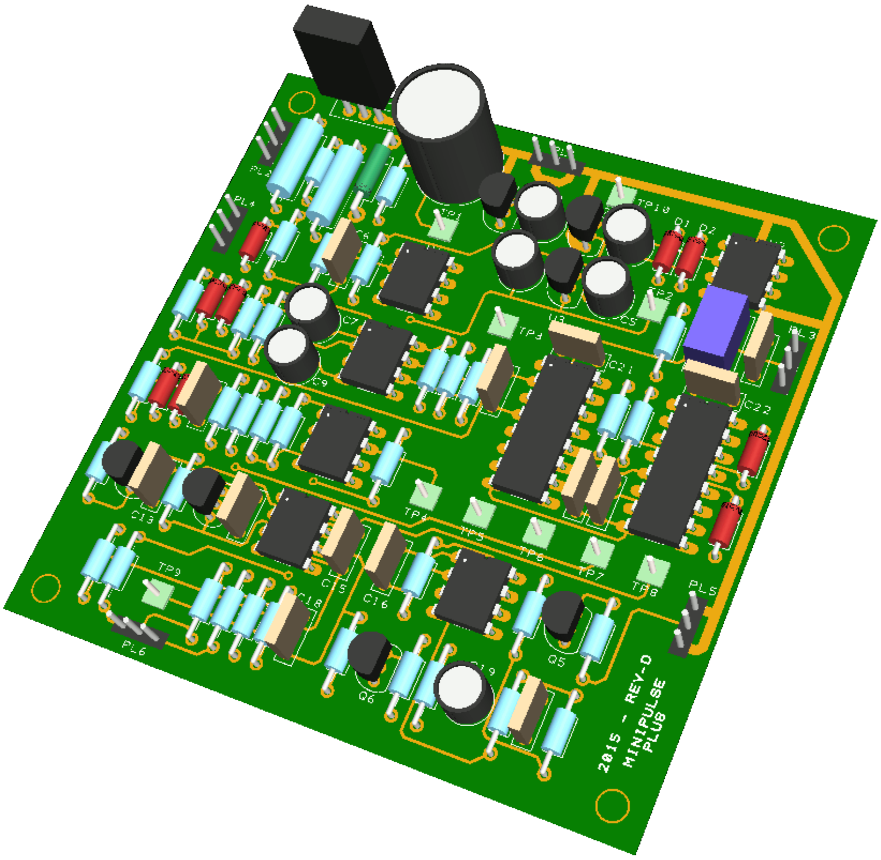

Building the

Minipulse Plus (Rev-D)

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Table of Contents

Title Page -- *1*
Table of Contents --- *2*
Introduction -- *3*
Important Points -- *4*
Step-by-step Instructions ------------------------------------- *5*
Other Points -- *7*
Component Parts List -- *8*
Technical Description --- *18*

List of Figures

Fig. 1 - Negative 5V Supply ---------------------------------- *10*
Fig. 2 - Checking the -5V Supply ----------------------------- *10*
Fig. 3 - Positive 5V Supply ---------------------------------- *11*
Fig. 4 - Transmit (TX) Oscillator ---------------------------- *11*
Fig. 5 - TX Oscillator Waveform ------------------------------ *12*
Fig. 6 - TX Circuit -- *12*
Fig. 7 - Coil Configurations --------------------------------- *13*
Fig. 8 - RX Pre-amp -- *13*
Fig. 9 - Sample Pulse Generator ------------------------------ *14*
Fig.10 - Sample Timing --------------------------------------- *14*
Fig.11 - Sampling Integrator --------------------------------- *15*
Fig,12 - Second Integrator ----------------------------------- *15*
Fig.13 - Audio (VCO) Stage ----------------------------------- *16*
Fig.14 - PCB External Connections ---------------------------- *17*

Introduction

The Minipulse Plus is based on the original Minipulse from Pulse Technology. However, several modifications have been made to improve the design, such as:

1. The transmit (TX) pulse rate has been increased from 80pps to 1000pps, and the pulse width reduced from 234us to 58us. This should make the detector more sensitive to small targets.

2. The original single stage (1000x gain) pre-amp has been upgraded to a 2-stage pre-amp, to allow earlier sampling.

3. The discrete diode pump circuit has been replaced with an LT1054. This modification was made to eliminate some unreliability problems with the original circuit. The battery pack can now decrease from a nominal 12V to around 8.4V before the +5V supply starts to drop out. The LT1054 is also synchronized with the TX oscillator.

4. The PCB size has been reduced to 3.5" square.

5. There is now only one on-board trimmer. This is the setting for the minimum sample delay.

6. The battery check circuit has been eliminated due to potential difficulties in calibration for users who do not possess an adjustable bench power supply.

7. There are separate connectors for TX and RX loops to allow the use of a balanced coil if required.

8. The loudspeaker amplifier is now the default output, which simplifies the wiring for the headphone socket.

All of the above changes were made after building the Rev-A version, and to differentiate the Minipulse Plus from either the Surf-PI or the Baracuda, particularly the ability for earlier sampling.

Changes for this revision (REV-D) - from REV-C:

1. Added a diode (D10) in series with the MOSFET.

2. Added the sync capacitor (C20), missing from REV-C.

3. Added decoupling capacitors (C21 & C22) to U6 and U7 (sampling gates).

4. Re-routed the -5V rail so that the opamps are fed from a different branch than the sampling gates and audio VCO.

5. Increased resistor, capacitor and diode pad diameters to 70mil, with a 39mil (1mm) hole size.

Please note that it is highly recommended you have access to an oscilloscope during the setup procedure. Although it is not impossible to successfully build a working unit without one, you will need to be very careful and methodical during the construction. However, it *is* mandatory that you possess a multimeter.

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 not 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 not 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.

