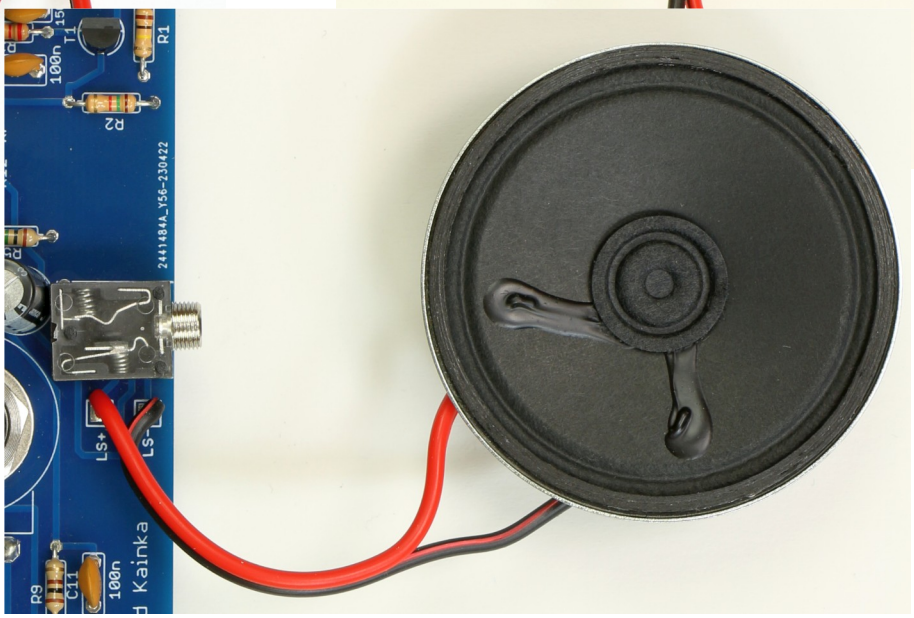
Solder the black cable of the battery holder to the "**GND**" connection on the circuit board from below.

ATENTION: The GND-connection on the final board is in a different location on the board than the photo above.

4.3.16. Connect speakers to circuit board

ATTENTION: All cables are (contrary to the pictures in the instructions here) soldered to the board from below!

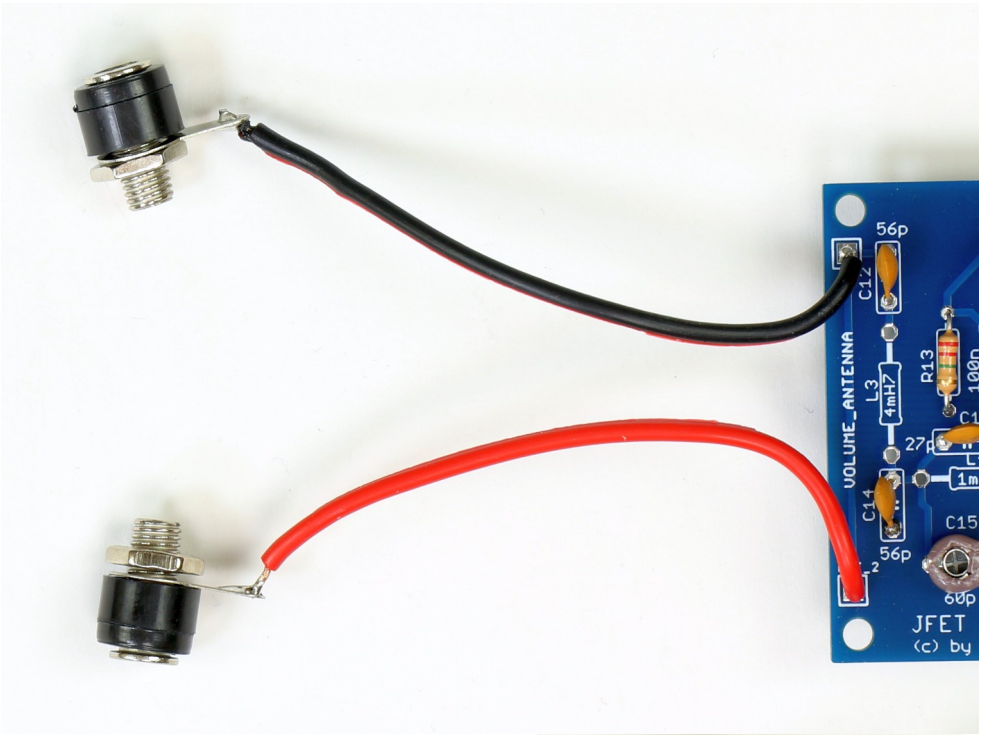
Cut off a piece (approx. 10 cm) of the red-black wire, strip a short piece (approx. 5mm) on all sides, twist and tin with some solder.
Then carefully solder one side to the two tabs on the speaker and then solder the other side to the two terminals "**LS+**" and "**LS-**". The polarity doesn't matter.
When doing this, make sure that the wire of the loudspeaker coil and the loudspeaker membrane are not damaged.



