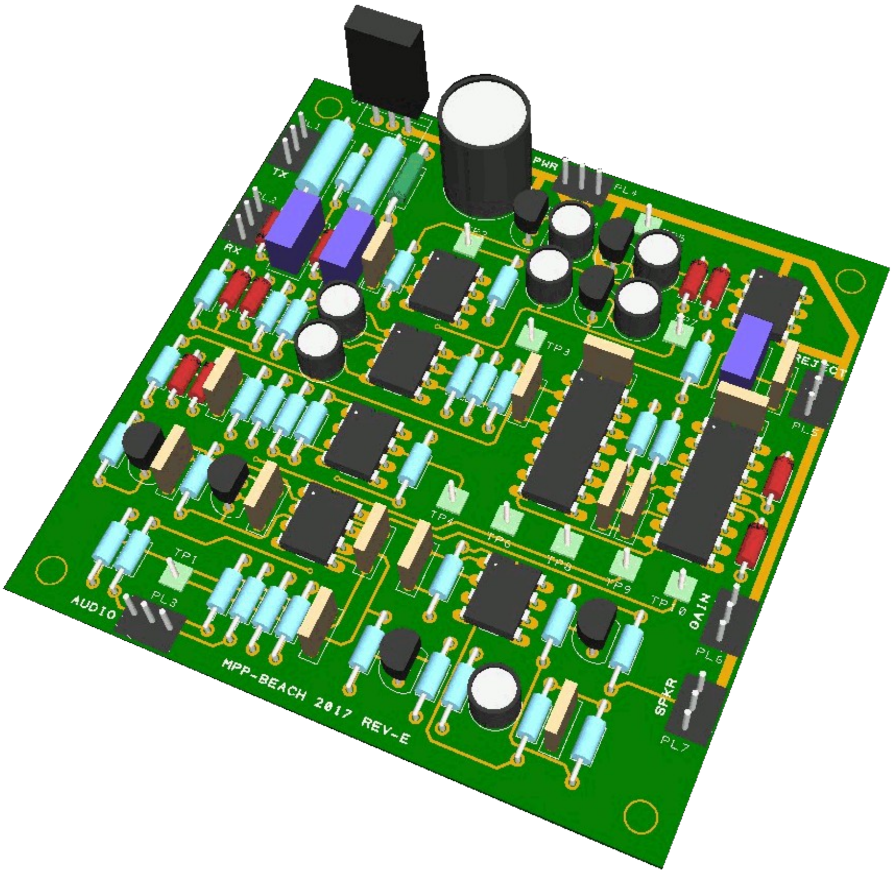

Building the

MPP Beach (Rev-E)

March 2018

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Introduction

The MPP Beach (REV-E) is a modified version of the Minipulse Plus (REV-D) design. The intent of this version is to provide a detector that caters specifically for beach detecting. The benefits of this version are as follows:

1. The TX oscillator can now be adjusted by on-board trimmers, with the pulse width and pulse period being independently adjustable. The range is such that flat-topping the coil current is possible for most coils.

2. As before, both mono and balanced coils can be used.

3. The positions of some components have been adjusted for easier assembly.

4. The PCB remains the same size at 3.5" square.

5. The sample pulse width is now available as an external 10k pot. This effectively provides some adjustable gain.

6. TL061 and TL062 opamps have been changed to TL071 and TL072. Silverdog kits were already being supplied with these parts.

7. Audio threshold pot changed from 250k to 220k.

8. MOSFET changed from IRF740 to IRF840 to increase flyback voltage.

9. 100nF capacitor in audio circuit increased to 470nF.

10. Moved TX oscillator testpoint from input of sample pulse generator to output of TX oscillator.

11. Changed silkscreen on connectors to show correct orientation. (Vertical bar on inside.)

Although this revision is referred to as MPP Beach, there is nothing to prevent the various settings being adjusted to detect lower conductivity items such as gold nuggets.

Please note (for this revision) it is imperative that you have access to an oscilloscope during the setup procedure. Given the adjustable nature of this version, it would be extremely difficult to set up the detector without one. It is also mandatory that you possess a multimeter.

As stated in previous revisions, if you go through the following steps carefully, and in order, you will have a greater chance of ending up with a detector that actually works. Please do <u>not</u> proceed to the next step until you have solved any problems encountered in the current step. If you get stuck at any stage during the build, then seek help in the Geotech forums before moving on. Do <u>not</u> simply populate the whole board; discover it doesn't work (which will be the most likely result) and then post in the forums: "I've built the Minipulse Plus, and it's not working. What's wrong?" …. as you will receive little sympathy from other Geotech members. You have been warned!

To reiterate: **Please follow the instructions step-by-step.**

Important Points

Check the value of each component before you start soldering. Fitting an incorrect value in the wrong place is one of the most common mistakes.

The positive (+ve terminal) of the battery pack is treated as ground (0V) in this design. All voltages and currents are referenced to this point.

Step-by-step Instructions

STEP 1

Starting with the -5V supply (see Fig. 1):

Fit C10 (22uF), TP5, PL4 and U5 (79L05)

This is a simple linear regulator that provides the -5V power supply. Check the supply is correct by connecting a 12V battery pack to PL4 (the positive terminal is the middle pin, and both outer pins go to the negative terminal). This is to prevent the circuit from being accidentally connected to the battery in reverse. Measure the voltage at U3 pin 4 (see Fig. 2) and confirm that it is -5V. Remember that all voltages and signals are referenced to battery positive (TP5).

STEP 2

Next we will build the +5V supply (see Fig. 3):

Fit C14 (10uF), C11 (22uF), C15 (100uF), D8/D9 (1N4148), TP7, U6 (78L05) and U9 (LT1054)

The LT1054 is configured as a positive voltage doubler (referenced to the -VB supply), which boosts the battery voltage to twice its normal value, and is then regulated by U6 (78L05) to +5V. Measure the voltage at TP7, with reference to 0V (TP5), and confirm it is +5V.

STEP 3

The transmit (TX) oscillator (see Fig. 4):

Fit R5 (100k trimmer), R14 (1M trimmer), R17/R23 (10k), R34 (20k), C3 (47nF), C22 (100pF), C7 (1000uF), TP2, D1/D6 (1N4148), Q4 (2N3904) and U1 (NE555)

Monitor the TX oscillator output at TP2 with an oscilloscope, and adjust R5 to give a TX pulse width of 400us. Next adjust R14 to give a TX pulse period of 8ms. The TX pulse rate should then be 125pps (see Fig. 5). Note that the frequency remains stable with changes in battery voltage, but the pulse width gets wider as the voltage is reduced. This helps to keep the TX power stable, even when the power supply is low. The final pulse width and period can be adjusted again later to suit the particular coil you plan to use.