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 C2 (22uF), TP10, PL1 and U1 (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 PL1 (the positive terminal is the middle pin, and both outer pins go to the negative terminal). This is to prevent the circuit from accidentally being connected to the battery in reverse. Measure the voltage at U8 pin 4 (see Fig. 2) and confirm that it is -5V. Remember that all voltages and signals are referenced to battery positive (TP10).

STEP 2

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

Fit C3 (10uF), C4 (22uF), C5 (100uF), D1/D2 (1N4148), TP2, U3 (78L05) and U2 (LT1054)

This supply replaces the original discrete diode pump, which was found to be unreliable, and could generate noise on the power lines. 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 U3 (78L05) to +5V. Measure the voltage at TP2, and confirm it is +5V.

STEP 3

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

Fit R7 (1k2), R8 (27k), R4/R9 (10k), R5 (20k), C6 (47nF), C20 (100pF), C1 (1000uF), TP1, D3 (1N4148), Q2 (2N3904) and U4 (NE555)

If you have an oscilloscope, monitor the TX oscillator output at TP1. The frequency should be ~1kHz, with a pulse width of 58us [when battery voltage = 12V] (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. If no scope is available, then attach a speaker between TP1 and 0V, and you should hear a low-volume high-pitched audio tone.

You can also see that the TX oscillator is synchronized to U2 (LT1054 voltage converter) by monitoring TP1 with an oscilloscope (channel 1), and U2 pin2 (channel 2).

STEP 4

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

Fit R1 (470R - 2W), R2 (10R), R3 (3R3 - 2W), D10 (MUR460), Q1 (IRF740), PL2 and PL4

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 (R1) 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 will be required. Please see Fig. 7 for connection details for both mono and balanced coil configurations.

If you have an oscilloscope, then monitor the signal across the damping resistor using a x10 probe, where you should see a flyback signal of about 350V. If no oscilloscope is available, then put on a set of headphones and place your head close to the TX coil. A high-pitched audio tone will be induced into the speaker coil of the headphones if the TX circuit is working correctly.

STEP 5

RX pre-amp (see Fig. 8):

Fit R12/R16 (1k), R14/R15 (27R), R13/R17 (33k), C7/C9 (47uF), D5/D6 (1N4148), TP3, U5 (NE5532)

Monitor TP3 with an oscilloscope. If no scope is available, then measure with a voltmeter. There will be a DC voltage present at TP3. 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 R10 (10k), R11 (22k), C8 (220pF), C11 (2n2), C10 (10nF), C21/C22 (100nF), D4/D7 (1N4148), TP5 to TP8, PL3, R6 (100k trimmer), U6/U7 (MC14538BCP)

Monitor the TX oscillator at TP1 using an oscilloscope (channel 1), and TP5 (channel 2). Trigger off channel 1. Short pin2 of PL3 to either pin 1 or pin 3, and adjust R6 for a minimum sample delay of 22us. The final minimum sample delay will depend on the coil you've constructed, but 22us will be ok for initial setting up. If no oscilloscope is available, then build the sampling integrator in Step 7 before adjusting R6.

(See Fig. 10):
Main sample delay = 22us (TP5)
Secondary sample delay (EFE) = 100us + main sample delay (TP6)
Main sample pulse width = 58us (TP7)
Secondary sample pulse width = 58us (TP8)

Note that R6 will most likely require some slight readjustment after the Reject pot (100k) is connected to PL3.

STEP 7

Sampling integrator (see Fig. 11):

Fit R18 (220R), R19/R21 (10k), R24/R25 (2k2), R20/R23 (6k8), R22 (56k), C12/C13/C14 (470nF), D8/D9 (1N4148), TP4, Q3/Q4 (J113), U8 (TL062)

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

If you did not make the adjustment to R6 (Step 6) using an oscilloscope, then do it now while monitoring TP4 with a voltmeter. Set the DC voltage level to around 500mV. Make sure you short pin2 of PL3 to either pin 1 or pin 3 (before adjusting R6) otherwise the voltage will not change.

STEP 8

Second integrator (see Fig. 12):

Fit R30/R32/R33 (1k), R31 (27k), R29 (1M), R34 (47k), C15 (470nF), C18 (1uF), TP9, PL6, U9 (TL061), Audio [threshold] pot (250k LIN)

Monitor TP9 with an oscilloscope, and adjust the Audio (threshold) pot. This should allow the DC voltage level at TP9 to swing from -5V to +5V. Set the DC level to around 0V. While still monitoring TP9, 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 PL3, or the pins shorted (as described in Step 7).

STEP 9

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

Fit R26/R27/R35 (10k), R36 (4k7), R38/R39 (680R), R28/R37 (100R), C16 (47nF), C17 (470nF), C19 (100uF), PL5, Q5 (2N3906), Q6 (2N3904), U10 (NE555)

Connect a speaker or headphones to PL5. 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.

Adjusting the Audio [threshold] pot will produce a DC level from -5V to +5V at TP9. When the audio output is set to a low growl, this voltage will be around -1.5V. 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 will run from a 9V supply, but since the +5V supply will drop out when the battery voltage gets to +8.4V, this is not a good idea. A 12V battery pack (8 cells) will allow the individual cells to drop to 1.06V before operation of the detector starts to become erratic.

2. The original Minipulse's Reject (sample delay) pot was 50k, but now the minimum possible sample delay is below 10us, the range of adjustment was found to be insufficient for rejecting some low conductivity targets such as pulltabs. Hence this pot has been increased in value to 100k for REV-D, to provide a maximum delay of approximately 32us (when the minimum delay is set at 10us).