4.3.17. Wire banana jacks to circuit board

ATTENTION: All cables are (contrary to the pictures in the instructions here) soldered to the board from below!

Cut off a piece (approx. 10cm) of the red-black wire. As usual, strip all 4 ends approx. 5mm, twist and tin.
Solder one end to the lugs of the 2 banana jacks of the same color, solder the other end to the two "**VOLUME-ANTENNA**" connections on the left side of the circuit board.



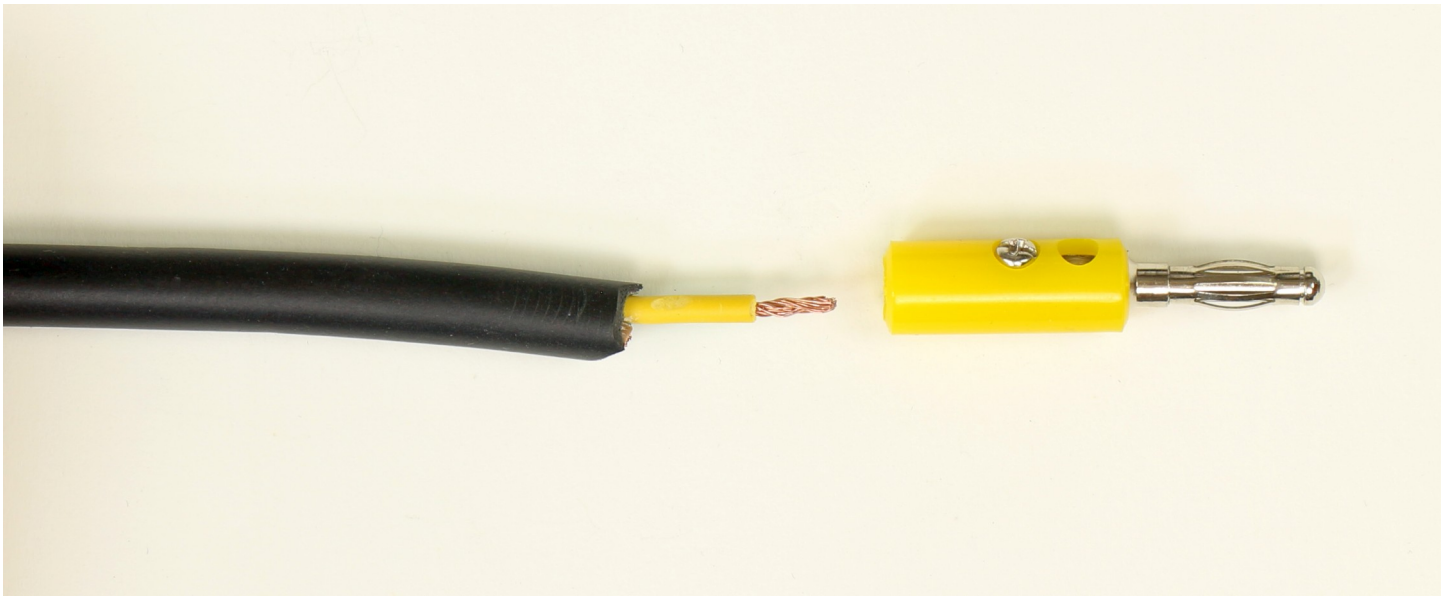
Solder the differently colored banana socket (yellow or green) with the remaining black piece of wire in the same way to the second, free "**EARTH**" connection on the circuit board.