You can also see that the TX oscillator is synchronized to U9 (LT1054 voltage converter) by monitoring TP2 with an oscilloscope (channel 1), and U9 pin2 (channel 2).

STEP 4

Transmit (TX) circuit (see Fig. 6):

Fit R4* (470R - 2W), R7 (10R), R10 (3R3 - 2W), D7 (MUR460), Q2 (IRF840), PL1 and PL2

The coil inductance should be between 300uH and 500uH. You can utilise the Coil Calculator (at the top of the Coil forum) to determine the correct number of turns for the diameter you intend to use. *The damping resistor (R4) may need to be adjusted to suit your particular coil. This resistor can be positioned on the PCB, or alternatively it can be fitted on the back of the coil connector, or even inside the coil shell itself. If you wish to use a balanced coil, then two separate damping resistors may be required. Please see Fig. 7 for connection details for both mono and balanced coil configurations.

Monitor the signal across the damping resistor using an oscilloscope with x10 probe, where you should see a flyback signal of about 350V or higher.

STEP 5

RX pre-amp (see Fig. 8):

Fit R1/R26 (1k), R11/R24 (27R), R8/R27 (33k), C4/C5 (47uF), D2/D4 (1N4148), TP3, U2 (NE5532)

Monitor TP3 with an oscilloscope. Place a cola can close to the coil, and the voltage should drop by a few 100s of millivolts. A coin will only drop the voltage by a few 10s of millivolts.

STEP 6

Sample Pulse Generator (see Fig. 9):

Fit R35 (4k7), R32 (10k), C13 (220pF), C19 (2n2), C18 (10nF), C16/C21 (100nF), D10/D11 (1N4148), TP6, TP8, TP9 and TP10, PL5 and PL6, R37 (100k trimmer), U7/U10 (MC14538BCP)

Monitor the TX oscillator at TP2 using an oscilloscope (channel 1), and TP6 (channel 2). Trigger off channel 1. Short pin2 of PL5 to either pin 1 or pin 3, and adjust R37 for a minimum sample delay of 10us. The final minimum sample delay will depend on the coil you've constructed, but 10us will be ok for initial setting up.

Next switch the channel 2 probe to TP8, and confirm that Earth Field Elination (EFE) delay pulse width is approximately 100us.

Finally, short pin2 of PL6 to either pin 1 or pin3, and confirm that the pulse width at both TP9 (sample pulse width) and TP10 (EFE pulse width) is approximately 10us. Once the gain pot (22k) is attached, this will allow the sample and EFE pulse widths to be adjusted from 10us to 57us.

(See Fig. 10):
Main sample delay = 10us (TP6)
Secondary sample delay (EFE) = 100us + main sample delay (TP8)
Main sample pulse width (min) = 10us (TP9)
Secondary sample pulse width (min) = 10us (TP10)

Note that R37 will most likely require some slight readjustment after the Reject pot (100k) is connected to PL5.

STEP 7

Sampling integrator (see Fig. 11):

Fit R2 (220R), R12/R16 (10k), R3/R13 (2k2), R15/R25 (6k8), R18 (56k), C1/C2/C6 (470nF), D3/D5 (1N4148), TP4, Q1/Q3 (J113), U3 (TL072)

Monitor TP4 with an oscilloscope, and confirm that the DC voltage level increases when a target is placed near the coil.

STEP 8

Second integrator (see Fig. 12):

Fit R9/R20/R21 (1k), R19 (27k), R6 (1M), R22 (47k), C9 (470nF), C8 (1uF), TP1, PL3, U4 (TL071), Audio [threshold] pot (220k LIN)

Monitor TP1 with an oscilloscope, and adjust the Audio (threshold) pot. This should allow the DC voltage level at TP1 to swing from -4V to +4V approximately. Set the DC level to around 0V. While still monitoring TP1, look for a change in the DC voltage level as a target is moved across the coil. Note the self-adjusting threshold (SAT) will restore the signal to its previous value if the target is not kept moving. Also, either the Reject pot should be connected to PL5, or the pins shorted (as described in Step 6).

STEP 9

Audio (VCO) stage (see Fig. 13):

Fit R28/R29/R33 (10k), R30 (4k7), R36/R39 (680R), R38/R31 (100R), C12 (47nF), C20 (470nF), C17 (100uF), PL7, Q5 (2N3904), Q6 (2N3906), U8 (NE555)

Connect a speaker or headphones to PL7. You should use headphones with built-in volume controls, otherwise it will blow your ears off. If you would like to add a volume control on the front panel, a 5k audio taper would be the best solution, although a standard linear pot will probably suffice.

The audio can range from 0Hz to approximately 1.6kHz. Bringing a metal target near the coil will produce an increase in the frequency of the audio output.

Other Points:

1. The detector requires a nominal 12V battery pack (8 cells). Operation will start to get erratic once the voltage drops below about 9V.

2. Although the minimum sample pulse delay can be adjusted below 10us, it will depend mainly in the particular coil you intend to use, and also the detecting environment. For beach use it is normal to set the minimum sample delay to 15us in order to avoid false signals due to wet salty sand.

3. The audio response of the Minipulse Plus is loud, even for deep targets. As metallic items get closer to the coil, the frequency of the audio increases to a maximum of 1.6kHz.

4. The Audio [threshold] pot should be adjusted to a low growl. The response is set to a high sensitivity, so it increases quite rapidly when a coin is detected. You will not need to concentrate on hearing the difference between a 1Hz and a 2Hz tone.

5. All of the components, that connect to the PCB via connectors, can be inserted either way round without any problems. However, the Audio [threshold] pot will react differently depending on its orientation. You can fit it either way, depending on whether you want the audio to increase or decrease as you turn it clockwise.

6. The original Minipulse incorporated the Audio [threshold] pot with the on-off switch. This seems to be a sensible solution, but you are free to use a separate on-off switch if desired.