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)

R3	3R3 2W
R2	10R
R14,R15	27R
R28,R37	100R
R18	220R
R1	470R 2W (damping resistor)*
R38,R39	680R
R12,R16,R30,R32,R33	1k
R7	1k2
R24,R25	2k2
R36	4k7
R20,R23	6k8
R4,R9,R10,R19,R21,R26,R27,R35	10k
R5	20k
R11	22k
R8,R31	27k
R13,R17	33k
R34	47k
R22	56k
R6	100k multiturn preset
R29	1M

* Actual value is dependent on coil

Capacitors

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

Diodes

D1-D9	1N4148
D10	MUR460

Transistors

Q2,Q6	2N3904
Q5	2N3906
Q1	IRF740
Q3,Q4	J113

Integrated Circuits

U3	78L05
U1	79L05
U2	LT1054
U6,U7	MC14538BCP
U4,U10	NE555
U5	NE5532
U9	TL061 (or TL071)
U8	TL062 (or TL072)

Miscellaneous

Battery pack	8x AA batteries (12V nominal)
Search coil	300uH to 500uH (TX)
Reject (sample delay) pot	100k LIN
Audio (threshold) pot	250k LIN
Speaker	8ohm to 64ohm
On-Off switch	Either separate or combined with Audio (threshold) pot