ATTENTION: The EARTH connection on the final board is in a slightly different location on the board than in the photo shown on the right.

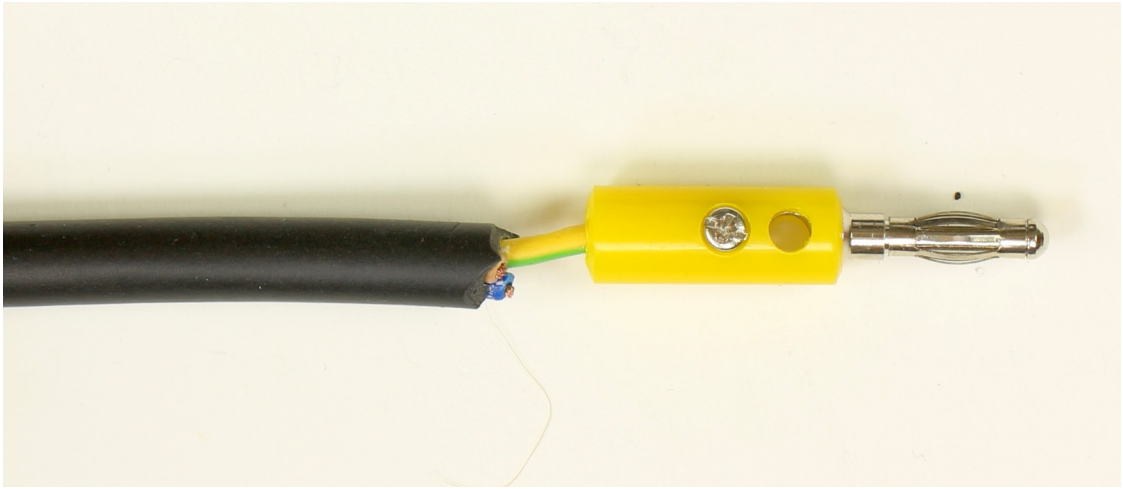
4.3.18. Prepare earth wire

Strip approx. 10mm of the yellow-green strand of the prepared grounding cable, twist it and do **not** tin it.

Then cover the transition from the thick mains cable to the yellow-green conductor strand with a piece of shrink tubing (not shown here; it may have been done by us in advance on delivery.)