Component Parts List

Resistors (1% 250mW, unless stated otherwise)

R10	3R3 2W
R7	10R
R11,R24	27R
R31,R38	100R
R2	220R
R4	470R 2W (damping resistor)*
R36,R39	680R
R1,R9,R20,R21,R26	1k
R3,R13	2k2
R30,R35	4k7
R15,R25	6k8
R12,R16,R17,R23,R28,R29,R32,R33	10k
R34	20k
R19	27k
R8,R27	33k
R22	47k
R18	56k
R5,R37	100k multiturn preset
R6	1M
R14	1M multiturn preset

* Actual value is dependent on coil

Capacitors

C22	100pF
C13	220pF
C19	2n2
C18	10nF
C3,C12	47nF
C16,C21	100nF
C1,C2,C6,C9,C20	470nF
C8	1uF
C14	10uF 10V
C10,C11	22uF 10V
C4,C5	47uF 10V
C15,C17	100uF 10V
C7	1000uF 16V

Diodes

D1-D6,D8-D11	1N4148
D7	MUR460

Transistors

Q4,Q5	2N3904
Q6	2N3906
Q2	IRF840
Q1,Q3	J113

Integrated Circuits

U6	78L05
U5	79L05
U9	LT1054
U7,U10	MC14538BCP
U1,U8	NE555
U2	NE5532
U4	TL071CP
U3	TL072CP

Miscellaneous

Battery pack	8x AA batteries (12V nominal)
Search coil	300uH to 500uH (TX)
Gain (sample width) pot	22k LIN
Reject (sample delay) pot	100k LIN
Audio (threshold) pot	220k LIN
Speaker	8ohm to 64ohm
On-Off switch	Either separate or combined with Audio (threshold) pot
TP1-TP10	Single-pin testpoint
PL1-PL7	3-pin 100th pitch connector