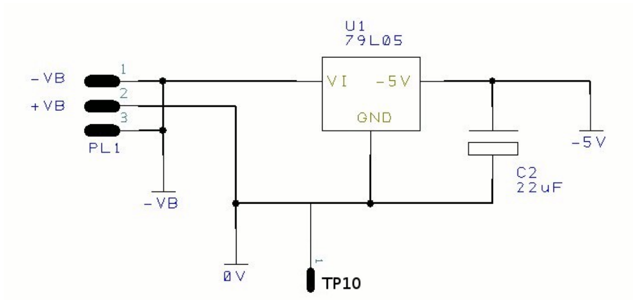

Fig. 1: **Negative 5V Supply**

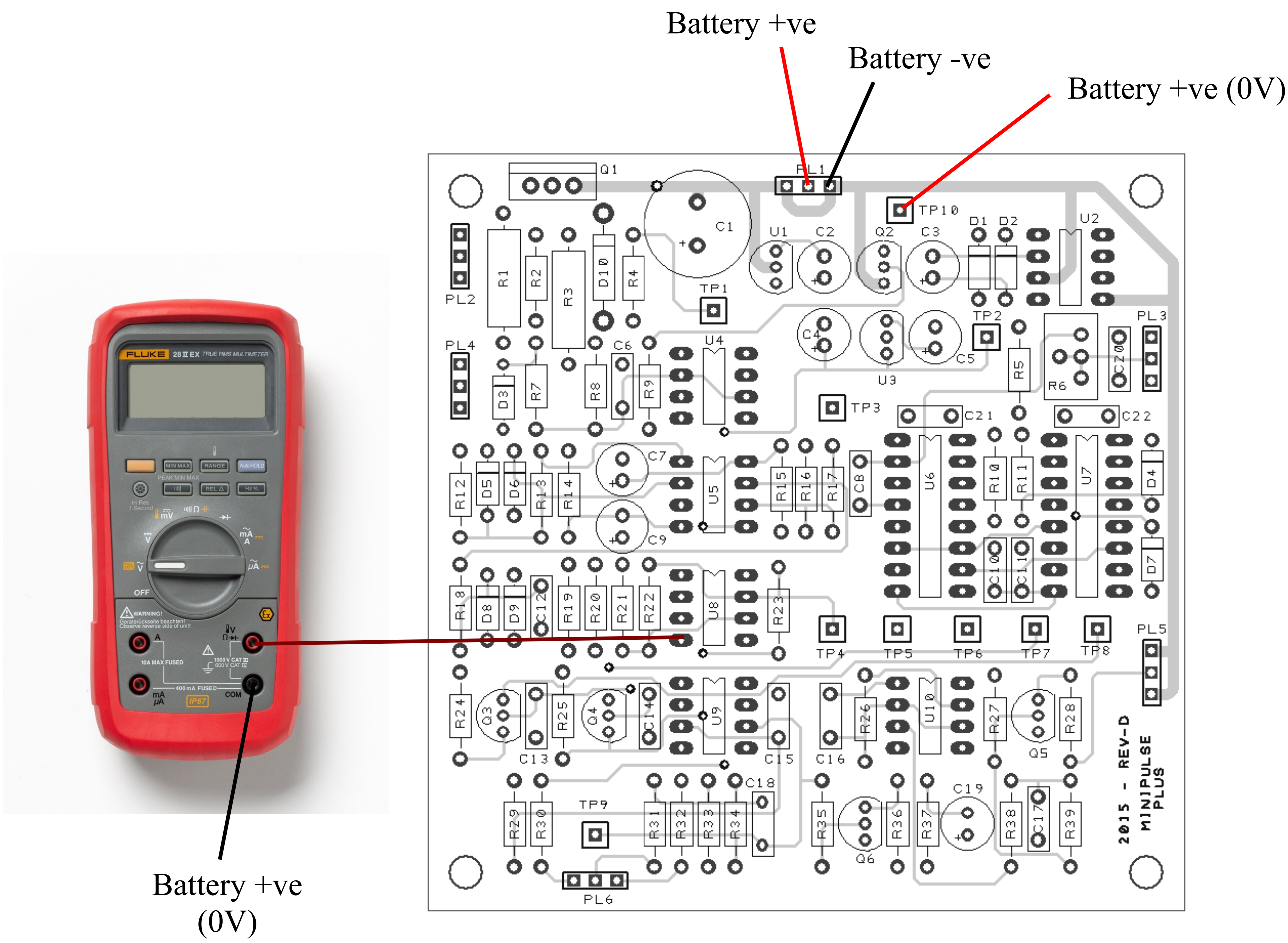

Fig. 2: **Checking the - 5V Supply**

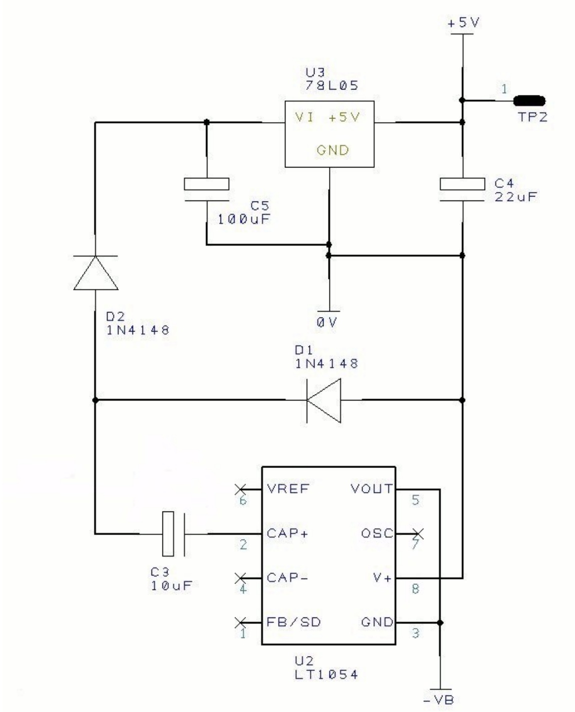

Fig. 3: **Positive 5V Supply**

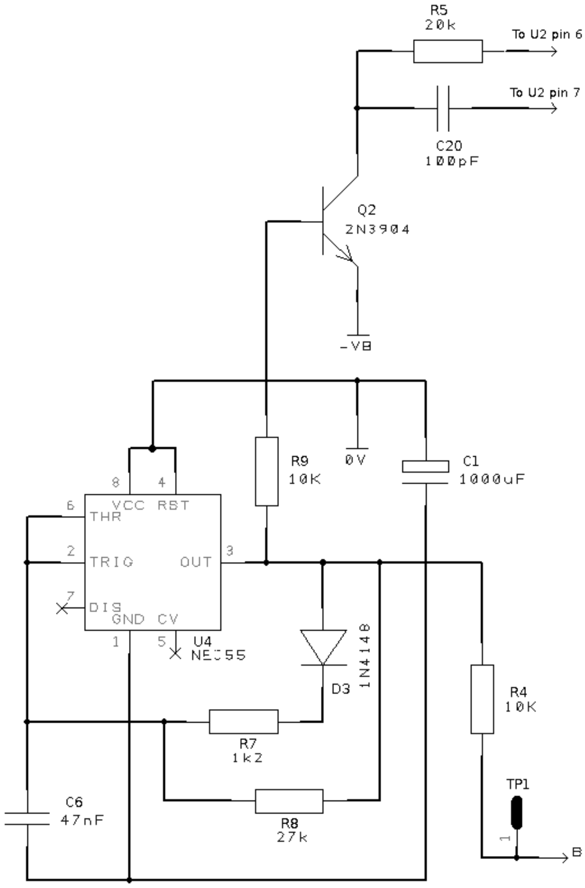

Fig. 4: **Transmit (TX) Oscillator**

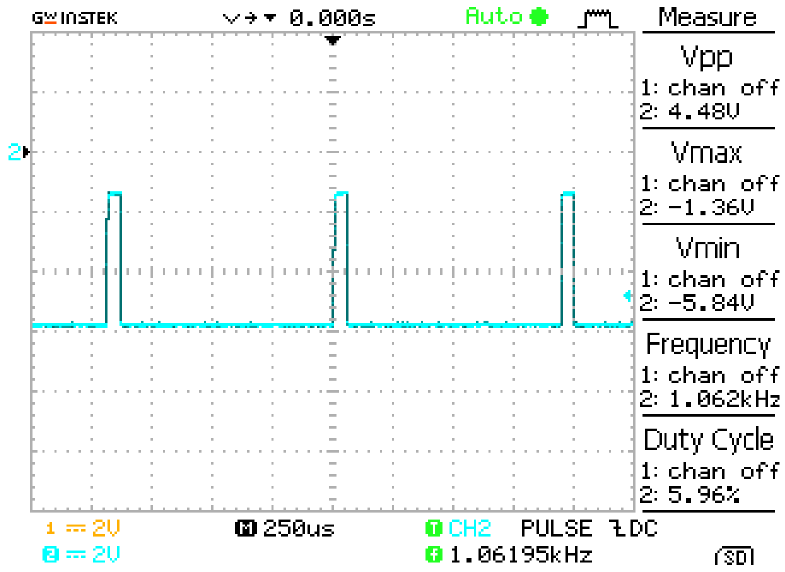

Fig. 5: **TX Oscillator Waveform**

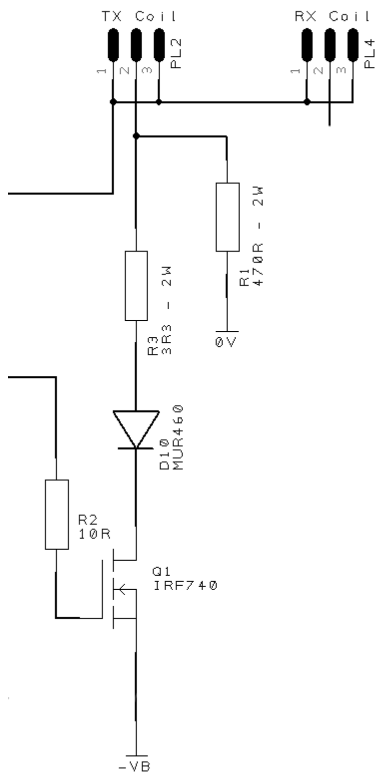

Fig. 6: **TX Circuit**

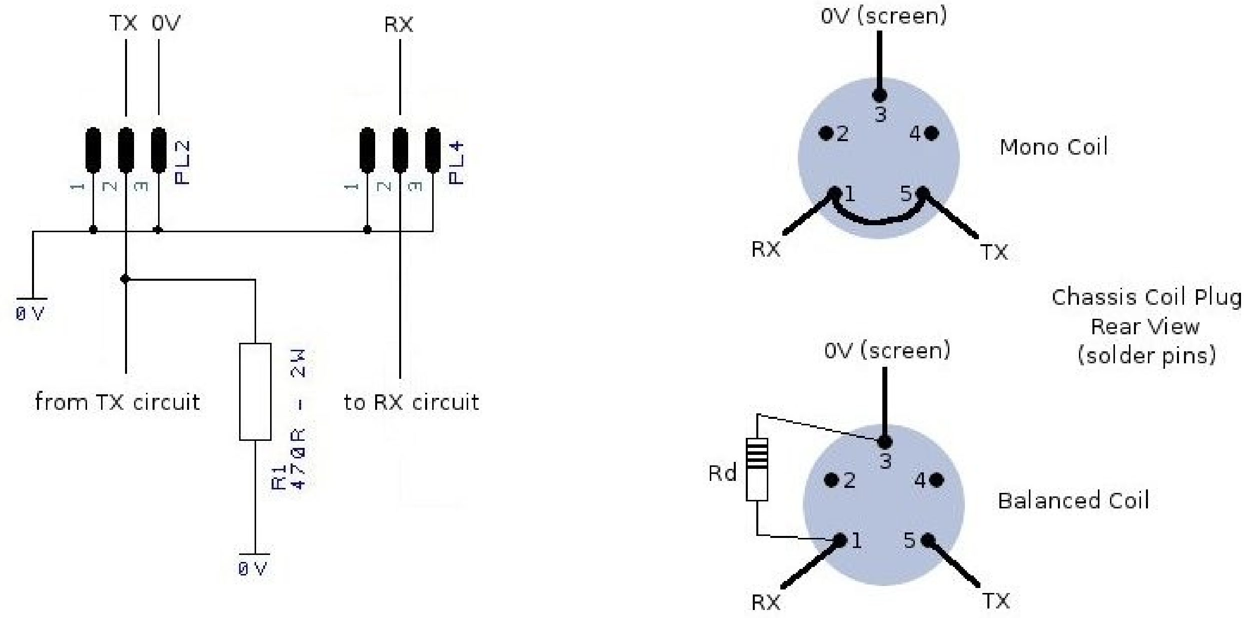

Fig. 7: **Coil Configurations**

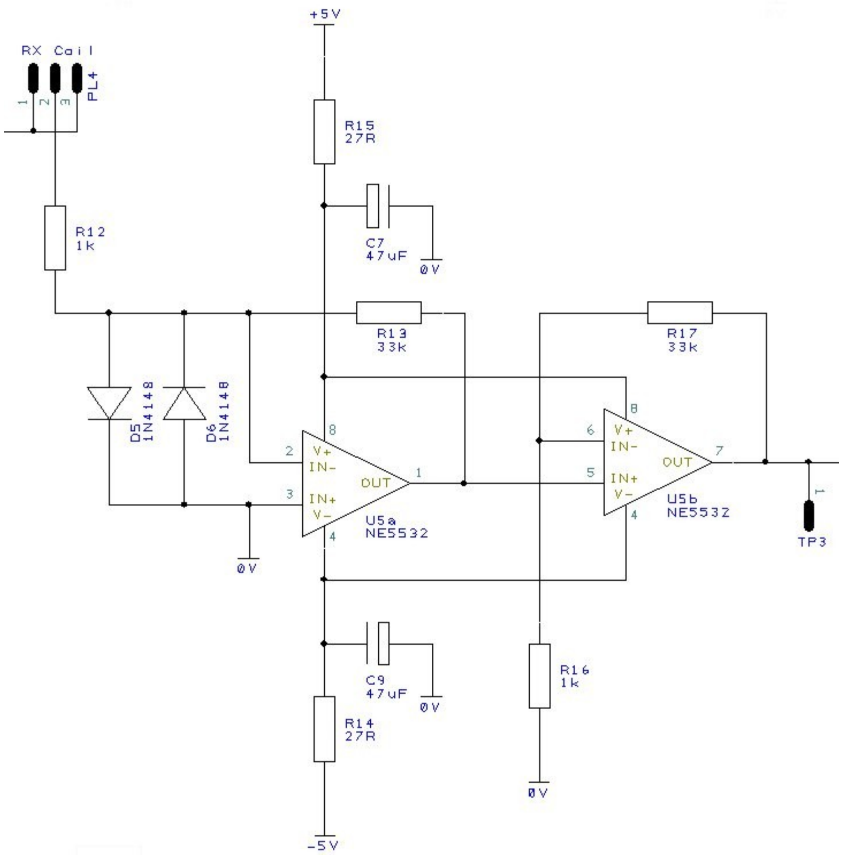

Fig. 8: **RX Pre-amp**

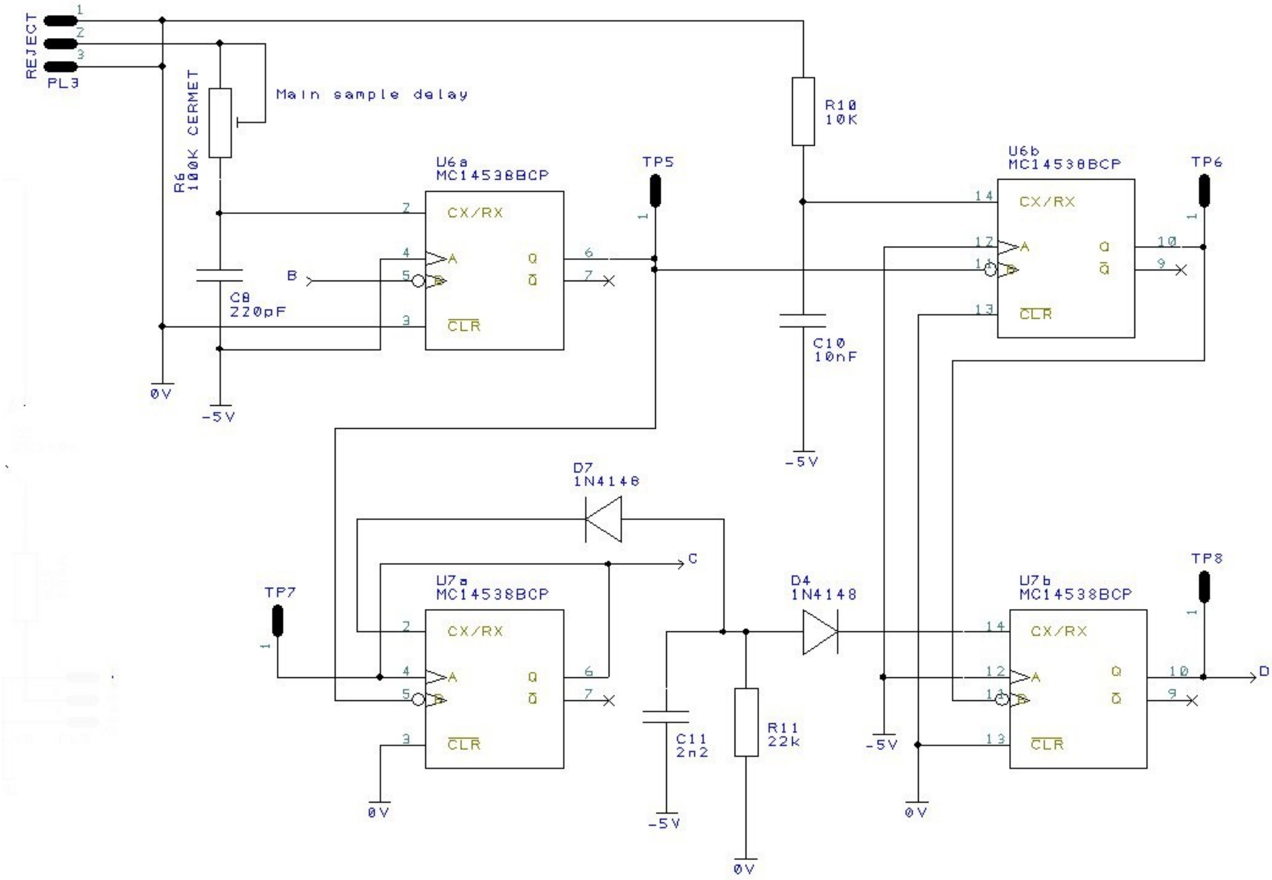

Fig. 9: **Sample Pulse Generator**

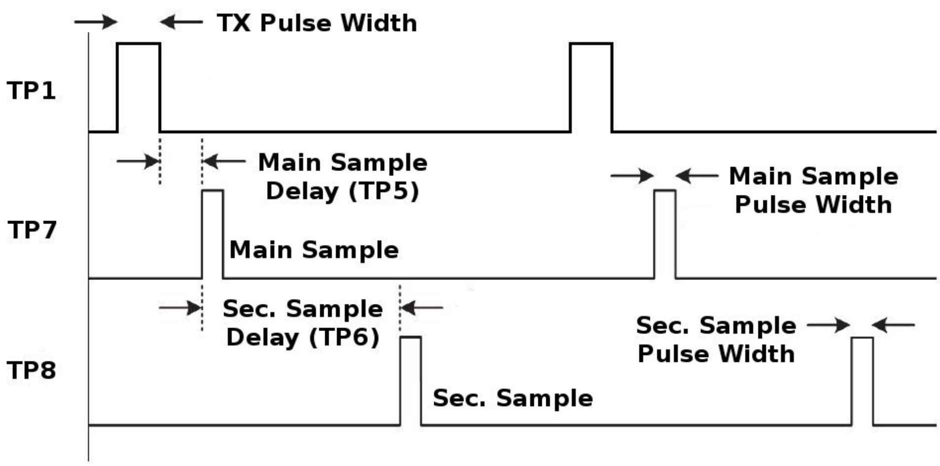

Fig. 10: **Sample Timing**