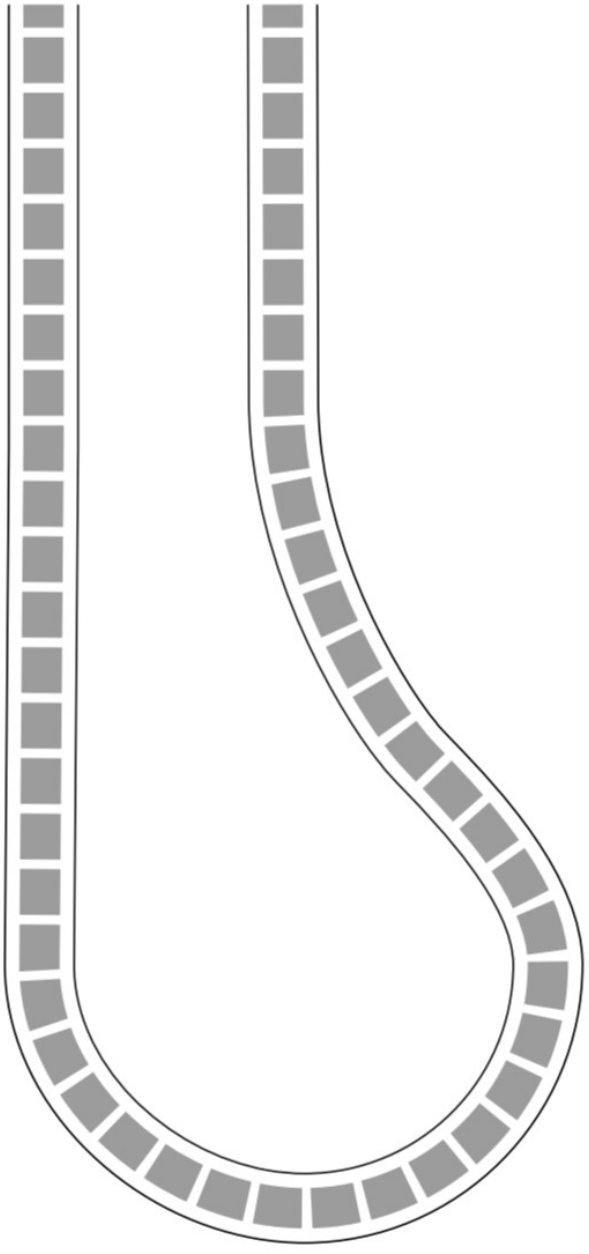
Then screw the wire end tightly to the banana plug.
If the screw doesn't hold the stranded wire properly, you have to "fold over" the bare piece of stranded wire so that it doubles in thickness.



4.3.19. Bend the volume antenna

Bend the piece of copper tubing by hand (or with a “spiral spring”) into the loop shape of the volume antenna according to the template. The exact form is not important.
The distance between the two ends must approximately match the two holes in the side part of the acrylic housing.

The bending template should be printed out beforehand in a 1:1 scale.
(1:1 scale see last page of these instructions!)



4.3.20. Testing, adjustment and troubleshooting

Prepare the following for a first test:

- Check the circuit board again for complete assembly, short circuits ("solder bridges") or bad solder joints.
Tip: It is helpful to use a strong flashlight to illuminate the circuit board from below for finding those.

- Try putting the two knobs onto the shafts of the potentiometer and the varaible capacitor.

- Bring the volume potentiometer to the right stop (= maximum).

- Plug the earth-wire into a wall-outlet and insert the banana plug into the earth socket.
(**Note:** You can also initially carry out the adjustment without the grounding cable.
Experience has shown that the theremin also works without a grounding cable. However, the setting of the variable capacitor and the capacitance trimmer is then different!
You also have to try out whether any interference from switched-mode power supplies etc. is minimal or disappears with or without an earthing cable.)

- Plug the volume antenna (copper tube) into the two sideways banana sockets.

- Extend the pitch antenna (telescopic antenna) halfway.

- Insert the 8 AA-batteries into the battery holder. Pay attention to the correct polarity!

- There should be no metal parts, cables, etc. near the pitch and volume antenna.
A tubular steel frame of the work table can also be a nuisance!

- Flip the power switch
→ The blue LED on the circuit board must light up
(if not: check the polarity of the batteries and the LED).

- Slowly turn the knob on the variable capacitor back and forth.
→You must be able to change the pitch of an easily audible (loud!) sine tone

- With no hand near the telescopic antenna, use the knob to set the frequency step by step to the lowest frequency (only slow crackling or completely inaudible).
Since you inevitably have your hand near the pitch antenna when turning the knob, you have to approach the "zero beat" in small steps and take your hand away again in between.