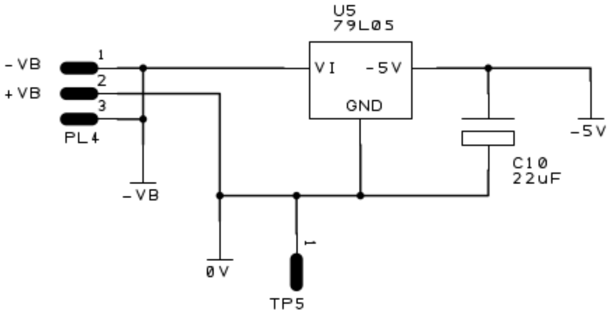

Fig. 1: **Negative 5V Supply**

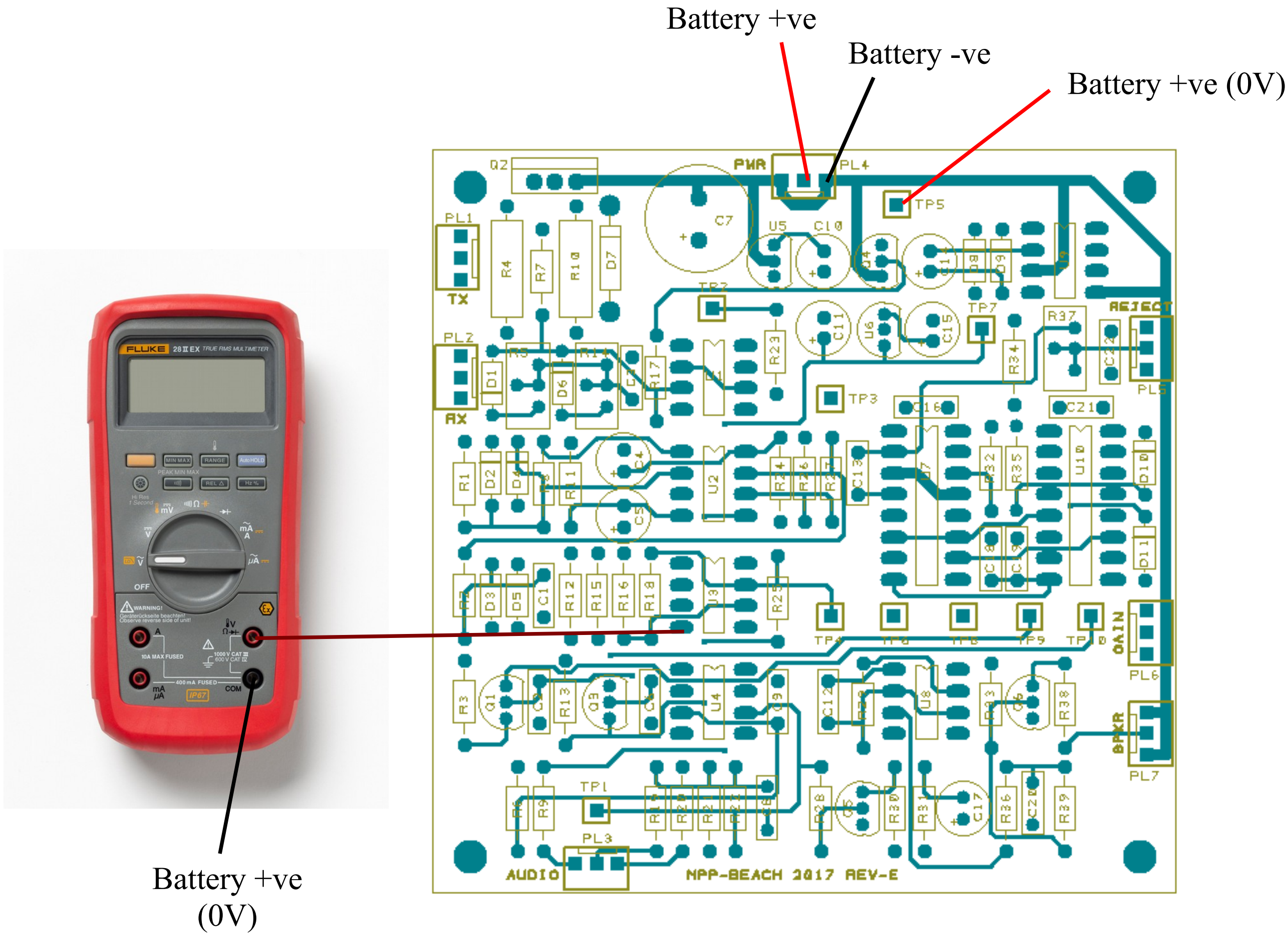

Fig. 2: **Checking the - 5V Supply**

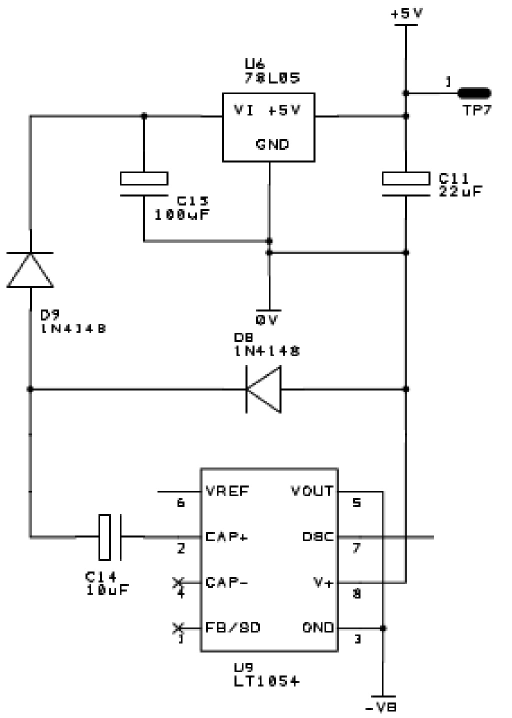

Fig. 3: **Positive 5V Supply**

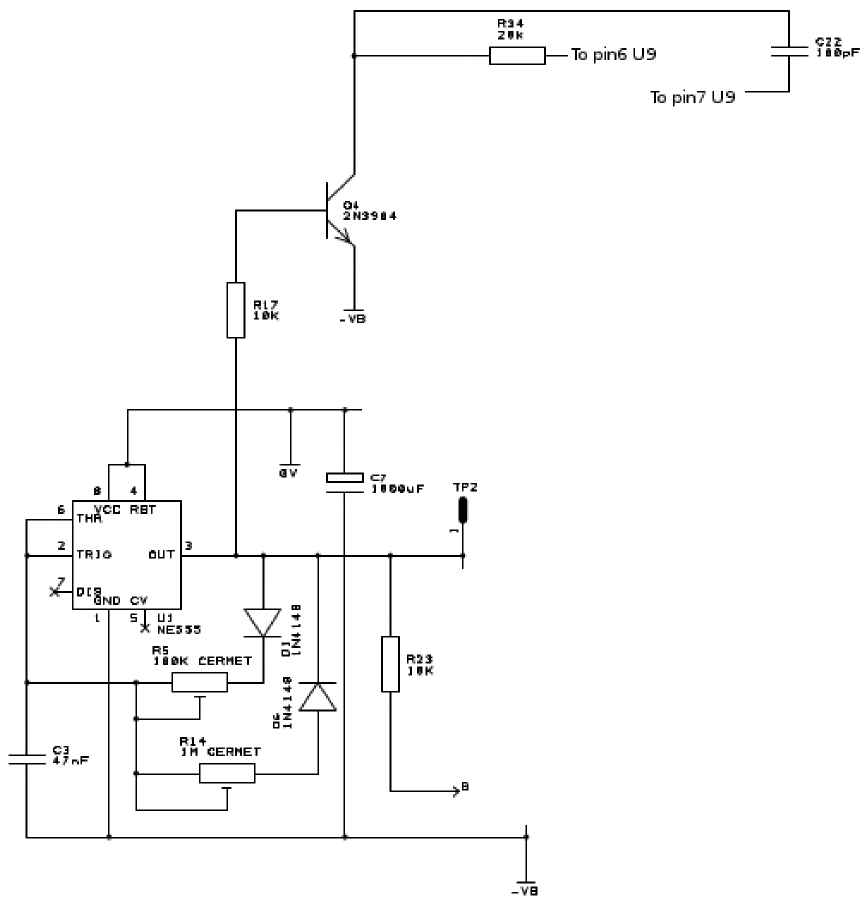

Fig. 4: **Transmit (TX) Oscillator**

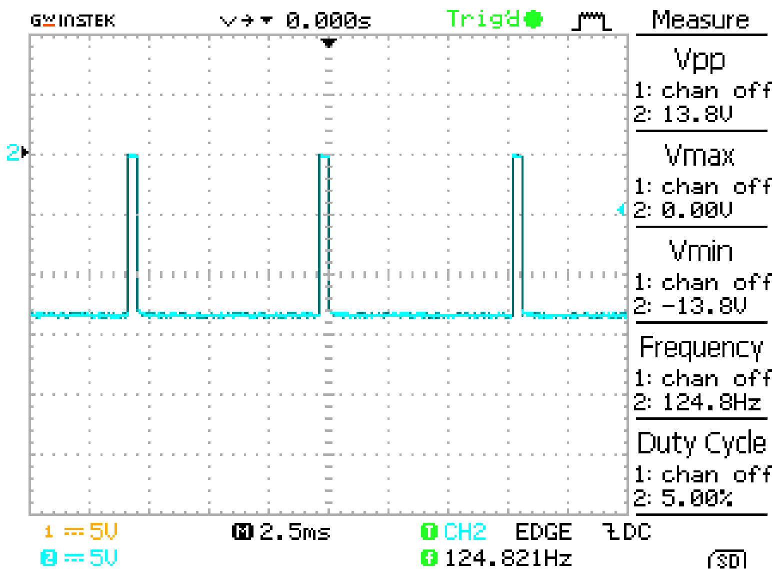

Fig. 5: **TX Oscillator Waveform**

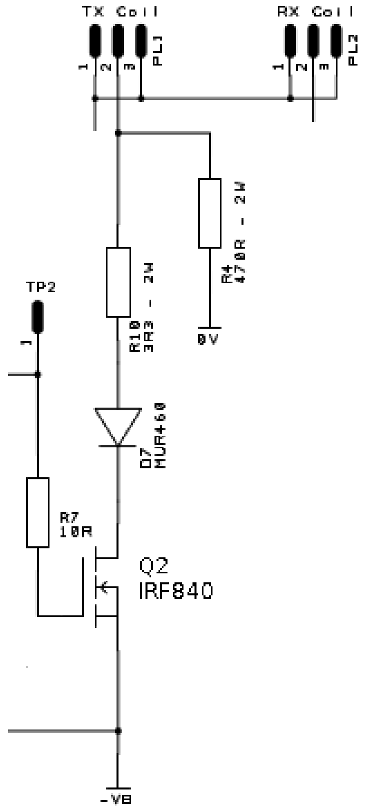

Fig. 6: **TX Circuit**

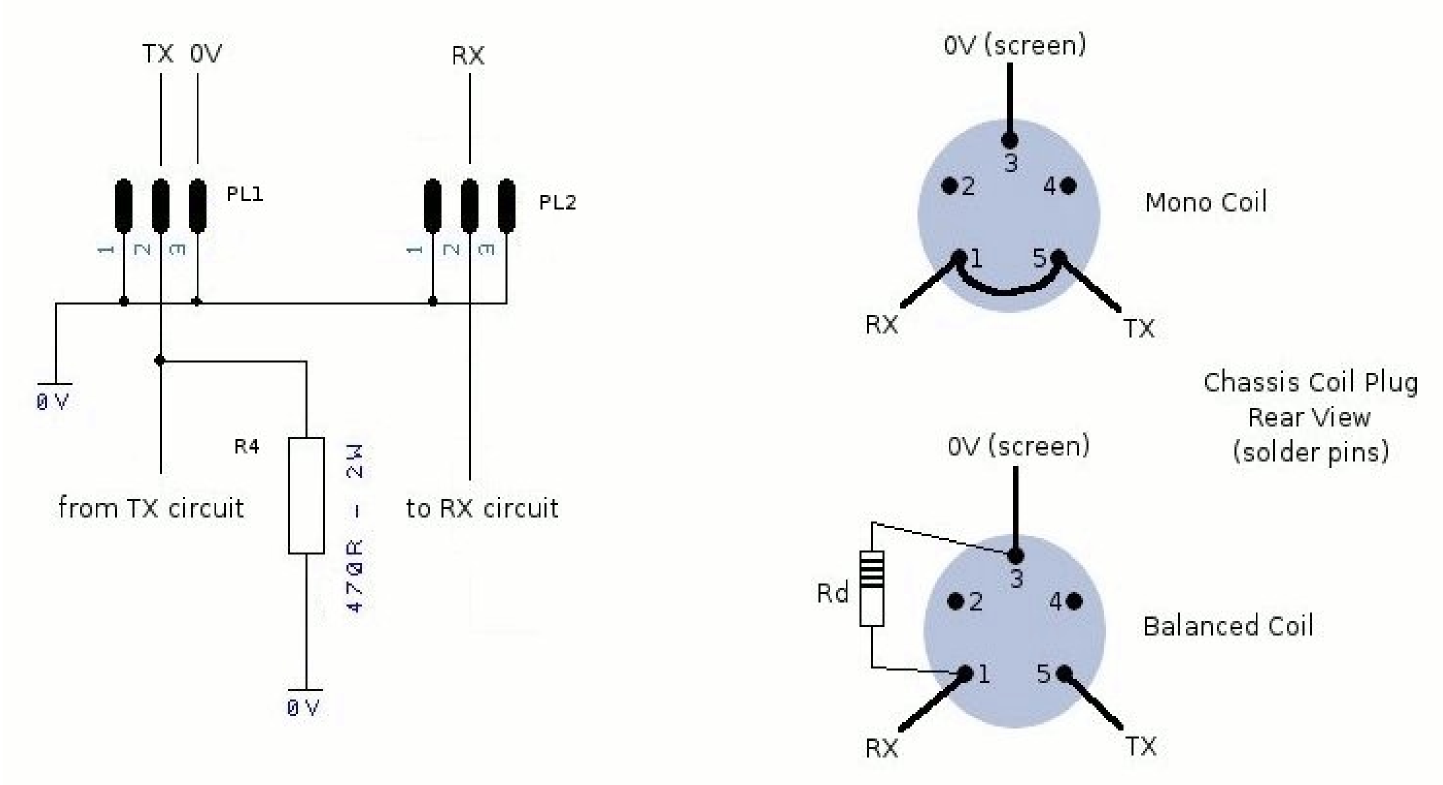

Fig. 7: **Coil Configurations**

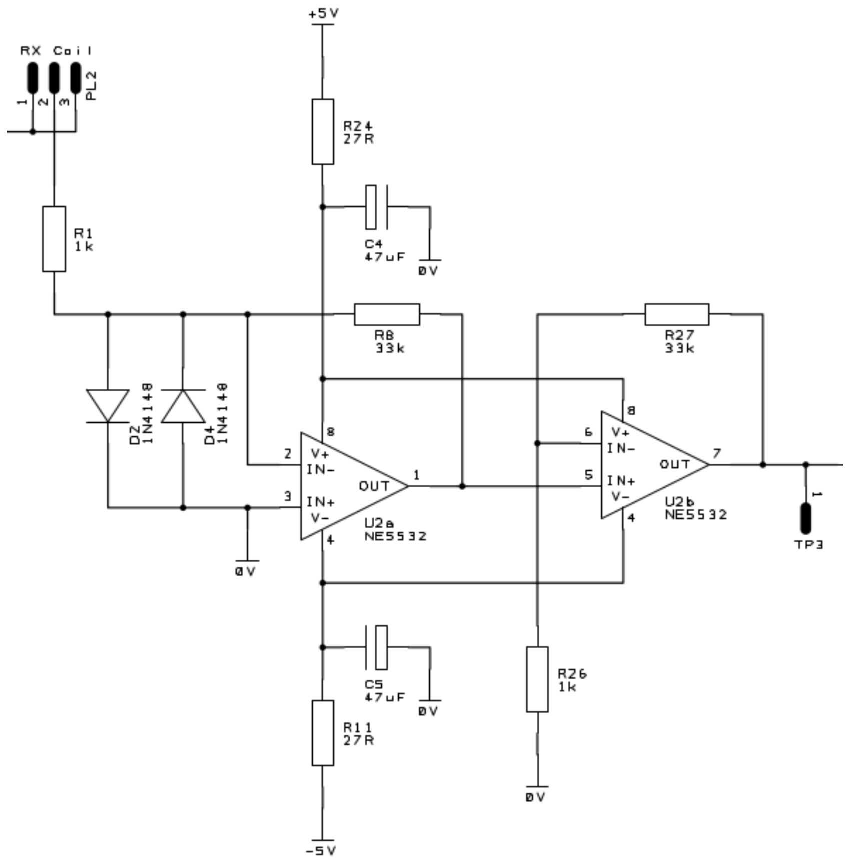

Fig. 8: **RX Pre-amp**

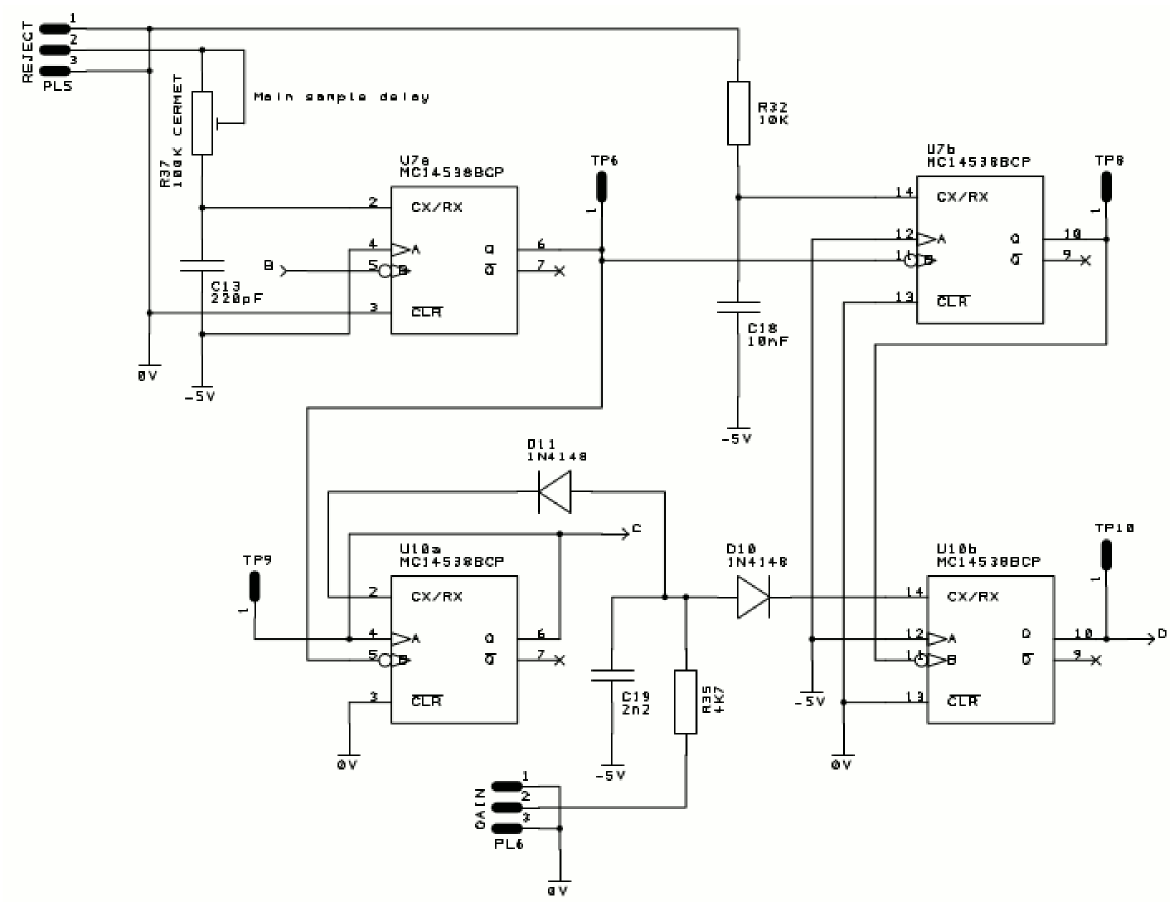

Fig. 9: **Sample Pulse Generator**

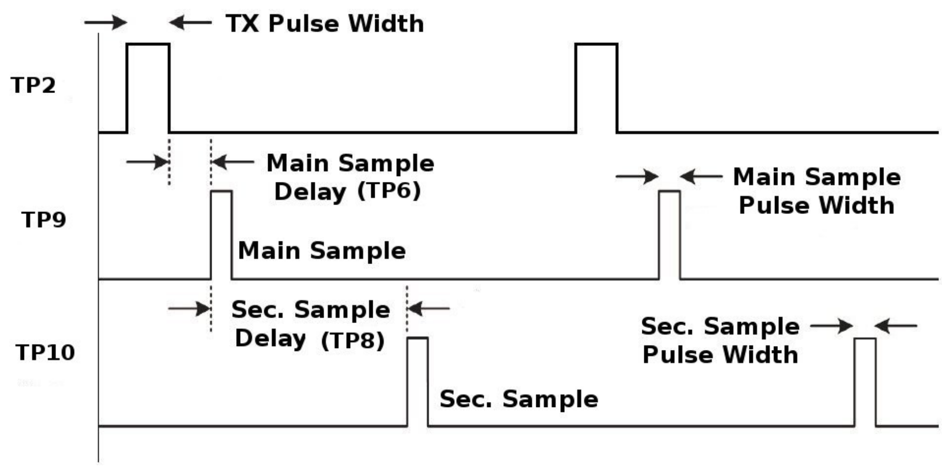

Fig. 10: **Sample Timing**

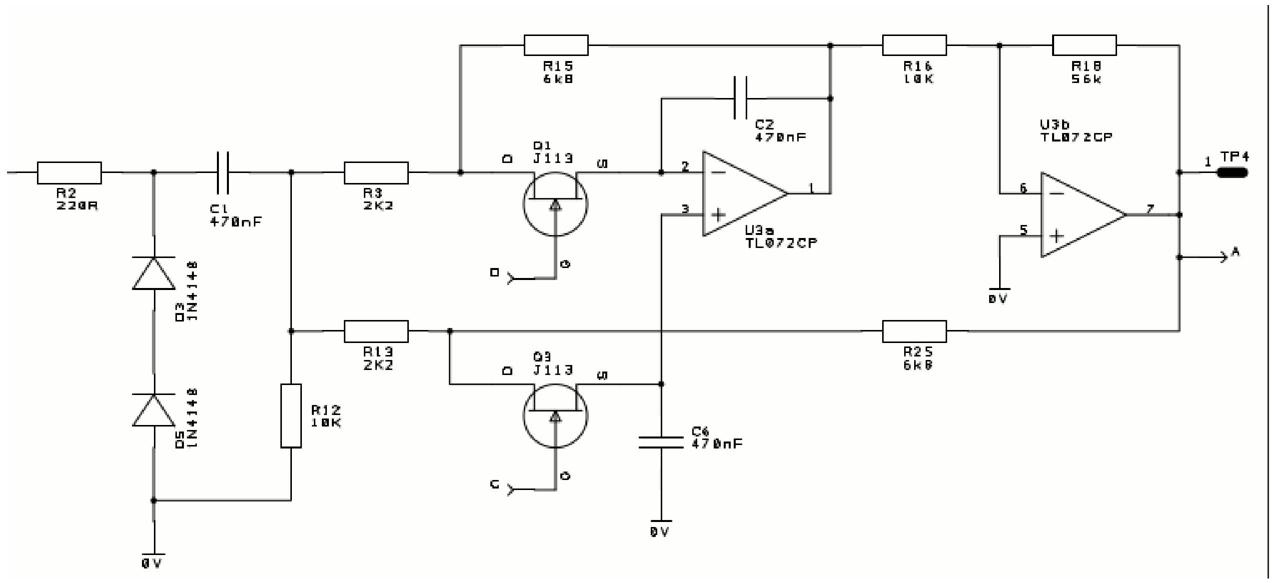

Fig. 11: **Sampling Integrator**

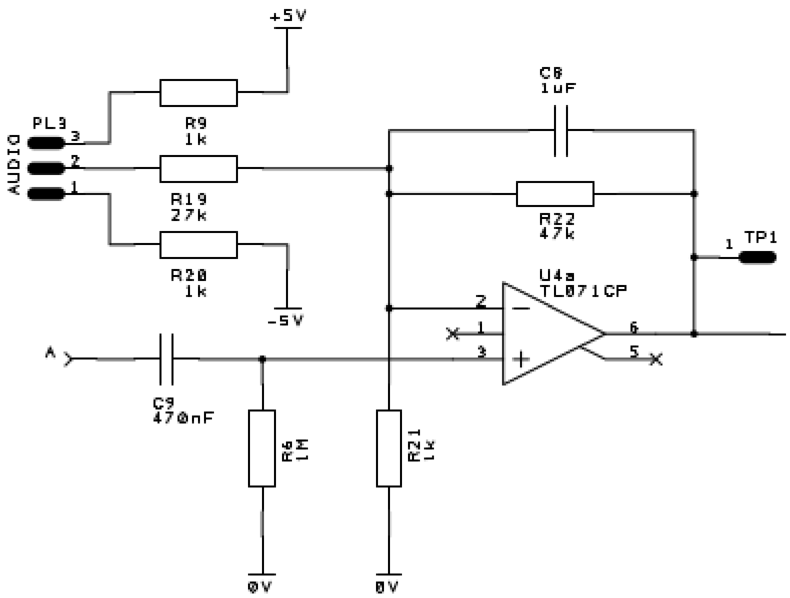

Fig. 12: **Second Integrator**

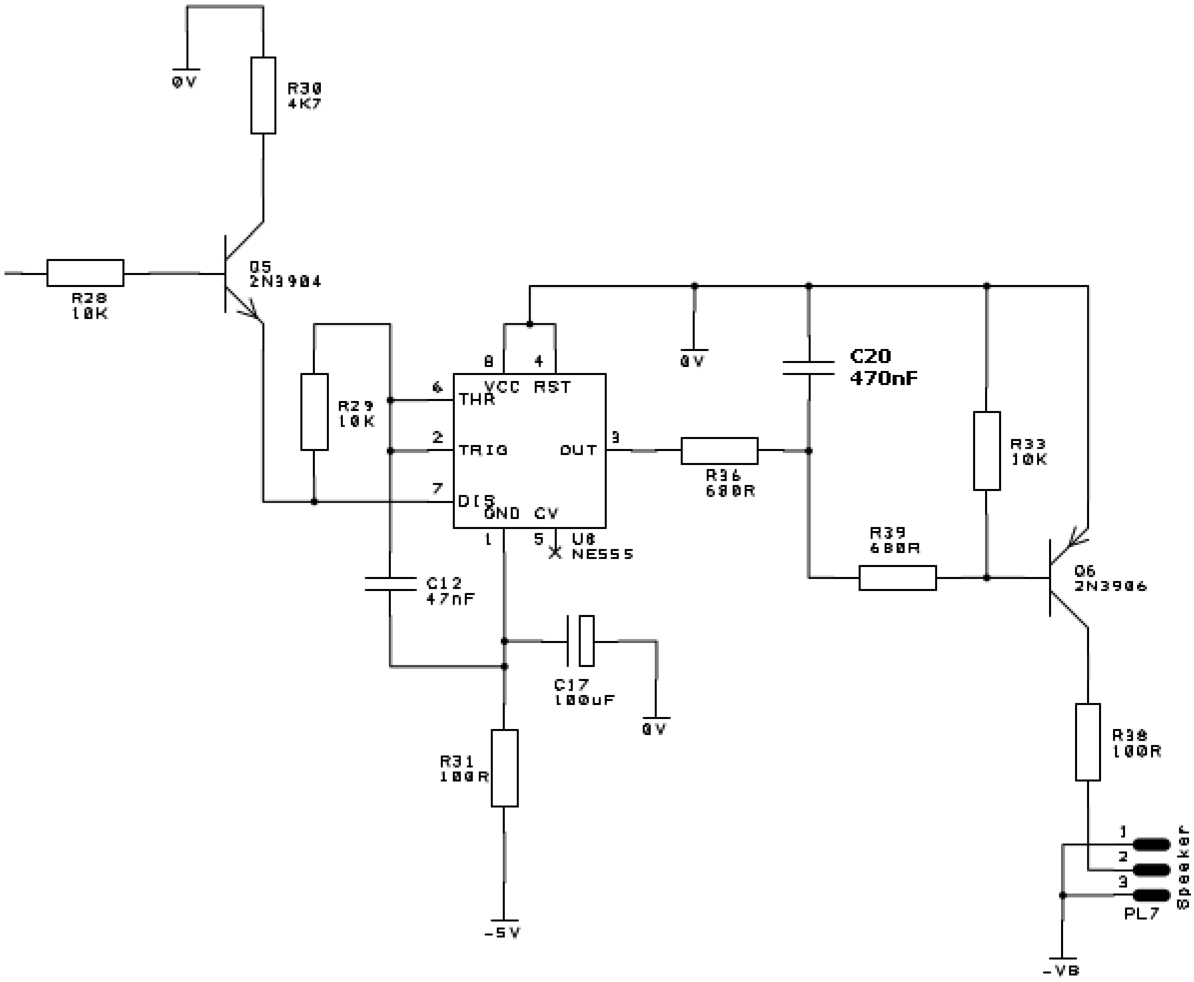

Fig. 13: **Audio (VCO) Stage**

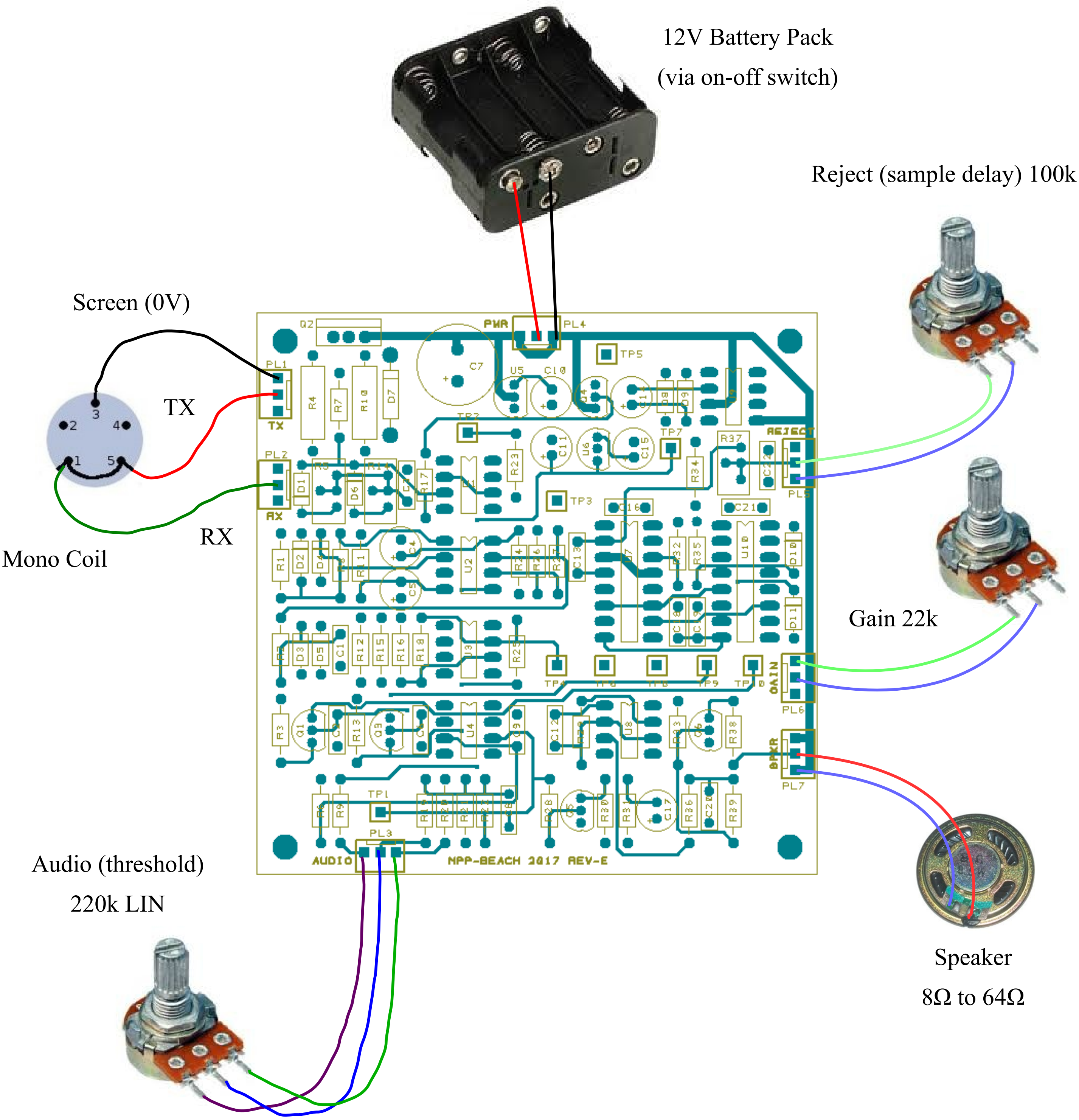

Fig. 14: **PCB External Connections**

Technical Description

The original Minipulse is from the 1980s, and was designed by Eric Foster for Pulse Technology Ltd., from Abingdon, Oxon, England. The Minipulse Plus (MPP) is an improved version designed for easy construction at home using this Build Document, and REV-E benefits from more adjustable settings than the previous revisions. Although this gives it more flexiblility, it also increases the difficulty of setting-up the detector. Hence it is highly recommended that you have access to an oscilloscope.