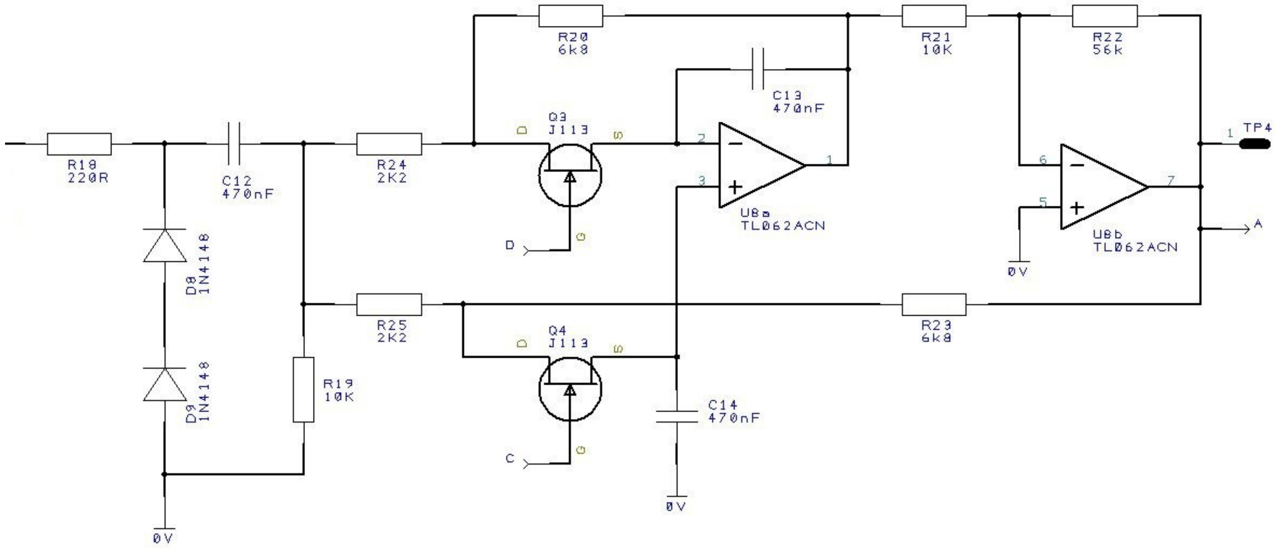

Fig. 11: **Sampling Integrator**

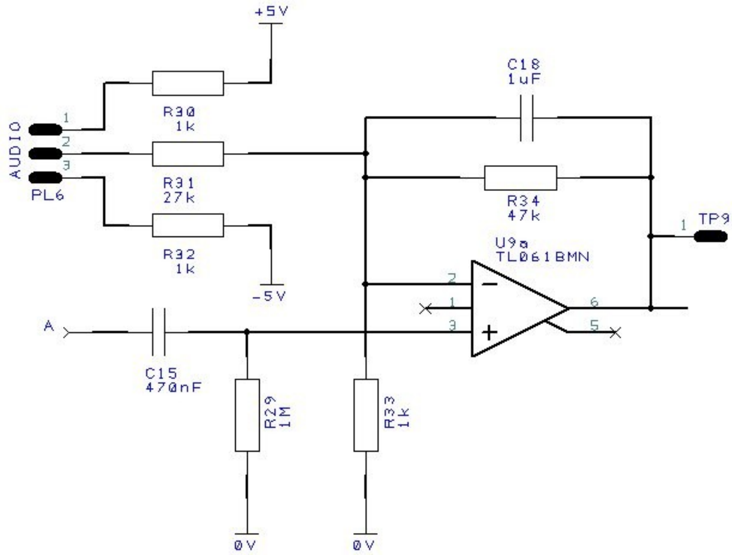

Fig. 12: **Second Integrator**

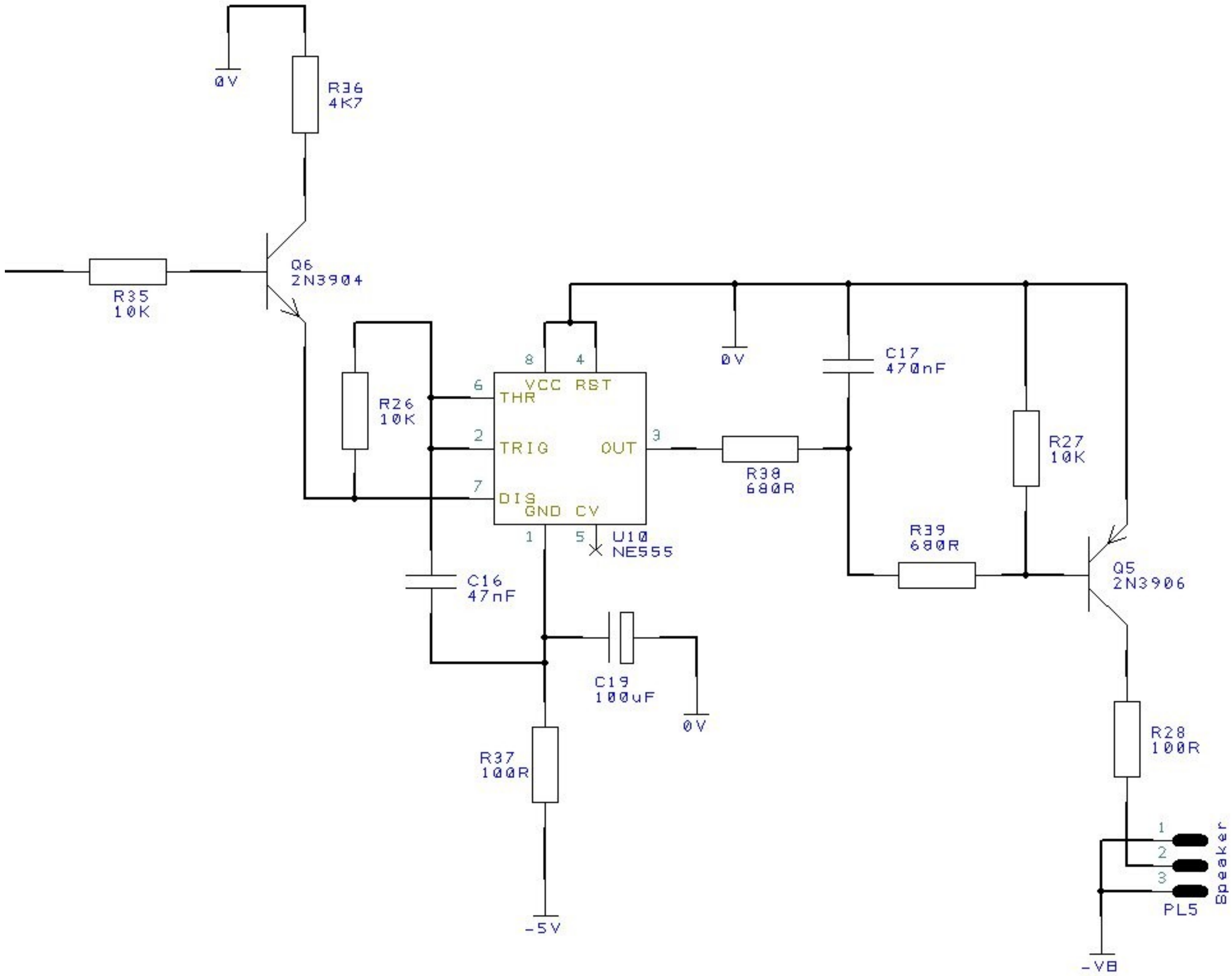

Fig. 13: **Audio (VCO) Stage**

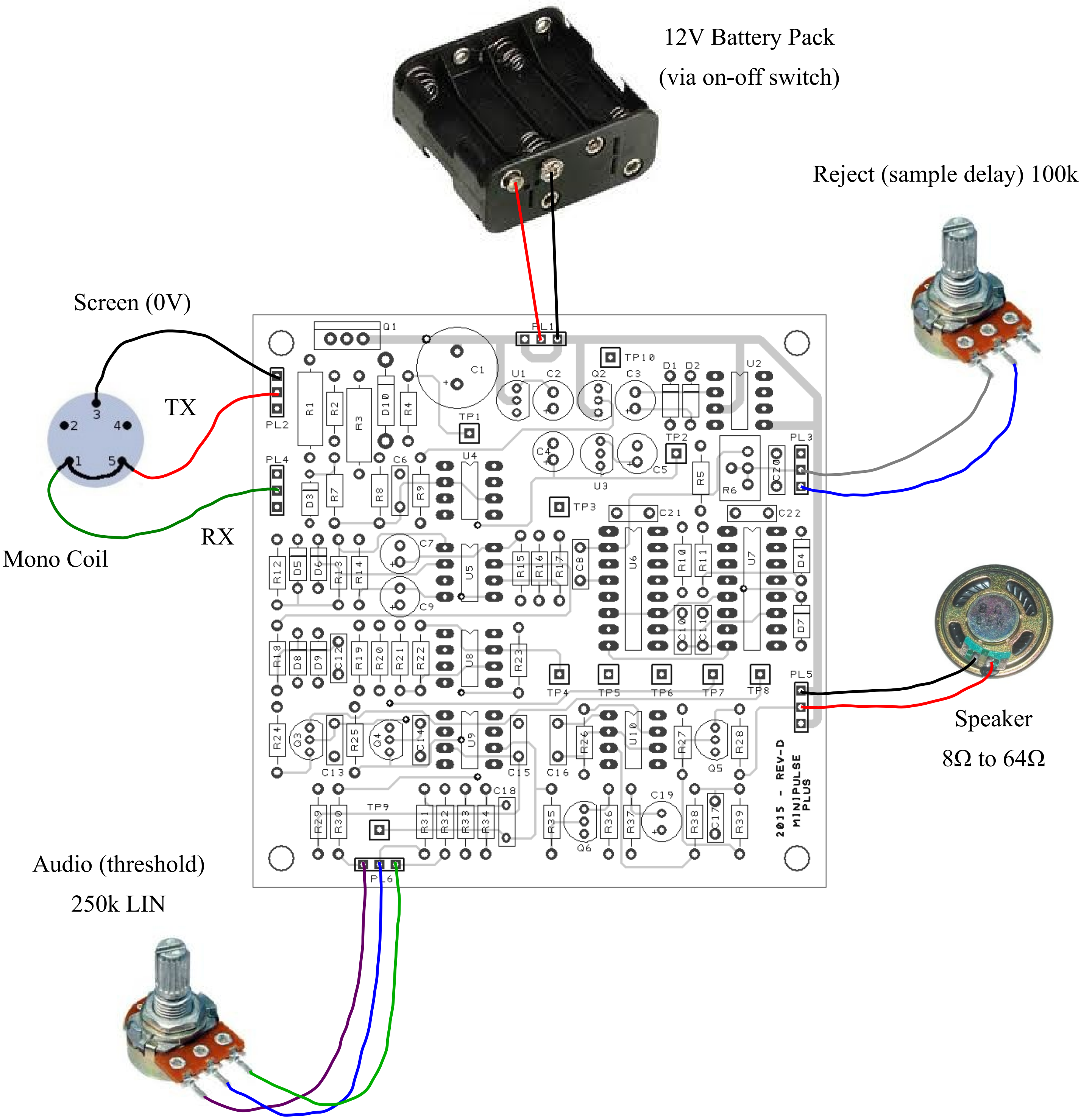

Fig. 14: **PCB External Connections**

Technical Description

The original Minipulse is from the 1980s, and was designed by Eric Foster for Pulse Technology Ltd., from Abingdon, Oxon, England.

The technical specification states that the transmit pulse rate is 86pps, but the one I have was measured as 80pps, and the transmit pulse width is a whopping 234us. Normally such a low pulse rate is used by PI detectors with large coil frames for finding huge