- When you approach your hand to the telescopic antenna, the tone must become higher and higher.
With an optimal setting, the range of frequency change by approaching the hand is about 15 cm or more.

- Finally, the capacitance trimmer C15 for the volume antenna is adjusted.
When adjusting with an isolated (!) screw driver (ideally: a ceramic screw driver) the position must be found where the sine tone just starts to become lower in volume without your hand being close to the copper tube loop antenna.
If this point cannot be reached with the turning range of the trimmer, now C14 is soldered in. It´s place is directly next to the trimmer C15. You should now be able to find the point where the volume is just decreasing.
When the hand approaches the volume loop antenna, the volume becomes lower in the last few centimeters of approach and when the loop antenna is touched, it becomes completely silent.
The manual sensitivity can be further optimized by slightly adjusting the trimmer C15.

Troubleshooting with multimeter and oscilloscope:
You need a multimeter with (at least) 10 MΩ input impedance and an oscilloscope with a 1:10 probe and also (at least) 10 MΩ input impedance. Bandwidth of the oscilloscope: at least 1 MHz.

First of all you have to check again whether there are any solder bridges, “cold” or forgotten solder joints or components that have been inserted the wrong way round or are incorrectly assembled.

If you only have a multimeter at hand, the DC voltages given on the next page must be measured in the circuit diagram (approx. +/- 0.5V with a battery voltage of 12.3V).

With an oscilloscope you can check the function of the 3 oscillators:

- 455 kHz (or 470 kHz) BFO: at the junction of Q1/C8/R5 the 455 kHz signal (+/- 5 kHz) must be sinusoidal with a few V_{SS} amplitude

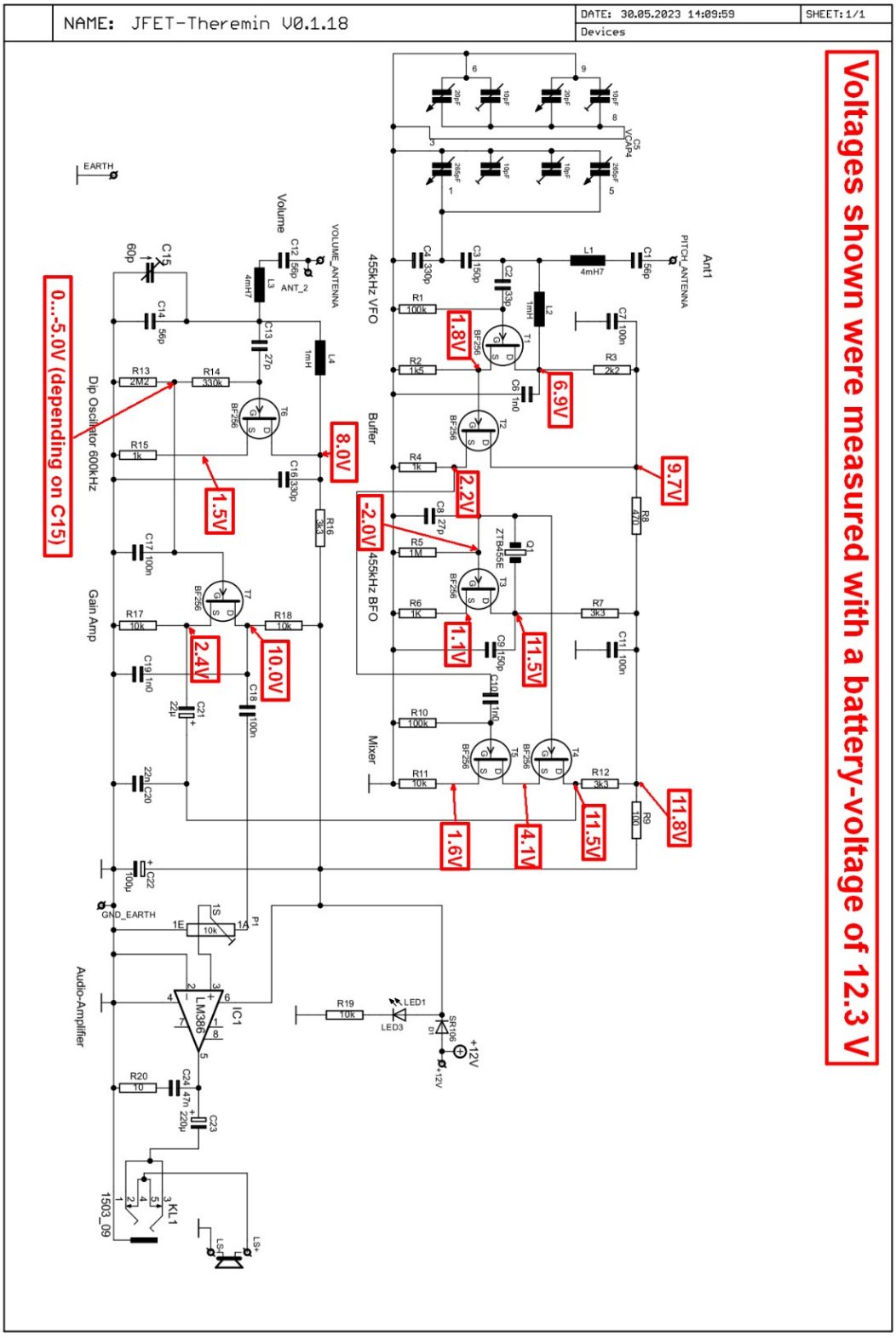
- Pitch oscillator: the pitch oscillator signal must also be present at the junction of R4/C10/T2 with a few V_{ss} amplitude. However, the signal (with a large amplitude) is mostly "clipped" and no longer sinusoidal. The frequency must be able to be set to exactly the frequency of the BFO with the variable capacitor, i.e. 455 kHz (or 470 kHz).
In addition to the variable capacitor you have a second adjustment option for the frequency-range by the length of the telescopic rod. When the rod is halfway extended, the amplitude is usually at its maximum at exactly the right frequency.