Since there is no substitute for knowing what you're doing, here's a brief technical description of the operation of the MPP Beach, which may help you to figure out what's gone wrong … just in case you are unlucky enough to hit a problem.

The power supplies are quite simple. The -5V supply is generated by a linear regulator that is connected across the battery pack. The original Minipulse used a 6-cell pack (9V), but the Minipulse Plus requires an 8-cell pack (12V), which should provide a much longer detecting time. All voltages and waveforms are referenced to the positive side of the battery, which might be a bit confusing if you're not used to it. However, this is common practice with PI designs, and is also used in the Hammerhead. The +5V supply is generated with the help of an LT1054, which is a switched-capacitor voltage converter and regulator. In this design the device is configured as a voltage doubler that is used to boost the battery voltage. With the GND connection of the LT1054 connected to the negative battery terminal, the voltage is boosted high enough that a positive voltage regulator [referenced to the positive battery terminal (0V)] can be used to generate a stable +5V supply.

The TX oscillator uses a 555 timer to provide an adjustable [preset] pulse rate, and an adjustable pulse width. This is different to previous versions of MPP that used fixed resistors. One unique feature of this oscillator is that the pulse width increases as the battery voltage drops. This helps to maintain a TX power output that is relatively independent of the battery voltage. For this revision an additional diode was included in the TX oscillator to isolate the two adjustments. The diode pump is synchronized to the TX oscillator, allowing the sampling integrators to eliminate any switching noise that is introduced into the receive chain. Since the TX oscillator pulse rate is considerably lower than the LT1054's internal oscillator, it is not possible to synchronize the diode pump from this external signal. In this circuit the TX oscilator causes the diode pump's internal oscillator to pause momentarily, and then restarts it so that both oscillators are in sync.

The MPP also provides connection points for separate TX and RX coils, similar to Hammerhead, allowing the use of either mono or balanced coils.

In the original Minipulse, the pre-amp was a standard single-stage design with a gain of 1000 (60dB). This has been replaced with a 2-stage pre-amp where each stage has a gain of 33 (30dB). This allows the use of faster coils, which is not possible with either the Surf-PI or Baracuda. The pre-amp output is AC-coupled to the sampling integrator, eliminating the need to provide a means of null-offsetting the opamps.