buried targets. The Minipulse also had a discrete diode pump circuit to generate the +5V supply. Both Andy (Silverdog) and myself discovered (during the REV-A build) that this circuit was unreliable, and often the +5V supply would occasionally not start up at switch-on. There were also two superfluous resistors discovered on the original Minipulse PCB that were doing nothing but bridging the -5V supply to ground. It was decided that there was little point in just replicating the original Minipulse, as we already have the Surf-PI and Baracuda designs available on the Geotech website. Therefore the Minipulse Plus was created as an improved version, with features that would provide something new. It is hoped (with the help of this build document) that constructing the Minipulse Plus will be less traumatic than building either the Surf-PI or the Baracuda, as there is only one trimmer that needs to be adjusted. With care, it should also be possible to build this detector without having access to an oscilloscope, as long as you follow the step-by-step guide and don't try to rush ahead without completing each stage before moving onto the next.

Obviously there is no substitute for knowing what you're doing, so here's a brief technical description of the operation of the Minipulse Plus, 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 a pulse rate of 1000pps, and a pulse width of 58us. 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. The diode pump in the original Minipulse was free-running, but the replacement LT1054 has been synchronized to the TX oscillator, allowing the sampling integrators to eliminate any switching that is introduced into the receive chain.

The Minipulse Plus 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 (say 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 (R1) 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 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 C15 and R29 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.

The above description is just a short technical overview, but hopefully it will help you to understand the detector's operation.

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