If the BFO frequency cannot be reached exactly:
- Are L1 and L2 the correct inductors?
- Is the variable capacitor soldered in the right way round?

- Volume oscillator: at the junction of C13/R14/T6 the volume oscillator signal must also have a few V_{ss} amplitude. The frequency must be significantly higher than the BFO frequency (approx. 500...600 kHz).
The amplitude can be set to the right level with the trimmer C15 (possibly after soldering in C14).
The DC voltage at the junction of R13/R14/C17 must be approx. -2.5V without your hand neat the volume antenna. As a result, T7 is just about fully conducting. T7 is used as a "controllable resistor".
When the hand approaches the volume antenna this voltage drops to -3.5V or lower and T7 is no longer conducting and the volume drops to zero.

If this behavior cannot be achieved exactly:
- Are L3 and L4 correct or accidentally swapped ("thicker" and "thinner" type)?

- Solder the C14 as a test. (But this is only in very rare cases the reason for the error!)


NAME: JFET-Theremin V0.1.18
DATE: 30.05.2023 14:09:59
SHEET: 1/1
Devices
Voltages shown were measured with a battery-voltage of 12.3 V
0...-5.0V (depending on C15)
1.8V
6.9V
8.0V
9.7V
1.5V
2.2V
-2.0V
2.4V
10.0V
1.1V
11.5V
1.6V
4.1V
11.5V
11.8V
455kHz VFO
455kHz BFO
Buffer
Mixer
Gain Amp
Dip Oscillator 600kHz
Audio-Amplifier
Volume
Ant1
VOLUME_ANTENNA
PITCH_ANTENNA
ANT_2
EARTH
GND_EARTH
LM386
IC1
LED3
+12V
KL1
1503_09