There are two samples taken during each receive cycle. The main sample is taken shortly (15us, for example) after the TX pulse switches off. This is long enough for the coil flyback to decay close to 0V, but short enough that eddy currents generated in any nearby metal targets have not completely decayed away. The actual sample delay will depend on the coil being used. Also, the damping resistor (R4) may need to be a different value for different coils, in order to provide the critical damping needed (for optimum target sensitivity), and to avoid either an under-damped or over-damped condition. PI detectors are sufficiently sensitive that simply moving the coil will generate a signal at the end of each swing due the Earth's magnetic field. Therefore a second (later) sample is provided, which is subtracted from the main sample. The idea here is that any external signal (such as the Earth's magnetic field) will be present in equal quantities in both samples. Taking the difference between these samples will eliminate the Earth field, leaving the target signal. This is often referred to as EFE (Earth Field Elimination). The effectiveness of the EFE can be tested by waving a fridge (or whiteboard) magnet a few inches from the coil.

The second integrator amplifies the signal further and acts as a low-pass filter, letting through the relatively slow target signals and removing unwanted signals above a few Hertz (cutoff frequency is set at 3.4Hz). The combination of C9 and R6 act as a simple self-adjusting threshold (SAT) which stops the audio output from drifting, removing the need for constant threshold adjustments. This feature was missing in the original Minipulse.

From there, the signal is used to drive a voltage-controlled oscillator (VCO) and finally a small speaker or headphones. The closer a metal target gets to the coil, the higher the tone generated at the VCO output.

Tests have been made with both mono and DD coils:

Initially a simple 400uH 9” diameter mono coil, wound with 0.56mm enamelled wire, was connected. The TX pulse width was set to 100us, with a pulse period of 1ms (1000pps). Due to this being a “slow” coil, the earliest sample delay possible was 30us. The sample pulse width was set to 57us. A Victoria penny was detectable at 12” in an electrically quiet environment.

The DD coil was a Garrett Infinium LS, which an elliptical coil of 14” x 10”. The initial (more aggressive) settings defined in step 3 were used. i.e. a pulse width of 400us, with a pulse period of 8ms (125pps). Since the Garrett coil is a much “faster” coil, the preamp was coming out of saturation at 8.4us. In this case the minimum sample delay was set to 10us, with a sample pulse width of 57us. A Victorian penny was then detectable at 13 to 14”.

The above description is just a short technical overview of the detector, but hopefully it will help you to understand the detector's operation, and allow you to experiment further with this flexible design.

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